

Crocodile Specialist Group, Species Survival Commission

# CROCODILES



Proceedings of the 26th Working Meeting of the Crocodile Specialist Group  
of the Species Survival Commission of IUCN  
-The International Union for Conservation of Nature-  
Convened at Chetumal, Mexico, 3-9 July 2022  
(Unreviewed)

2022

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Proceedings of the 26th Working Meeting of the Crocodile  
Specialist Group of the Species Survival Commission  
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Spectacled caiman, *Caiman crocodilus*. Photograph: Matías Domínguez Laso. CONABIO.

(Unreviewed)

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Front cover: Morelet's crocodile, *Crocodylus moreletii*. Photograph: Jorge Douglas Brandon Pliego. CONABIO.

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### **The Crocodile Specialist Group**

The Crocodile Specialist Group (CSG) is a worldwide network of biologists, wildlife managers, Government officials, independent researchers, non-government organization representatives, farmers, traders, tanners, manufacturers and private companies actively involved in the conservation, management and sustainable use of crocodilians (crocodiles, alligators, caimans and gharials). The CSG is supported financially through the International Association of Crocodile Specialists Inc. (IACS), and operates under the auspices of the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN). The CSG members in their own right are an international network of experts with the skills needed to assess conservation priorities, develop plans for research and conservation, conduct surveys, estimate populations, provide technical information and training, and to draft conservation programs and policies. The CSG itself keeps its members updated on international events with crocodilians, conducts reviews of country programs, and tries to track and prioritise issues in forums such as CITES that encourage legal trade and discourage illegal trade. CSG Working Meetings are generally held every two years.

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## Foreword

The tradition of the CSG's biennial Working Meeting was broken this time, with the COVID-19 pandemic making it impossible to hold the meeting in Chetumal, at the scheduled time in 2020. It was initially postponed until 2021, and finally to 3-9 July 2022. These were challenging times for the world in many ways, and the CSG Working Meeting was no exception. As the delays continued, we even looked at the idea of a virtual working meeting, despite the face-to-face component of Working Meetings being so important.

Fortunately, the hosts of the Mexican meeting, the Government of the State of Quintana Roo, the Mexican Federal Government, El Colegio de la Frontera Sur, and the Cocodrilia farm, maintained their commitment to organize the event despite the uncertainty! Unfortunately, the pandemic still prevented some people from different parts of the world from attending, and for the very first time I was one of those people. I was most grateful to CSG Deputy Chair Alejandro Larriera, who was able to represent me at the meeting.

It was an exceptionally well-organized meeting, with some 250 participants from 34 countries, presenting 158 papers. The working meeting was preceded by the CSG Steering Committee Meeting and three workshops.

The theme for the Working Meeting was "Sustainable Use for Conservation", emphasizing that the sustainable use of biodiversity, based on the best available knowledge, is one of the main ways to conserve natural capital under a scheme of co-responsibility among the various stakeholders in society. To this end, it is essential to strengthen integration between academia, local communities



and indigenous peoples, and authorities at all levels, to ensure the responsible participation of the private sector.

As an example of the industry's proud support for sustainable, legal and traceable use of crocodylians, they organized a fashion show, with more than 20 articles manufactured with the skin of Morelet's crocodile. In addition, Cocodrilia farm offered tasting of crocodile meat. Interestingly, at the CITES CoP19 meeting in Panama (November 2022), the organizers followed the CSG example and also had a fashion show.

Parallel to the CSG Working Meeting, and for the first time in the history of the CSG, a program, comprising 25 presentations and 77 audiovisuals, was open in person to the public, with more than 11,000 people participating "virtually" and through the social networks of the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and the Comisión Nacional de Áreas Naturales Protegidas (CONANP).

So finally, the Working Meeting was a huge success, overcoming unusual problems in unusual times. Our congratulations and thanks to all who made that possible.

Professor Grahame Webb, CSG Chair



American crocodile, *Crocodylus acutus*. Photograph: Matías Domínguez Laso. CONABIO.





## Summary of the Meeting

The 26th CSG Working Meeting was held at the Centro Internacional de Negocios y Convenciones de Chetumal, Chetumal, Mexico, from 3-9 July 2022. It was attended by 233 registered participants (186 in face-to-face and 47 in virtual mode) from 35 countries; most from Mexico (98), followed by United States of America (42), Argentina (13), Brazil (8), Colombia (7) and Australia (7). The remaining countries participated with less than five delegates (Belize, Cuba, Philippines, Japan, United Kingdom, France, Guatemala, Israel, Panama, South Africa, Ivory Coast, Costa Rica, Malaysia, West Africa, Germany, Benin, Bolivia, Canada, Spain, Ghana, Ireland, Italy, Jamaica, Nepal, Portugal, Czech Republic, Trinidad and Tobago, Venezuela and Zambia).

Parallel to the meeting, for the first time in the history of the CSG, a program open to the public was presented, where 25 presentations were given, and 77 audiovisuals were shown. This forum was attended in person and virtually and reached more than 11 thousand people through the social networks of the Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) and the Comisión Nacional de Áreas Naturales Protegidas (CONANP).

The meeting was hosted by the Government of the State of Quintana Roo, represented by the governor Carlos Joaquín González, the Secretariat of Agricultural, Rural Development and Fisheries (Luis Torres Llanes), the Secretariat of Ecology and Environment Ministry of Environment (Efraín Villanueva Arcos), as well as the Federal Government, represented by Hesíquio Benítez Díaz (CITES Scientific Authority at CONABIO), Roberto Aviña Carlín (General Directorate of Wildlife of the Ministry of the Environment and Natural Resources) and Carmen



Pozo from ECOSUR (El Colegio de la Frontera Sur, public center of the National Council of Science and Technology), and the crocodile farm Cocodrilia, represented by Rolando Coral Hoil.



Figure 1. Opening of Working Meeting by Carlos Joaquín González, Governor of State of Quintana Roo. Photograph: José Rogelio Cedeño Vázquez.

The Organizing Committee led by representatives from SEDARPE (Secretaría de Desarrollo Agropecuario, Rural y Pesca), CONABIO, Cocodrilia farm, ECOSUR, CONANP, higher education institutions, research institutes, and non-governmental organizations, ensured that the venue, program, sponsors, entertainment, etc., were in place. The Organizing Committee also assisted with the complex logistic arrangements required by delegates from around the world.

The official opening of the working meeting on 5 July, included addresses by CSG Deputy Chair Alejandro Larriera on behalf of CSG Chair Grahame Webb, Carlos Joaquín González (Governor of the State of Quintana Roo), Luis Torres Llanes (SEDARPE), Hesiquio Benítez Díaz (CONABIO), Carmen Pozo (General Director of ECOSUR), Yensunni I. Martínez Hernández (Municipal President of Othón P. Blanco), Rolando Coral Hoil (Manager of Cocodrilia farm), Roberto Aviña Carlin (General Director of Wildlife of the Ministry of the Environment and Natural Resources), Efraín Villanueva Arcos (Secretariat of Ecology and Environment Ministry of Environment), Rafael Robles de Benito (Director of Institute of Biodiversity and Natural Protected Areas of Quintana Roo) and



deputy Eduardo L. Martínez Arcila (President of the Board of Government and Political Coordination of the H. XVI Constitutional Legislature of the State of Quintana Roo).

Considering that the theme for the meeting was “*Sustainable use for conservation*”, it was emphasized that the sustainable use of biodiversity, based on the best available knowledge, is one of the main ways to conserve natural capital under a scheme of co-responsibility among the various sectors of society. To this end, it is essential to strengthen integration between academia, local communities and indigenous peoples, authorities at different levels and the responsible participation of the private sector. In this context, and as an example of the industry's potential to support the sustainable, legal and traceable use of crocodiles, Grupo CUADRA organized a fashion show with more than 20 articles manufactured with Morelet's crocodile skin. In addition, the crocodile farm Cocodrilia offered a degustation with receipts based on crocodile meat.



Figure 2. Fashion show Grupo Cuadra. Photograph: Gabriela López Segurajáuregui.

Three workshops preceded the working meeting, two of which were held at the farm Cocodrilia on 3 July: Veterinary (29 participants) coordinated by Jonathan Nácar, Marisa Tellez and Luis Bassetti; Drones (27 participants) coordinated by Carlos Piña, Lonnie McCaskill and Marco A. López Luna. Special thanks to Rolando Coral Hoil and his staff for providing hospitality and logistics for the workshops. The Taxonomy workshop, organized by Kent Vliet and Perran Ross



was held on 4 July in the facilities of the Centro Internacional de Negocios y Convenciones de Chetumal, was attended by 20 participants (16, face to face; four, online via Zoom).



Figure 3. Workshops at Cocodrilia farm. Photograph: Gabriela López Segurajáuregui.

#### VETERINARY WORKSHOP (reported by Luis Bassetti)

The Veterinary Workshop took place on July 3, 2022, being hosted by the commercial enterprise Cocodrilia (Moreletii's Farm). This meeting was coordinated and assisted by Jonathan Nácar Muñoz, Marisa Téllez and Luis Bassetti.

As in previous years, our meeting received a large number of participants (30), with different professional profiles (zoo, commercial breeding, wildlife veterinarians, biologists, etc.).

Lasting seven hours, the meeting was divided into two stages. During the morning, several topics were discussed, such as the diagnosis of the main diseases in crocodilians (signs, control measures and treatment); anesthesia in crocodilians; necropsy protocol; parasitology in crocodilians and bacterial resistance to antimicrobials.

In the afternoon, practical classes were held. Participants had the opportunity to work with juvenile *Crocodylus moreletii* specimens, where they learned about blood collection techniques and the assessment of the animals' health status. In a second moment, the participants were divided into groups and received dead animals for necropsy procedures. It was suggested to create a database for the results of necropsies. In this context, the findings were forwarded in a document by Jonathan Nácar.



It is important to point out that we continue with the mission of training new generations of veterinarians and, therefore, we seek to adapt the Veterinary Workshop to local realities, while presenting new perspectives, showing new diagnostic technologies.

#### DRONE WORKSHOP (reported by Carlos Piña)

The Drone Workshop had more than 20 participants. During this workshop, we identified the CSG members that are working with drones or interested to work with drones in the future and set up a baseline in the understanding of this technology.

During the CSG meeting, we have live, online, and recorded presentations of different capabilities of the drones in the conservation/management of crocodiles and alligators. We also presented different software's developed to use with these devices that allow wild populations monitoring, and did a practical on flying a few drones available in the workshop, including an autonomous flight to survey a polygon.

Finally, participants filled out a survey list of ideas about the possible use of this technology in crocs conservation:

- Nests: thermal images for nest, 3D models for nest, using drones to survey for nesting timing, endangered species nests protection.
- Individuals: thermal images for individual's detection, HCC patrols, estimation of population densities, track individual over time, health surveillance, 3D models to estimate body mass of individuals without capture.
- Habitats: monitoring potential habitat, modeling dry/wet habitat, monitoring crocs movements.
- Samples: water samples, tissue samples, croc capture.
- Radio telemetry: developing VHF system to attach to a drone to locate/triangulate individuals.

There is potentially also spinoff to other areas of science and law enforcement.





## TAXONOMY AND IDENTIFICATION GROUP WORKSHOP (prepared by Kent Vliet)

The CSG Taxonomy and Identification Working Group met on Monday, July 4. We had 16 people in attendance in person and an additional four participated by Zoom. I led the discussion and Perran Ross moderated the meeting. In a Zoom meeting a couple of years ago we discussed trying to form collaborations between various research labs around the world that worked on crocodilian genomics and phylogenetics. A bit of discussion had occurred since that point so we encouraged that to continue to move forward.

In all the meetings with the group, we have spent some time discussing what criteria we would use for the determination of species status. I consider these discussions, and their redundancy, to be crucial for the group to develop consensus on these issues. This is not an easy topic, every biologist probably has their own understanding of what is meant by "species". Our working group is made up of neontologists, paleontologists, genomicists, and field biologists. Our goal is to have broad agreement across the group as we discuss the diversity of living crocodylians. We've agreed to use an integrative taxonomy model to differentiate species.

Early in this meeting we had two presentations to the working group. Evon Hekkala, from Fordham University and the American Museum of Natural History, gave us an update of the crocodilian genomic work that she, George Amato, and colleagues, have been doing with genetic samples from field collections and museum specimens, including ancient DNA techniques. Evon has gotten access to and re-analyzed all of Jacob Gratten's specimens. Veshak Gvoždík, from the Czech Republic, then talked to us about his work differentiating *Osteolaemus osborni* from *O. tetraspis*.

We have been working on a list of extant species, a primary objective of this group, and a goal of this meeting was to come to an agreement as to what taxa this list should include. In consideration of potential taxonomic changes in the list, we have consciously acted very conservatively, understanding that any new taxa we support may have significant consequences and ramifications to international agreements and regulations, a point that has been made to us by Grahame Webb, Peter Paul van Dyke, and most recently by Hesiquio Benítez Díaz. A clear directive to avoid taxonomic inflation. We have not considered any changes that have not already appeared in peer-



reviewed literature, though publication is certainly not the sole criterion for inclusion.

The main list is broken into Alligatoridae, Crocodylidae, and Gavialidae. We list each species, its common name in English, a biogeographic description of the species' distribution, its conservation status, and all the countries in which the species are found. There's then a reference to a note section below the list in which common names are given in Spanish, Portuguese, Italian, French, and German; more information concerning taxonomic issues, and some current references are listed. Related taxa that have not been included in the list are discussed briefly.

We began with 24 species. Our draft list currently includes 27 species, including newly recognized cryptic species of African crocodiles. We are withholding judgement on the recently described *Crocodylus halli* pending further genetic support. We have not considered subspecies. In the caimans (Caimaninae), several recently published papers have revealed deep genetic structure in most species, though much less diversity morphologically. We are again being conservative and not considering any possible splitting at this time.

A secondary objective of this group, though equally important, is to provide means of physical identification of crocodylian species, for customs inspectors among others. Some of us have been working on this aspect of the work but progress is laborious and slow.

The list is being distributed to the entire Taxonomy working group for comments, which is why we are not including the list in this summary review. It will then be submitted to the CSG Executive Committee for review before we publish it.

It is worth mentioning that on July 4th, parallel to the Taxonomy workshop, the Crocodylian Specialist Group of Mexico (GEC-MX) met at the convention center with 35 national experts, who reviewed several topics of interest including advances in the monitoring of Mexican species, steps to follow on the ranching of the Morelet's crocodile, traceability of skins, S.O.S crocodile groups on human-crocodile interaction and the planning of the next formal meeting of the group.







Figure 4. Meeting of Mexican crocodile specialists. Photograph: Gabriela López Segurajáuregui

For some presenters, this was their first time participating in a CSG meeting, and the simultaneous translation for presentations was very helpful to both English- and Spanish-speaking participants. To assist translators, the schedule of presentations was coordinated based on themes and the language of presenters.

Oral presentations in plenaries (86), and posters (72), covered the following thematic areas: research and knowledge (natural history, systematics and evolutionary biology, population status); *ex-situ* conservation (veterinary, intensive management, zoo contribution); socio-economic issues (tourism, indigenous peoples and local communities: perception and culture, industry, human-crocodile interaction); *in-situ* conservation and sustainable use (habitat management, conservation in protected areas and other schemes, sustainable use).

On each of the four days of the meeting, a keynote speech was delivered: José Sarukhán Kermez (Sustainable use for conservation); Grahame Webb (History of crocodile management in Northern Territory: lessons learned); Álvaro Velasco Barbieri (Conservation and sustainable use of crocodiles); and Bruce Swedick (CSG's *Tomistoma* Task Force: final report). In his keynote address, Grahame Webb (Australia) presented lessons learned in crocodile management in northern Australia that can be useful for working with species in other countries. Similarly, Alvaro Velasco's (Venezuela) keynote presentation, emphasized that countries



with good wild populations (as is the case of the Morelet's crocodile) should strive to take advantage of the potential to establish sustainable use programs.

The poster session took place in the afternoon on 07 July (before the traditional auction), where participants could spoke with poster authors.

In addition to the oral presentations and the poster session, various thematic and working groups met as side-meetings, including Human-Crocodile Interaction (Paulino Ponce Campos and Simon Pooley), Zoos (Kent Vliet and Colette Adams), Industry and Fashion (Rolando Coral Hoil), IUCN Red List Assessment (Perran Ross and Sergio Balaguera-Reina).

To consult the general program and the abstracts book, visit:

<https://www.biodiversidad.gob.mx/planeta/csg2022/programa.html>; <https://www.biodiversidad.gob.mx/planeta/csg2022/pdf/CSG26-Abstracts-Program.pdf>

The following are the reports of several of the side meetings that were held during the Working Meeting, including:

#### ZOOS THEMATIC GROUP (prepared by Kent Vliet)

Early this year, Colette Adams, Deputy Director and COO of Gladys Porter Zoo in Brownsville, Texas, was named a co-Vice Chair with me for this group. This is a very welcome addition.

The Zoos group met on 6 July, with 15 attendees from 7 countries. We only had 1 hour to meet so discussions were limited. As always, I began the meeting by introducing the zoo group, its purpose and goals, to new attendees to indoctrinate them into the group. We discussed the importance of networking and capacity building by building membership in a greater diversity of countries and zoo associations. We want our group to be diverse and representative of all geographic regions and zoo associations. This takes constant effort as previous contacts drop out. We need this broad representation to share expertise to strengthen the ability of zoos to contribute meaningfully to crocodilians; to aid with equipment needs, professional assistance, finances, etc.; to provide connections with genetics, diagnostics, and other, laboratories; and, most importantly, to facilitate connections between living collections and *in-situ* crocodylian conservation projects. We also discussed means of fundraising



for crocodylian conservation, including several successful models used in North America (like Crocfest, Brew at the Zoo, and Croctoberfest) which can be easily replicated in zoos in other parts of the world.

Since its inception, the group has been communicating primarily through a Google Group listserv. We discussed the formation of a closed Facebook group as the primary mode of communication within the group, to increase communication, and coordinate zoos' publicity efforts for specific events – e.g., Tomistoma Day, World Crocodile Day, etc.

Reporting of relevant information, such as collaborative programs between zoos and *in situ* projects, zoo educational programs focused on crocodilians, new crocodilian exhibits opening at zoos, and fundraising and spending on *in-situ* conservation, needs to be collected and compiled in a systematic fashion for inclusion in the Zoos Thematic Group report presented to the CSG Executive Committee for the Standing Committee meeting at each Working Meeting. This helps demonstrate the positive impact zoos have on *in-situ* conservation of crocodylians.

Lastly, we discussed encouraging members of the zoo community to present at the CSG Working Meetings. Although there was a session nominally devoted to Zoos during the meetings, none of the presentations in that session had anything to do with zoos.

#### RED LIST GROUP (prepared by Perran Ross)

A side-meeting to discuss the Red List Assessments for crocodylia was convened on 8 July (1600 h). It was attended by 30 participants from 14 countries. A brief introduction to the Red List process and current status of assessments was presented by Perran Ross, and Sergio Balaguera explained the process for Red List mapping. The role of various CSG elements were outlined:

- Red List Authority and coordinating team (Sally Isberg, Sergio Balaguera, Brandon Sideleau and Perran Ross)- overall coordination and process management.
- CSG members- assessors, expert contributors and reviewers.
- CSG Chair and Executive -final review and approval.



The workshop then focused on the short list of 'Priority' assessment needs based upon 1) the most overdue species, 2) species with assessments not currently underway or initiated, and 3) newly recognized species:

Current assessment priority needs

- *Osteolaemus tetraspis* (VU 1996) never assessed with current criteria and does not appear on the IUCN Red List. *O. osbourni* is recently resurrected and a new clade *O. spp nov.* is proposed
- *Melanosuchus niger* (LR 2000)
- *Crocodylus suchus* ? new
- *Crocodylus halli* ? new
- *Crocodylus noveaguineae* (LC 2019) needed if *C. halli* is separated

Discussion on various points followed with recommendations underlined.

The *Mecistops* assessments for both species are done, have been externally peer reviewed, and just waiting final mapping - which is also almost done.

For the *Osteoleamus* group, Matt Shirley reported that efforts were underway using regional experts to collect information but the widely dispersed nature of the species made assessments difficult. The taxonomic situation, dividing *Osteoleamus* into three species, was considered stable and had been reviewed by the CSG taxonomy workshop earlier. Given the paucity of current information, and the fact that *Osteoleamus* has never been assessed using current criteria, one strategy would be to immediately submit an assessment of *O. tetraspis* as "Data Deficient" including basic text of biology, distribution and three species status, as a holding marker that could be replaced by better assessments as information is compiled. Vaclav Gvodzdik of Czech Republic is working with the group and agreed to coordinate assessment of *O. osborni*.

For *M. niger*, Robinson Botero reported that the Brazilian Regional Red List assessment was completed 3-4 years ago but still serves as an accurate assessment and covers most of the species' range. Adding information from Ecuador, Peru and Guyana would easily complete this assessment. Luis Bassetti would be potential assessor along with Bill Magnusson and Ronis Da Silveira.

For *C. suchus*, Matt Shirley reported that the basic status of the species is compiled, and the outline of mapping points established by regional



experts dating from the meeting in Abidjan in 2015. Bringing this process to a conclusion is a priority.

*Crocodylus halli* and *C. novaeguineae*. At a workshop earlier in the week the CSG taxonomy group considered the taxonomic status of *C. halli*. While the species is thought to be valid, and recent re-assessment of previously published genetic data by Jacob Gratten supported the split, the genetic support remains thin by currently accepted standards. The taxonomy group recommended a) that previous samples possibly still in possession of Nancy Fitsimmons in Australia be recovered and analyzed and b) CSG coordinate outreach to Mainland Holdings/ Eric Langlet in PNG to obtain specimens that Evon Hekkala could analyze. Therefore, the Red List assessment of *C. halli* should be deferred pending further data on genetics, noting that the species remains covered under LC status of *C. novaeguineae* and general CITES listing of all Crocodylidae in Appendix II.

In final discussions, Iri Gill of Chester Zoo UK, James Hennessy of National Reptile Zoo, Eire and Jesus Reyes indicated they have student/volunteer resources that could assist with routine data entry (e.g., references). Perran Ross will follow up and coordinate with Sally Isberg to mobilize these resources as needed.

Shawn Heflick suggested that other groups are using closed Facebook pages as an efficient method of communication and discussion that is easier than multiple emails. These can be established with security and by-invitation-only access. Brandon Sideleau of The Red List Authority Group could be asked to investigate this possibility. Meeting participants were thanked for their valuable discussion and the workshop closed at 1800 h. Workshop participants:

NAME	COUNTRY
Marco A. Lopez Luna	Mexico
Sergio Balaguera Reina	USA/Colombia
Hesiquio Benítez Díaz	Mexico
Robinson Botero Arias	Colombia/Brazil
Venetia Brigs Gonzalez	USA
Pierre Charruau	Mexico
Valerie Corado García	Guatemala
Terri Cox	USA



Jennifer de la Fuentes Patricio	Mexico
Iri Gill	UK
Sidney Godfrey	USA
Robert Godshalk	USA
Phoebe Griffin	UK/Nepal
Vaclav Gvosdik	Czech Republic
Shawn Heflick	USA
James Hennessy	Ireland
Nicole Jennings	USA
Rainier Manalo	Philippines
Jesus Manuel Reyes	USA
Sandra Marcela Hernández	Colombia/Brazil
Alex Meurer	Germany
Gualberto Pacheco Sierra	Mexico
Andy Parks	USA
Catalina Pinzón Barrera	Colombia
Paulino Ponce	Mexico
Paul Reilly	Zambia
Perran Ross	USA
Yatzil S. Mendoza Rodríguez	Mexico
Kyle Shaney	USA
Matt Shirley	Africa
Mohamed I. Z. Aboul Gani	Malasya

#### HUMAN-CROCODILE CONFLICT GROUP (prepared by Simon Pooley and Paulino Ponce)

Problematic human-crocodilian interactions have increased around the world, in many species and countries due to population recovery, often resulting from conservation interventions. This has certainly been the case in several regions across the Americas, which is the geographic focus of this report.

Commercial use of crocodilian skins began in the late 1800s in the Americas, but particularly after World War II, demand for crocodilian skins from resurgent leather and fashion industries in Asia, Europe and the USA soared. This was facilitated by the widespread availability of guns and ammunition (and men trained to use them), along with improved technologies for accessing remote marshy regions and transporting out skins. Crocodile populations were also hit by habitat transformation, dam building and water pollution.





It was only in the early 1960s that Florida (1961) and Louisiana (1963) closed the hunting season on alligators statewide, and in 1969 the Endangered Species Act was passed, listing alligators as endangered - ironically in the year that population recoveries, following closed seasons, was noted. Alligators were listed as Appendix I in the first CITES listings, but went onto Appendix II in 1979 due to recovered populations and detailed management plans.

In various Latin American countries, a similar decline occurred after the World War II, and the populations of various species decreased. In 1971, during the first CSG Working Meeting, it was reported that almost all crocodilian species (23 recognized at the time) were in danger, depleted or declining (Chabreck argued American alligator were not), by the 1990s when crocodile ranching and farming had stemmed the illegal trade in several regions, IUCN records registered 11 species in danger, 7 critically. At present, some species and populations are recovering, for example in Costa Rica, Guyana, Mexico and parts of Colombia. Together with the growth of human populations and their impacts on the habitat of crocodilians, this has resulted in an increase in human-crocodile interactions in these regions, specifically attacks on humans.

For these reasons, there has been a history of meetings and collaborations within the CSG to investigate various strategies to reduce crocodilian attacks on humans. The subject has been discussed in individual papers at almost every CSG Working Meeting, and group sessions have also been held. Subsequently, a group led by Alan Woodward and others focused on the issue, culminating in key sessions at the Louisiana CSG meeting (2014). Most recently, a group session was held in Santa Fe, Argentina (2018), led by Simon Pooley and Pablo Siroski.

Since the 2018 meeting, an informal group of CSG members has been working on HCC, including standardising data collection methods, collecting materials on handling problem animals, and conducting surveys on human-crocodilian interactions across Latin America and the Caribbean. In the CSG, we have identified a range of causes of HCC, and a range of possible management responses currently in use, but requiring more systematic testing, and which will vary in effectiveness according to local circumstances.

Efforts are being made around the world in order to diminish negative human-crocodilian interactions with a focus on attacks, and since 2013 there has been a strategy to improve our knowledge about crocodilian





attacks worldwide (formerly on CrocBITE collated by Brandon Sideleau), with more than 5,000 records for most of the extant species. Published information on human-crocodilian interactions and responses to these are available in Pooley *Croc Digest* (2022). As has been the case in previous CSG Working Group Meetings, during the 26th meeting of the CSG in Chetumal, various titles of presentations and posters mentioned HCC in different countries, and even presentations with titles that did not mention HCC, often did so during the talks or on the text of posters. This issue clearly remains a priority for conservation and for crocodile specialists around the world.

For these reasons, we gathered together at the Chetumal Working Meeting, to discuss where information on HCC and/or attacks is missing and likely to be needed, where problems are increasing, what the main management challenges are, and which mitigation strategies are being applied. The aim was to prioritise research and knowledge sharing needs, and decide a shortlist of actions, to guide CSG work on this, for sharing by the next Working Group meeting. Paulino Ponce (Mexico) managed the meeting, with the assistance of Pablo Sirosky (Argentina), and Simon Pooley in attendance online.

Prior to the HCC side-meeting, a simple questionnaire was circulated to attendees (thanks to Dr. Rogelio Cedeño), and 14 were completed by participants from: Nepal, Belize, Guatemala, Mexico, Philippines, USA, Costa Rica and Guatemala. These were analyzed and a summary of results presented (see figure 6). At the live session, there were 50 attendees from 10 countries, with others on line. Attendees discussed information based on the questionnaire in groups, and shared their conclusions at the end of the session.





Figure 5. Details of the HCC Working group. Photographs: Pablo Siroski

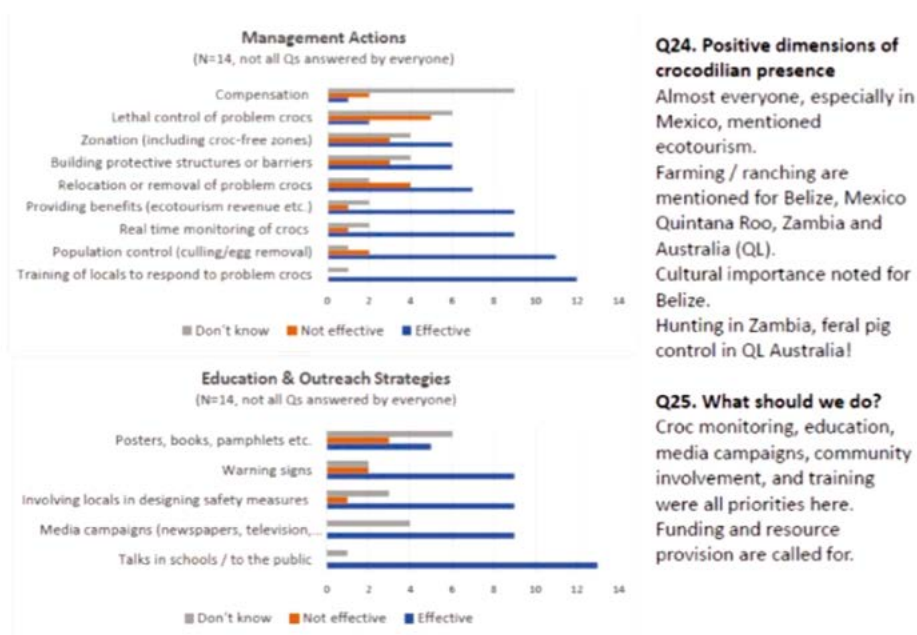


Figure 6. HCC questionnaire feedback summary.

The main conclusions from the live session were that, when it comes to mitigation actions, the following were to be prioritised for further investigation, evaluation and sharing of results, in particular:



- Education / outreach, notably on safe fishing practices (a regional priority), and with a focus on more careful use of language.
- Community-based conservation areas, including urban areas. This involves learning from communities who manage to coexist with crocodilians, for example in some areas of Gujarat in India, and likewise in Nepal.

Other favoured strategies include working to establish refuges for crocodilians, relocating problem animals, expanding and improving monitoring and protection by government agencies, and improved reporting of attacks and other negative incidents.

We believe that a collection of case studies of situations where good outcomes have resulted from such interventions would be valuable. However, we also feel that reported good outcomes should be properly evaluated, and any new interventions designed in such a way that monitoring and evaluation are possible, and analysis can confirm causal links between interventions and outcomes, or provide clear reasons for why they don't work.

Feedback on the questionnaire included the observation that some preferred options on the questionnaire do not apply to some species or regions. Factors to take into account should include: the relevant Law, particular crocodilian species behaviour, population density and habitat.

Finally, our analysis and the discussions in the session brought out the realisation that there are both linguistic and cultural differences in how some aspects of human-crocodile interactions and efforts to mitigate attacks and other negative interactions are understood and communicated. It is obvious to us that questionnaires and similar investigations should be adapted for their regional contexts with the input of CSG members with relevant cultural and local experience and expertise.

Following the CSG Steering Committee meeting on 4 July, a dinner reception was organized by the hosts at a local restaurant (Rivero's Restaurant & Marina), overlooking the Chetumal Bay. During the welcome dinner on 5 July, a folk music group performed traditional dances of the region.

The traditional auction held on the evening of 7 July aimed to raise funds for a crocodile conservation project. It was choreographed by the enthusiastic participation of Carlos Piña and Shawn Heflick. A variety of items was donated



by participants, and \$US6565 was raised for the Cuban crocodile (*Crocodylus rhombifer*) Conservation Program in Cuba.

During the closing dinner, awards provided by the CSG were presented to the best student oral and poster presentations. We thank the judges who devoted their time and effort to assessing the 55 student presentations and posters.

For oral presentations, the following students were awarded prizes:

- 1st Betzaida Rivera-Rivera, Miryam Venegas-Anaya and Llewellyn D. Densmore III. Characterization of heavy metals found in *Crocodylus acutus* from Coiba Island and Gulf of Montijo, Panama.
- 2nd José Antônio Lemos Barão-Nóbrega, Mauricio González-Jáuregui, Sergio Padilla-Paz and Robert Jehle. N-mixture models provide informative crocodile (*Crocodylus moreletii*) abundance estimates in the region of Calakmul (Campeche, Mexico).
- 3rd Matías Bella, Melina Simoncini, Alejandro Larriera, Carlos Piña and Pamela Leiva. Effect of temperature fluctuation during incubation on sex determination in *Caiman latirostris*.

The following students were awarded prizes for their poster presentations:

- 1st Laura Kojima, Benjamin Parrott and Tracey Tuberville. Investigating relationships between contaminant bioaccumulation and movement behavior in the American alligator (*Alligator mississippiensis*).
- 2nd Terri L. Cox, Sara Nash, Subbiah Seenivasan, Jordan Crago and Llewellyn D. "Lou" Densmore. Detecting the emerging contaminant amphetamine in the apex predator *Alligator mississippiensis*: a novel study.\*
- 3rd Mila Piazza, Matías Bella, Mariela Fernández, José Vilá, Carlos Piña and Melina Simoncini. "Intracascara space" - an eggshell structure of *Caiman latirostris* eggs.



Figure 7. Students awarded prizes for their oral and poster presentations. Photograph: Andy Parks

\* *Erratum*: by an oversight, another contribution was included in the summary published in the CSG Newsletter 41(3):10-17.





The “Castillo Award for Crocodile Conservation” was presented to Jeffrey W. Lang for his more than 30 years of work with crocodiles, and more recently with Gharials in India. Phoebe Griffith accepted the Castillo Award on behalf of Professor Lang, who was unable to attend the meeting.

The Chair’s Encouragement Award was presented to Gustavo Sosa Rodriguez of Cuba.



Figure 8. Welcome dinner, with traditional dancers. Photograph: Gabriela López Segurajáuregui.



Figure 9. Kent Vliet, Venetia Briggs-Gonzalez and Rogelio Cedeño.  
Photograph: Erandi Cedeño Zacarías.



For the second time in CSG history, the meeting website provided an option for participants to donate money for student travel grants through the registration process. This resulted in \$US1500 (500 from Peter Ebey + 1000 from Regina Anavy) being raised. The Ebey family had previously provided a significant donation for student travel, which was matched by the CSG. These donations allowed financial assistance to be provided to 7 students (Catalina Pinzón, Hernán Ciocan, Jennyfer de la Fuentes, Ángel Echeverría, Jeremy Calcano, Robinson Botero Arias and Melciellyne Aguilar).



Figure 10. Auction. Photograph: Gabriela López Segurajáuregui.

Luis Sigler gave a presentation (with the support of Sol Guerrero in the English translation, and the intervention of Roberto Rodríguez Soberón on line), to pay a posthumous tribute to Dr. Manuel Alonso Tabet “Manolito”, who passed away in August 2021 by COVID-19 in Cuba. Alejandro Larriera, Interim CSG Chair, then offered a few words on behalf of the CSG in honor of the members who lost their lives during the COVID-19 pandemic.

Alejandro Larriera, in his closing remarks, thanked Secretary Luis Torres Llanes and his entire team from the Ministry of Agricultural, Rural Development and Fisheries of Quintana Roo for the organization and development of all the activities in Chetumal. He also informed that the next CSG Working Meeting will be held in mid-2024, in Darwin, Australia.

On behalf of CONABIO, Hesiquio Benítez Díaz, General Director of International Cooperation and Implementation, also thanked Governor Carlos Joaquín



González and his team for offering the venue for this important event and for being excellent hosts, to Rolando Coral and the entire UMA Cocodrilía team for opening the doors of the farm for the workshops, to Rogelio Cedeño and ECOSUR for their support in the design and development of the academic program, and to CONANP for making the public forum possible.

Finally, the Secretary of Environment of Quintana Roo, Efraín Villanueva Arcos, thanked the CSG for choosing Mexico as the venue for its 26th working meeting, and for its tireless dedication and effort for the conservation and sustainable use of the world's crocodilian species, thus formalizing the closing of the event.

As part of the working meeting activities, excursions were offered to visit different protected natural areas in the Yucatán Peninsula, Mexico (Sian Ka'an Biosphere Reserve, Calakmul Biosphere Reserve, and Arrecifes de Xcalak National Park), which reservations were made directly with the service providers. Sian Ka'an offers a nature immersion tour, including the visit to an archaeological site, then a travel by boat to swim among mangroves with crystalline water and finish on an interpretative trail for nature observation. In Calakmul, the archaeological site stands out, where monkeys and a great diversity of birds can be seen. Xcalak stands out for the presence of numerous species of fish and coral reefs for those who are inclined to an aquatic adventure.

*J. Rogelio Cedeño Vázquez*, member of the 26th CSG Working Meeting Organizing Committee ([rcedenov@ecosur.mx](mailto:rcedenov@ecosur.mx)).



Figure 11. Participants of 26th Working Meeting, including virtual participants on background screen. Drone photograph: Iván Alonso Aguirre Salazar and Roger Yashamir Ortiz Castro.





## LIST OF PARTICIPANTS

NAME	PARTICIPATION MODALITY	INSTITUTION	COUNTRY
Adam Rosenblatt	Virtual	University of North Florida	EUA
Adir Goren	In-person	Crocoloco Ltd.	Israel
Adriana J. Vargas Lezama	In-person	UMA El Colibrí de A. SPR de RL de CV	Mexico
Alba Inhof	In-person	UNL; CONICET; Proyecto Yacaré	Argentina
Alejandro Larriera	In-person	UNL; CONICET; Proyecto Yacaré	Argentina
Alejandro Villegas	Virtual	UNAM	Mexico
Alexa Coral Silveira	In-person	COCODRILIA	Mexico
Alexander Meurer Meurer	In-person	RASRLP	Germany
Alfonso Llobet Querejazu	Virtual	Word Wildlife Fund. Inc. Bolivia	Bolivia
Allan Woodward	Virtual	Florida Fish and Wildlife C. C.	EUA
Álvaro Velasco	In-person	Fauna Silvestre productos y servicios	Venezuela
Ana G. Romero Calderón	In-person	El Colegio de la Frontera Sur	Mexico
Ana Rosa Méndez García	In-person	COCODRILIA	Mexico
Andrea Escamilla López	In-person	U. Autonoma de Campeche	Mexico
Andrew Parks	In-person	Texas Tech University	EUA
Ángel Coral Silveira	In-person	COCODRILIA	Mexico
Ángel D. Trujillo Martínez	In-person	Educación e Inv. para la C. de la N.	Mexico
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Tagging of a Morelet's crocodile, *Crocodylus moreletii*. Photograph: Berenice García Reyes. CONABIO.



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## Oral presentations and poster abstracts



# Nest temperature assessment in an American crocodile (*Crocodylus acutus*) population on the central coast of Oaxaca, Mexico

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## Abstract

The temperatures at which eggs of crocodilians are incubated play an important role in embryo survival, rate of embryonic development and sex definition. The aim of this study was to assess the nest temperatures of an American crocodile (*Crocodylus acutus*) population on the central coast of Oaxaca state in Mexico. The fieldwork was carried out from February to June 2018 at Palmasola Lagoon, Oaxaca. Ten natural nests of *C. acutus* were carefully excavated to determine clutch size. When putting the eggs back in the nests, we placed a data logger in the center of the egg mass to determine the temperature parameters in the nest chamber environment, as well as the variation in temperature during the incubation period. All nests were revisited to count the number of hatched eggs (NHE) and to determine the hatching success (HS), along with the duration of the incubation period (IP). Hatching success was 89.04%. The mean clutch size in the American crocodile nests was  $30.7 \pm 7.83$  eggs (ranging from 17 to 46 eggs), and the mean incubation period was  $77.6 \pm 5.89$  days. The mean nest incubation temperature throughout the reproductive season was significantly different among nests. Based on the average temperature during the middle third of the incubation period, the nests should have produced both sexes, but with a higher proportion of males. This study tried to elucidate the impact of nest temperatures during the incubation period on embryo survival, as well as hatchling sex ratio in a local climate on the central coast of Oaxaca.

## Keywords

Clutch size, Embryo survival, Incubation temperature, Sex ratio.



# Effect of temperature fluctuation during incubation on sex determination in *Caiman latirostris*

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## Abstract

*Caiman latirostris* presents temperature sex determination (TSD). Most of the studies on TSD have been done under constant incubation temperature, but such situation does not occur in nature. In this work we evaluate the sex ratio of nests incubated under fluctuating thermal daily cycles. We also evaluated if cycles affect hatching success, incubation period, and hatchling size. We set up four treatments, (a) 15 hours at 31°C and 9 hours at 33°C; (b) 9 hours at 31°C and 15 hours at 33°C, and 24 hours constant (c) 31°C and (d) 33°C. Sex ratio in treatment (a) was 77% females, (b) 23% females, and as expected (c) 100% females and (d) 100% males. Hatching success and morphological parameters were not affected by cycling incubation temperature; on the other hand, incubation period was shorter as incubation time at 33°C was longer. Analysis of females indicated that as incubation time at 33°C increased, females were smaller; no relationship was found for males, suggesting a possible stress effect only for females. Our results indicate that staying up to 40% of the day at male inducing temperature compared to constant incubation at 31°C reduced female production from 100% to 77% but staying about 60% of the time at male inducing temperatures reduces female production to 23%.

## Keywords

Broad-snouted caiman, Incubation, Sex ratio.



# A recent change in crocodile's behaviour in a Mexican Caribbean atoll: possible causes and short-term actions

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## Abstract

Banco Chinchorro Biosphere Reserve, an atoll situated 30 km off the southern coast of Quintana Roo state, Mexico, harbors an important population for the conservation of the American crocodile (*Crocodylus acutus*) in the region. During the last 4 years (2016-2019), we observed an increase in human-crocodile conflicts in the main island of the reserve. As those conflicts include bites to humans (5 cases), we started to collect data to understand the situation, its causes, and possible solutions to avoid a reprisal of fishermen towards crocodiles. We first collected data on the incidents (e.g., date, victim sex, age and activity, injuries, crocodile size) by reviewing local press articles, incidents reports and victim interviews. Then, to obtain historical data about the relationship between crocodiles and fishermen in the area, we interviewed a former crocodile hunter of the zone. We also reviewed the crocodile hunt bans in the region, the creation date of the reserve and the activities related to crocodiles in the protected area. Furthermore, we analyzed the data collected on the crocodile population and reproduction since 2003 to detect changes in abundance and size of individuals. Based on the results, we hypothesize that the crocodile's behavioral change might be due to the interaction of three main factors: the increase of crocodile size, the feeding of crocodiles by fishermen and the crocodiles conduct reinforcement through stimulation by a touristic activity. In consequence, we propose to carry out the following actions in short-term to prevent future conflicts: stop feeding crocodiles, suspend and review the "swimming with crocodiles" touristic activity for better practice, and apply measures of security and information for users of the protected area. As other factors could be involved, we must also implement a monitoring/study of the





crocodile's behavior as the population and individuals continue to recover and grow.

**Keywords**

*Crocodylus acutus*, Human activities, Human-crocodile conflict, Population recovery.



# Maternal effect influence phenotypes variations on eggs and progeny of *Caiman latirostris*

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## Abstract

In oviparous animals, mothers can influence offspring phenotypes through resource allocation to eggs. Maternal effects mediated by egg's quality may affect offspring performance, and mothers may adjust egg traits according to environmental influences. We have evaluated influence of climatic variables and body and physiological condition of *Caiman latirostris* reproductive females, and their relationship with eggs chemical characteristics (yolk Fatty Acids, FA), hatching success and hatchling phenotype. Fourteen females were captured defending their nests. We recorded: body (Scaled Mass Index) and physiological conditions (muscle and blood samples). For every nest, one group of eggs was derived for chemical analysis and other for incubation. Precipitation and temperature of March-April (previous reproductive season) and September-October-November-December (prior to the oviposition) were obtained. We found that eggs of female with better body condition, presented higher proportion of C20:4, total polyunsaturated (PUFA) and low 18:2, and were associated with higher hatching success. Low PUFAs percentage in female's muscle were related to better female body condition and offspring's weight, giving indications that these FA were mobilized and invested by the female in the egg. Also, egg's C18:2 content was positively correlated with that of the maternal muscle tissue, which in turn is positively associated to minimum temperatures of September. These temperatures are negatively associated with local rainfall of months in which vitellogenesis occurs, indicating that females would be consuming dietary items that contribute high content of this essential FA. Therefore, it would be



advantageous for maternal investment, years where the local rainfall of the months in which vitellogenesis occurs is abundant because they have access to a greater diversity of prey items, to be able to invest quality resources to their progeny favoring reproductive success.

**Keywords**

Fatty acids, Female body condition, Maternal investment, Yolk egg.



# The impact of variable egg incubation regimes on hatchling American alligator genital differentiation

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## Abstract

Adult crocodylian genital morphology substantially differs by sex. However, the sexually dimorphic differences of clitero-penis (CTP) anatomy are subtle at hatching, with male genitals slightly larger than female. While egg incubation temperature determines American alligator (*Alligator mississippiensis*) gonadal sex, genitalia development (either clitoris or penis outcome) is predominantly delayed until post-hatching and is androgen-dependent. A constant 33°C nest incubation temperature determines testis differentiation in *A. mississippiensis* and subsequent male penis development. In contrast, 30°C results in ovary development and clitoral formation. However, it is unclear how intermediate and/or fluctuating incubation temperatures influence external genitalia differentiation and development. We investigated this question in week-old hatchlings incubated under the following conditions: 1) constant male producing temperature (33°C), 2) constant female producing temperature (30°C), 3) intermediate promoting temperature (31.2°C), and 4) intermediate promoting fluctuating temperatures one (31.2°C +/- 0.6°C) and 4) intermediate promoting fluctuating temperature two (31.2 +/- 2.8°C). To better characterize CTP morphological differences across incubation temperature regimes, we quantified: linear measures- lateral and ventral CTP dimensions of glands height (maximum vertical width at mid-section of the head), glands width (widest point of glands), and curve distance (from beginning of sulcus to end of tip)- and the geometric morphometry of landmarks and semi-landmarks of the CTP lateral aspect. We compared these results to total body morphometrics and circulating steroid hormone concentrations at tissue collection. The results we present here expand our understanding of “normal” alligator CTP sexual dimorphisms. Our project illustrates how the environment intimately shapes crocodylian biology and increases our ability to detect altered development in wild populations.

## Keywords

Genitalia, Sexual dimorphism, American Alligator, Clitero-penis.



# Biomechanics of prey capture in crocodylians

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## Abstract

The capture of small, free-floating prey in an aquatic medium presents difficulties for predators because water is incompressible. As jaws, beaks or other capture mechanisms close on the prey, the incompressible water pushes the prey away. The problem is greatest when prey size is much less than the predator and reduced as their size and water resistance/inertia converge. A solution is to 'trap' prey against the bottom or the surface, but in open water with small prey this problem is unavoidable. Aquatic vertebrate predators have solved this problem in several interesting morphological and behavioral ways. Many aquatic birds use a narrow profile, low resistance beak combined with a flexible extendable neck. Baleen whales use a very unique inversion of the tongue into a ventral space to ingest water, then expel it through baleen. Most toothed whales are suction feeders with unique structures to allow this. Most teleost fish expand their opercular apparatus to enlarge the mouth, sucking in prey that are retained on bony gill rakers and teeth while whale sharks and manta rays use a passive flow-through mechanism. Crocodylians do not demonstrate any of these structures or behaviors, but even large crocodylians ingest very small fish, shrimps and other tiny prey—How? This presentation reviews these mechanisms and using the general consideration that function is reflected in form, generates a hypothesis that crocodylians use a unique combination of their tongue and lingual morphology, their large hyoid apparatus and peg-like teeth to capture small prey by expanding their gular region and sucking the prey into their mouth where it is retained by the teeth as the water is expelled. Variations and exceptions like gharials, are discussed.

## Keywords

Small prey, Capture biomechanics, Crocodylians.



# The Crocodylia of Mexico by Alvarez del Toro: book presentation

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## Abstract

Miguel Alvarez del Toro was a Mexican naturalist who worked for 54 years in the state of Chiapas. In 1974 he published the book, "*Los Crocodylia de Mexico*" that positioned him as one of the pioneers in the knowledge of the natural history and conservation of the Crocodylia. Before passing away in 1996 he accepted to publish the second edition of the book that was released in 2001. Now in 2020, we have the honor and pleasure to review, translate into English, and invite more coauthors for this edition. The 2020 version has the seven original chapters written by Alvarez del Toro translated for the first time into English plus ten chapters that give a clear understanding of the current situation of these reptiles in Mexico. The last chapter is about the Human–Crocodile Conflict in Mexico, a situation that has been increasing lately. Nine coauthors contributed information about the conflict in their states and Brandon Sideleau updated and analyzed the information with the perspective of CrocBite. The book is published with colorful images, some of them reflecting facts never seen before in Mexico. Special thanks to Enrique Beltran Brozon who authorized the copyright under IMRNR power of attorney for this edition. Forty-six years after this book was published, we present it at the CSG meeting in Mexico to honor one man devoted to conservation.

## Keywords

Mexico, Crocodilians, Natural History, Conservation, Human–Crocodile Conflict.





## Winter survival of *Caiman latirostris* hatchlings: preliminary results

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### Abstract

To know winter survival and movement of *Caiman latirostris* hatchlings (CI < 25 cm SVL) we released 18 animals ( $15.5 \pm 1.1$  cm SVL) with radio transmitters in Santa Fe province, Argentina. We recorded the location of each transmitter, assigning each encounter to one of the following categories: Alive, Dead, Unseen, or Transmitter without the animal (TW). In a 106-day interval, we made six field trips, finding 55.5% of the individuals dead and 44.5% TW. We used the Kaplan-Meier test to evaluate survival under four possible scenarios, depending on whether each TW was taken as if the individual had been Alive or Dead: E1, all alive; E2: seven alive (all TW except the individual whose transmitter we found outside the lagoon); E3: two alive (transmitters without marked scratches on their carcass); and E4: all dead. Although we could not find any individual alive, the estimated survival probability for E1 was  $38 \pm 13\%$ , for E2  $35 \pm 12\%$ , for E3  $11 \pm 7\%$ , and for E4 0%. Caiman movements were heterogeneous: while five individuals remained close (between 0-30 m) to the release site, the rest firstly moved between 80-247 m and afterwards their displacements were circumscribed within a small area. Although we can only ascertain for those killed by thermal stress (38%), it is most plausible that, including predation and taking E3 as reference, survival is around 11%. However, considering that we have only evaluated a portion of the first year, and the animals were kept in



captivity for 2.5 months, the first-year mortality may be higher. Our findings regarding the mobility of CI show the necessity to thoroughly evaluate in advance the suitability of sites where hatchlings are planned to be released, to maximize their survival in the long term, as they do not move too much.

**Keywords**

Broad snouted caiman; Movement; Offsprings; Radio telemetry.



# Divergence of *Crocodylus acutus* in the Central American Isthmus

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## Abstract

Climatic and geological events have shaped life on Earth throughout its history. The rise of the Central American Isthmus (CAI) is an event that changed global circulation patterns, initiating glaciations, connecting the terrestrial biotas of South and North America and establishing the Caribbean Sea. The nature of this event makes it an excellent natural scenario to test vicariance and divergence by allopatry. Many studies have shown the effect of the formation of this land bridge on marine and terrestrial species, but no studies have been made on semi-aquatic ones. The American crocodile (*Crocodylus acutus*) is a semi-aquatic species that arrived to the Neotropics before the complete closure of the CAI, and a candidate to test how genomic divergence accumulated through time after a recent isolation event. We used Restriction Site Associated DNA sequencing markers (RADseq) on populations on both sides of the Isthmus of Panama to: a) understand how genomic variation is partitioned between different populations of *C. acutus*, b) infer the demographic history of *C. acutus*, and c) evaluate the effect of the recent opening of the Panama Canal. We recovered more than ~17,000 SNPs per population. We found three clear genetic clusters: 1) Caribbean and the Panama Canal, 2) Pacific Coast, and 3) Coiba. We suggest that the biology of the species played an important role on the resilience of the species to the rise of the CAI. Rather, the divergence coincides with the Last Glacial Maximum (LGM), an event that caused a global sea level drop. The LGM potentially affected the nesting and nursery sites isolating crocodile populations in Panama. We did not find alterations in the population structure caused by the reconnection of the Pacific and Caribbean, but mutation rates and long generation times of crocodiles may be masking this process.

## Keywords

*Crocodylus*, Evolution, Genomics, Central American Isthmus.



# Screening for evidence of hybridization and assessing genetic structure and relatedness of Morelet's crocodiles (*Crocodylus moreletii*) across the region of Calakmul (Campeche, Mexico)

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## Abstract

Knowledge on population genetics in crocodilian species has increased significantly over the last decades. Hybridization between the American crocodile (*Crocodylus acutus*) and the Morelet's crocodile (*Crocodylus moreletii*) has been reported in coastal regions of sympatry and at inland sites outside the distribution range of *C. acutus*. As such, populations routinely identified as *C. moreletii* in Mexico are very likely to be admixed (Pacheco-Sierra et al. 2016, 2018). In the region of Calakmul (Campeche, Mexico), *C. moreletii* inhabits semi-temporary and therefore highly dynamic natural ponds (aguadas) sustained by rainfall. Due to the geography of the region, reduced gene flow between localities may have led to a spatial population structure linked to family relationships, which is different from other studied populations in the Yucatan Peninsula. We evaluated genetic structuring and presence of individuals exhibiting genomic admixture between *C. acutus* and *C. moreletii* in Calakmul using four mitochondrial and approximately 5000 nuclear DNA markers (SNPs) from 95 crocodile samples. Our results show that putative *C. acutus*-specific alleles were detected in only 5-10% of our samples (and generally at low frequencies for nuclear markers), distributed amongst a small number of locations. Observed admixture proportions suggest a scenario of ancient admixture or incomplete lineage sorting rather than contemporary hybridisation. Our data also reveals some genetic differentiation and



geographic structuring within Calakmul (FST range: 0.05–0.16). Very few nonadmixed *C. moreletii* populations seem to still exist in the wild, and until this study none have been previously detected in the Yucatan Peninsula. Overall, our study highlights the conservation importance of *C. moreletii* populations in aguadas environments.

**Keywords**

Genetics, Hybrids, Population Structure, Mexico.





# Bone histology of *Caiman latirostris* as tool for morphophysiological inferences in Crocodylia

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## Abstract

Bone histology has been used as an important tool for the interpretation of living standards in past and present fauna animals, and crocodilians are studied as inferential models, since they have preserved morphological and physiological conditions for millions of years. This study aims to identify the bone tissue pattern in individuals of *Caiman latirostris* from the Abatedouro Aruman Ltda. This research was carried out from the osteohistological description of appendicular (humerus) and axial (rib) elements of ten captive individuals, with five pairs of different ages. The material was sectioned, enclosed in resin and worn to a thickness of 30-60 micrometers for observation under an optical microscope. Tissue gradient was observed in the humerus, with younger individuals having more significant presence of woven-fibred bone, indicating rapid growth strategies and, with the aging of the individual, there is a decrease in cortex vascularization and a change to parallel-fibred bone, indicative of slow growth. Also, was observed the presence of resorption cavities and Lines of Arrested Growth (LAGs) in some individuals. In general, the ribs showed a high rate of bone remodeling, with many resorption cavities, low vascularization, in addition to the presence of LAGs in some individuals. The observed fast growing tissues are not common in crocodilians, but in young animals and under optimal growth conditions, these characteristics are observed more often. The study of bone histology in *C. latirostris* helps to refine the osteohistological information of the Crocodylia group, adding information to the data already described for other species.

## Keywords

Caimans, Growth rates, Ontogeny, Osteohistology.



# The giant horned crocodiles that ate our ancestors: complex interplay between environment and crocodylian diversity in the late Cenozoic of Kenya

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## Abstract

The modern crocodylian fauna of the East African Rift System (EARS) is depauperate, with only one species of *Crocodylus* occurring at most localities, but as many as five may have co-occurred as recently as 7 million years ago. Historically, most were viewed as referable or ancestral to modern African species. Recent work on fossils from the Lake Victoria and Turkana Basins of Kenya reveals a complex history for the group. The record includes crocodylian-bearing deposits ranging in age from 19 to 15 million years (early and early middle Miocene) and from 7 million years almost to the present day (latest Miocene through Holocene). Early and middle Miocene sites preserve three or four species; none can be referred to *Crocodylus*, and most appear to be closely related to *Osteolaemus*, including *Euthecodon*. Others are gharials sharing derived features with both *Tomistoma* and *Gavialis*. Late Miocene sites preserve up to five forms – *Mecistops*, *Euthecodon*, a gharial, and two species of *Crocodylus*, neither of which is related to any extant species. Diversity diminishes thereafter, with only three remaining by the early Pliocene (~5 million years). Extant African *Crocodylus* did not appear until less than 200,000 years ago. Temperature is usually thought to be the primary driver of global crocodylian diversity, but the EARS remained within crocodylian thermal tolerances at low altitudes throughout this time. That early and middle Miocene forms might be related to *Osteolaemus* suggests a vegetational signal in crocodylid diversity – the continuous rain forests preferred by modern *Osteolaemus* gave way during the middle Miocene to grasslands and open savannahs. Loss of diversity during the Pliocene and Pleistocene presumably reflect regional xerification and loss of wetland habitats. The environmental may be the same as those often invoked in the rise of humans.

## Keywords

Crocodylia, Fossil, Kenya, Environment.



# Hybridization between caimans: the cherry on the (evolutionary) cake

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## Abstract

In the last decades, several studies on crocodilians have been carried out with a genetic focus from a macro-evolutionary perspective that has defined the phylogenies that we know so far; or from a micro-evolutionary approach that has determined the genetic conservation status of populations of different species at the local level. However, interspecific hybridization processes have a significant influence at both evolutionary levels (e.g. reticulation, divergence, speciation, phylogeographic continuum, introgression, variable genetic diversity, etc.) and they have been greatly underestimated, which can lead to the erroneous determination of phylogenies due to semi-permeability in species boundaries. Our objective was to identify if there is a pattern of hybridization between *Caiman yacare* and *Caiman latirostris* in the southernmost distribution of crocodilians in the American continent (South America) and compare it with the hybridization processes that we have studied in Mexico (North America). Our results determined the existence of a hybridization pattern between both species (using maximum likelihood and Bayesian analysis); with a marked hybrid zone that is potentially wider due to the large distribution of both species in South America. This hybridization process is bidirectional with potentially fertile offspring. From our mtDNA analysis it is not possible to determinate if this is an ancestral hybridization process or not. This comparison of the hybridization processes between crocodiles from the north and south of the continent allows us to infer that the hybridization processes between crocodilians have great potential to expansion of hybrid zone and possible displacement of non-admixed species. On the other hand, it confirms that hybridization processes between crocodilians are more common than we think, highlighting the approach that we must address in sympatry areas



between species that can potentially hybridize in Central and South America and attending to the evolutionary effects of hybridization as a natural process in wildlife.

**Keywords**

Hybridization, Evolution, Crocodilians, Species boundaries.



# How ancient crocodylomorphs adapted to life in the open oceans

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## Abstract

While the osteological adaptations that occurred during crocodylomorph evolution are well understood, the soft tissue ones are not. During their 230-million-year evolutionary history, Crocodylomorpha evolved from gracile terrestrial forms, into large-bodied semi-aquatic taxa and into bizarre ‘dolphin-like’ animals. The question remains, during these major evolutionary transitions what happened within the skull? In order to investigate the land-to-sea transition seen in Thalattosuchia, which resulted in the ‘dolphin-like’ metriorhynchids, our team CT scanned and digitally segmented the cranial endocasts of 16 extinct and extant crocodylomorphs. Our two ‘sphenosuchians’ had distinct brain, vasculature and sinus morphologies, noticeably different from extant species. However, our two protosuchians had the entire suite of pneumatic structures seen in extant crocodylians, suggesting modern crocodylian sinus patterns are over 200 million years old. The thalattosuchians however, had a unique array of endocranial vasculature and pneumatic anatomies; with





hypertrophy of several venous sinuses and arterial osteological canals. Based on the blood flow patterns of extant species, thalattosuchians would have had far greater blood flow entering and exiting the orbital and nasal regions. This increase corresponds with their proportionally large eyes, and suggests that the salt glands of Metriorhynchidae evolved at the base of Thalattosuchia. All thalattosuchians had a less extensive pneumatic sinus system when compared with 'sphenosuchians', protosuchians and extant species. Rather than having discrete diverticula, the sinuses were confluent with the tympanic cavity and hard to individualise. Moreover, the intertympanic and quadrate diverticula were absent. The lack of the intertympanic diverticula suggests thalattosuchians had poor acoustic coupling of the middle ears, and thus more limited directional hearing when compared to extant species. Our results suggest that at least some of the major soft tissue adaptations that underpinned the metriorhynchid radiation into the pelagic realm occurred much earlier in thalattosuchian evolution, prior to the reorganisation of the post-cranial skeleton.

### **Keywords**

Macroevolution, Neuroanatomy, Palaeontology, Thalattosuchia.



# Abundance and ecology of West African Slender-snouted crocodiles in unprotected community forests in Southern Ghana

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## Abstract

The Critically Endangered West African slender-snouted crocodile (*Mecistops cataphractus*) is one of the world's rarest and least studied crocodylians. *M. cataphractus* is a top priority Evolutionarily Distinct and Globally Endangered (EDGE) species. It is threatened by habitat loss, illegal hunting, reduced prey availability, and other anthropogenic-related population declines. Throughout its range, it has been extirpated from most unprotected areas and, where it still occurs, populations have been depleted to the point that even small disturbances will result in localized extinction. The Techiman-Tanoso stretch of the Tano River and the Jimi River in Obuasi, are among the few unprotected locations in West Africa that still holds significant numbers of *M. cataphractus*. For a two-year period (2017-2019), we sought to investigate the abundance, nesting and spatial ecology of *M. cataphractus*. We radio-tagged two adult females and five adult males ranging from 126 to 247cm total length in the Tano River. Crocodile abundance surveys were conducted using nocturnal spotlight surveys and nests were found through visual scanning of the riparian vegetation. The mean Minimum Convex Polygon (MCP) at 95% was 3.88 km<sup>2</sup>, SD±4.45. This average home range is very small compared to what has been reported for other crocodiles. The mean encounter rates were 2.7 individuals/km and 0.69 individuals/km at Tanoso and Obuasi, respectively, making them among the highest recorded for the species throughout its range. These results suggest that Tanoso could be the unprotected area with the highest known concentration of *M. cataphractus*. We found a mean clutch size of 16 eggs per nest (±2; range = 15-25; n=19) which support previous work on this species.



Despite the fact that these areas are unprotected, our findings suggest that capitalizing on local community traditional relationships with wildlife could provide a reasonable basis for community-based species conservation for this Critically Endangered species in Ghana.

**Keywords**

Ecology, Abundance, *Mecistops*, *Cataphractus*.



# **N-mixture models provide informative crocodile (*Crocodylus moreletii*) abundance estimates in the region of Calakmul (Campeche, Mexico)**

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## **Abstract**

Estimates of animal abundance provide essential information for population ecological studies. However, the recording of individuals in the field can be challenging, and accurate estimates require analytical techniques which account for imperfect detection. Here, we quantify local abundances and overall population size of Morelet's crocodiles (*Crocodylus moreletii*) in the region of Calakmul (Campeche, Mexico), comparing traditional approaches for crocodylians (Minimum Population Size—MPS; King's Visible Fraction Method—VFM) with binomial N-mixture models based on Poisson, zero-inflated Poisson (ZIP) and negative binomial (NB) distributions. A total of 191 nocturnal spotlight surveys were conducted across 40 representative locations (hydrologically highly dynamic aquatic sites locally known as aguadas) over a period of 3 years (2017–2019). Local abundance estimates revealed a median of 1 both through MPS (min–max: 0–89; first and third quartiles, Q1–Q3: 0–7) and VFM (0–112; Q1–Q3: 0–9) non-hatchling *C. moreletii* for each aguada, respectively. The ZIP based N-mixture approach shown overall superior confidence over Poisson and NB, and revealed a median of  $6 \pm 3$  individuals (min = 0; max =  $120 \pm 18$ ; Q1 = 0; Q3 =  $18 \pm 4$ ) jointly with higher detectability in drying aguadas with low and intermediate vegetation cover. Extrapolating these inferences across all waterbodies in the study area yielded an estimated ~10,000 (7,000–11,000) *C. moreletii* present, highlighting Calakmul as an important region for this species. Because covariates enable insights into population responses to local environmental conditions, N-mixture models applied to spotlight count data result in particularly insightful estimates of crocodylian detection and abundance.

## **Keywords**

Abundance, Mexico, N-mixture models, Population size.



# Current status of the American crocodile (*Crocodylus acutus*) population and their anthropogenic interaction in Izabal, Guatemala

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## Abstract

The American crocodile (*Crocodylus acutus*) is classified as Vulnerable in the Red List of the International Union for Conservation of Nature (IUCN) and in Guatemala is listed in Category II of the Threatened Species from the Consejo Nacional de Areas Protegidas (CONAP). This project was carried out from March to November 2021 in three rivers of Izabal (Sarstoon River, Rio Dulce and Rio Polochic at Refugio de Vida Silvestre Bocas del Polochic) aiming to provide the first population status and anthropogenic interaction data of *C. acutus* in Guatemala. Results showed a general encounter rate (ER) of 0.18 croc/km in 671 km covered, in which Bocas del Polochic provide the highest ER with 0.37 croc/km, followed by Sarstoon River (0.04 croc/km) and Rio Dulce (0 croc/km). Most of the crocodiles were spotted mainly in grassland, water lettuce and lilies, which is quality indicator of a well conserved area; additionally, specific threats were identified as environmental and socioeconomic aspects for each site influencing the crocodile's survival. Information on the social component has been obtained through surveys, which show a gap in the knowledge about biology and importance of the species, despite the constant interaction in past years; during participatory workshops, fishermen showed a collective concern for the accidents, between crocodiles and humans, that may occur while fishing, some of them showed a rejection toward the crocodiles and others recognized the importance of the species in the river; also, hunting and incidental death in gill nets was mentioned. Currently, the sampling sites showed a high anthropogenic pressure due to its economic activities which impact in a critical way the survival of the species. This project not only achieved a first diagnosis on *Crocodylus acutus* population status, but also promote the civilian population and decision makers inclusion and concern about the conservation of this endangered species.

## Keywords

Endangered species, conservation, American crocodile, crocodile-human interaction.





# **The present status of Indo-Pacific crocodiles in the Philippines: a summary report of the second forum on crocodiles in the Philippines**

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## **Abstract**

After twelve years of sealed commitments to conserve the two species of crocodiles present in the Philippines, the Indo-Pacific Crocodile (*Crocodylus porosus*) and the endemic Philippine Crocodile (*C. mindorensis*), a follow-up dialogue was successfully concluded in March 2019 to strengthen partnerships in crocodile research and sustainable management in the country. Seven resolutions directed towards the conservation and management *C. porosus* were adopted by the plenary on March 8, 2019. It included a special resolution encouraging all sectors in the ASEAN countries to support programs addressing human – crocodile conflicts (HCC). The Philippine government conservation plan of action for the *C. porosus* showed progress towards conservation and sustainable use management with 18 years of crocodile farming industry innovations. Based on general accounts, the increasing frequency of HCC was perceived to be related with the increasing non-hatchling population that was distributed in southern Palawan, Sulu archipelago, and along the southern coast of Mindanao. Ecological distribution modeling suggested that there were at least 20 new island localities with potentially extant populations.

## **Keywords**

Bionetwork, State, Policy.



# Population ecology and social appreciation of crocodilians (*Crocodylus acutus* and *Caiman crocodilus*) in the eastern portion of the Puerto Arista Estuarine System, Chiapas, Mexico

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## Abstract

Crocodiles and alligators are key species for the structure and function of the ecosystems where they inhabit, being an object of interest to humans for being linked to them in various ways. The objective was to know the population ecology and community appreciation of crocodilians (*C. acutus* and *C. crocodilus*) in the eastern portion of the Puerto Arista Estuarine System (SEPA), Chiapas, Mexico. Five transects were established for monthly tours (February-September 2017). Habitat was characterized, abundance, population structure was determined, and the nesting areas and spatial distribution of crocodilians were identified, finally the community appreciation of these species in areas adjacent to the study area was described. The mangrove was the main type of vegetation, 11 cavities and 8 nests were located in three transects. 320 individuals were counted, 173 of *C. acutus* and 136 of *C. crocodilus*. Encounter rates for crocodiles ranged from 0.15 individuals / km (La Laguna) to 3.12 individuals / km (Estero Prieto) and for alligators from 0.12 individual / km (Vuelta Rica) to 6.26 individuals / km (Estero Prieto). 165 interviews were applied to fishermen, housewives and older adults ( $\geq 60$  years); who have extensive knowledge of species biology, common names, and morphology. 46% of those interviewed know about attacks of crocodilians on domestic fauna or people. The human-crocodilian interactions were described with myths and differential perceptions between localities on the danger, use and management of species. 73.94% responded that they would participate in projects with crocodilians. Encourage the protection and surveillance of wild populations, delimit risk areas, carry out environmental education activities



and integrate community participation in conservation, management, and exploitation of crocodilians under current regulations.

**Keywords**

Crocodilians, SEPA, Abundance, Community appreciation.

\*Result of the support of the Student Research Assistance Scheme program of the IUCN-SSC Crocodile Specialist Group (CSG) in 2017.



# Broad-Snouted Caiman (*Caiman latirostris*) geographic distribution and population update

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## Abstract

*Caiman latirostris* populations are known to occur in Argentina, Bolivia, Brasil, Paraguay y Uruguay but their geographic distribution remains outdated. Some actions were considered to increase the knowledge about the distribution of *C. latirostris* based on new literature referred to geographic regions (inventories of protected areas, countries, provinces, etc.), new geographical records, or enlargements of distributional range based mainly on status surveys and interviews. The presence and registered sizes of individuals of *Caiman latirostris* in every Country were confirmed in nearby places or in the same places where they were. Paraguay reported new animales detected in places never registred. Brasil have continually surveyed in its whole distribution reporting very healthy populations with very often appearences of animals in disturbed places. Researchers from Uruguay reported a bigger number of specimens were detected than those observed during 2001-2004 in the same sites, and they suggest a healthy population, too. In Bolivia, there was some problems access to the potential sites, but they will report very soon. Probably, Argentina has one of the known populations based on the requiered studies for ranching



operations, and Argentinian populations is reported as permanent growth because of management and restocking. It is also very important to add to this update the enhancement of conservation and management capacity of national authorities, the national management plans for crocodilian conservation, and the development of economic incentives for crocodilian conservation through well-regulated sustainable use. All of them are considered the high priority actions to list and apply to this species as a guide to immediate needs.

**Keywords**

Conservation status, Ecology, Home-range.





# Effect of flaxseed and flaxseed oil supplemented in caiman diet on meat fatty acids

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## Abstract

Polyunsaturated or long chain fatty acid increment in meat for human consumption improves both nutritional quality, and consumer perception. Increment could be produced by addition of rich sources of fatty acids of omega-3 family (such as flaxseed or flaxseed oil) to the animal diet. We measured fatty profile in two different caiman meat cuts (neck and tail) from animals raised in individual enclosures, fed during 30 days with regular diet supplemented with: 10% crashed flaxseed (CF treatment), and 10% flaxseed oil (FO treatment). Animals were fed 5 times a week with regular diet (crashed chicken head and dry balanced food 70/30), and one day that food was supplemented with CF or FO depending on assigned treatment. After 30 days animals were processed, and tissues sampled were obtained (meat cuts from tail and neck). On the other hand, meat (tail and neck) from FO treatment have reduced level C16:0, and increment of C18:1 t10, C22:5n-6, C22:5n-3, C22:6n-3 (DHA), total unsaturated fatty acids, fatty acids of n-3 family, and the ratio n-6/n-3 was reduced. Diet enrichment with flaxseed oil once a week, during 30 days has improved omega-3 fatty acid in caiman meat, producing positive effects to consumers' health. In order to be implemented in caiman



farms, the cost of flaxseed oil is about 20 times more expensive than flaxseeds (but you should need more seeds since 10% once a week did not improved meat fatty acid profile), on the other hand it is easier to manage oil, and you save crashing time and costs.

**Keywords**

Broad-snouted caiman, Enrichment products, Management program, Polyunsaturated Fatty acids.



# Clinical cases of crocodiles in Puerto Vallarta

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## Abstract

The municipality of Puerto Vallarta is habitat of the American crocodile, a species that is protected in Mexico. In this work, the physical-clinical studies examinations of crocodiles of different sizes, which have been captured in the Municipality of Puerto Vallarta, due to conflict with humans, have been compiled from the last 5 years (2015-2019). In the course of these 5 years, 283 crocodiles have been captured in wildlife, of which 218 were found healthy by not presenting any physical or health problems and were released immediately; 51 crocodiles were rehabilitated, mostly due to malnutrition, so some of them had to be held captive for recovery, others had physical injuries that required surgery; and 14 crocodiles were found dead, in which it was not possible to perform a necropsy to know their cause of death due to their advanced state of decomposition, except for 4 adult crocodiles, of which one died from peritonitis because he suffered perforation in his stomach through a hook; the second due to suffocation due to improper handling; the third due to stress due to improper handling; the fourth presented liver damage and presence of granulomas throughout the ventral part. When analyzing each of the cases of death or requiring rehabilitation, we could see that most of the conditions and / or diseases that occur in the crocodiles under study are directly and indirectly caused by humans.

## Keywords

Crocodile, Puerto Vallarta, Veterinary, Clinical.



# Chemical restraint of large crocodilians: Aims and objectives for safe and reliable management

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## Abstract

The key objectives of chemical restraint of large crocodilians are to provide safe restraint for both crocodile and handlers, and to ensure best welfare practices are always carried out. Neuromuscular blocking agents have been used historically but are difficult to procure and present certain welfare concerns. Several other sedatives and muscle relaxants have proven very useful across a diverse range of activities and are discussed in the context of common capture and restraint scenarios. As well as considering the practical implications and limitations of each drug or combination of drugs, the physiological impact of each agent on the animal is reviewed. Effect of environmental temperature, recent animal activity level, route of administration, availability and reversibility of the drugs are discussed. Benzodiazepines (diazepam, midazolam) provide anxiolysis, muscle relaxation and alteration of consciousness. Midazolam has potent amnesiac properties which is particularly useful when relocating large animals or undertaking stressful procedures. Flumezanil antagonises benzodiazepines, although this is rarely required. Voluntary respiration and airway protection are particularly useful features of midazolam restraint. Alpha-2 agonists (xylazine, medetomidine) provide analgesia, potent muscle relaxation and an altered state of consciousness. The airway is poorly protected as the gular fold relaxes under alpha-2 agonists. These drugs are effectively antagonised by yohimbine and atipamezole respectively. Restraint is safe, repeatable, and highly effective. Intubation is possible under medetomidine alone, for ventilation or gaseous anaesthesia. Neuromuscular blocking agents (pancuronium, vecuronium, rocuronium) effectively paralyse the patient, but have no anxiolytic or analgesic properties, do not provide muscular relaxation, and have no effect on the conscious state. If used for restraint, these drugs must be given in combination with sedation that produces an altered state of consciousness and relaxation of skeletal muscle groups. Analgesia must also be provided for invasive procedures.

## Keywords

Crocodilian, Chemical restraint, Immobilisation.



# Hematology and blood chemistry of Cuban crocodiles (*Crocodylus rhombifer*) at the Zapata Crocodile Farm, Cuba

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## Abstract

The Cuban crocodile (*Crocodylus rhombifer*) is considered one of the most threatened crocodilian species in the world. The Zapata Crocodile Farm (ZCF) is home to the world's largest captive population of Cuban crocodiles and management practices currently include captive propagation for reintroduction. As sentinels for ecosystem health, biological samples from crocodilians can provide valuable data on individual animal and environmental health. As part of a multi-institutional partnership between the ZCF and Association of Zoos and Aquariums (AZA) institutions, health evaluations have been incorporated into the conservation efforts at the ZCF. In November 2019 we sampled 43 adult crocodiles (6 male:37 female) in human care at the Zapata Swamp Crocodile Farm in Matanzas, Cuba. Visual health evaluations were performed immediately after manual restraint and blood collection from the post-occipital sinus. We performed packed cell volume (PCV), total solids (TS), complete blood counts (CBC), and biochemistry profiles for each crocodile on the day of sampling. Mean PCV (n = 42) was  $21.1 \pm 5.0\%$  and TS (n = 42)  $7.3 \pm 1.2$  mg/dL, respectively. Absolute WBC (n=40) was  $9.6 \pm 5.7 \times 10^9/L$ . Like other crocodilian species, the dominant leukocyte was lymphocytes ( $70.7 \pm 10.4\%$ ), followed by heterophils ( $18.7 \pm 9.7\%$ ). Two of the crocodiles had high heterophil:lymphocyte ratios (0.87 and 0.74), although on visual exam they were both considered healthy. The range of creatine kinase was 41 – 1482 U/L, and may be a reflection of muscle exertion at time of handling. These are the first reference intervals reported for this species, including the first descriptions of WBC morphology and are valuable for the management of animals at the Zapata Swamp Crocodile Farm, for comparison with free-living Cuban crocodiles in Cuba, and for comparison





with those managed in human care outside of Cuba. Determining reference values for farmed Cuban crocodiles is the first step in a One Health approach to conserving this critically endangered species. Moreover, this data will be used to evaluate and guide management decisions at the ZCF, ensuring a healthy, sustainable population is managed for the long-term conservation goals of this unique species.

**Keywords**

One Health, Biochemistry, Health evaluation.



# Rock ingestion in Orinoco crocodile hatchlings under human care

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## Abstract

Twenty-five two-month-old Orinoco crocodiles divided in four groups were put on display at the DWA on 5/17/2007. The aqua-terrarium was 2m<sup>2</sup> with two UV lights, a small pond, some plants, and pebbles as substrate. The crocodiles were on display from 10 am to 5 pm and overnights in the crocodile nursery. Each group was displayed for one day and spent the next three days in the nursery in acrylic tanks without substrate. All groups were fed twice a day with ½ crickets dusted with calcium and minerals. After the first day on display, some pebbles were found in the bottom of the Group 1 tank in the nursery, and subsequently the same happened with the other three groups. The very first day the crocodiles were on display, they swallowed pebbles. A normal behavior in crocodiles, we did not pay much attention to that fact until a week later when many crickets were found alive in the tanks, meaning the crocodiles were not eating them as usual. All the pebbles from the exhibit were removed on 6/1/2007 and play sand was added as substrate. Some crocodiles threw up rocks the following days after swallowing. On 07/13/2007, one crocodile regurgitated nine pebbles (six weeks after the exhibit pebbles were removed). The average diameter and weight of the pebbles were 13.4x17 mm and 2.8 grams. 100 pebbles were recovered from the crocodile nursery tank. On 7/29/2007, crocodile #4 was taken to the clinic with signs of cachexia. Fluids were given subcutaneously and orally, as well as food. X-rays were taken on 7/31/2007 showing a stomach with 10 pebbles. The crocodile was hydrated orally and subcutaneously the following days; on 8/3/2007, the pebbles, representing 20% of the body weight, were removed manually with small forceps. The crocodile recovered satisfactorily.

## Keywords

Gastroliths, *Crocodylus intermedius*, Hatchlings, Captivity.



# Antioxidant effect of flaxseed in the fat of *Caiman latirostris*

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## Abstract

In Santa Fe (Argentina) Proyecto Yacaré is a program based on ranching (collection of *Caiman latirostris* eggs from wild populations for farming of hatchlings). Ten percent of the hatched animals are reintroduced into the same harvesting areas, and ninety percent is used for leather and meat production; until today lipid deposits of the carcass are discarded. Previous studies reported enrichment of caiman meat when ground flaxseed is included in the regular diet. For this reason, our work aims to assess whether the addition of flaxseed to the diet (considered a powerful antioxidant) also improves fat quality, delaying deterioration and extending fat integrity. In order to do so we grew during 30 and 60 days caimans of slaughtering size. Animals were fed ad libitum six times a week with the control diet (crashed chicken head + dry balanced supplement 70/30) (C30 and C60), and control diet + ground flaxseed (90/10) (FS30 and FS60). After the experiment we removed fat deposits and determined catalase and glutathione peroxidase activity, lipoperoxidation (LPO), and oxygen reactive species (ORSs). Flaxseed addition in diet increased antioxidant enzymes activity, and reduced lipidical peroxides and ORSs in both groups fed with flaxseed but in FS60 there was a greater decrease in LPO and ORSs compared to the other groups. Based on our results, we corroborated the antioxidant capability of the diet with flaxseed, increasing quality duration and integrity of fatty tissues. Future studies will evaluate possible commercial use of caiman fatty tissue.

## Keywords

Broad-snouted caiman, Fat deposits; PUFA.



# Lesions in phallus tissue of juveniles *Caiman latirostris* in captivity

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## Abstract

Main function of the intromittent phallus is to facilitate internal reproduction by allowing focused sperm delivery to the female reproductive tract. Therefore, phallic lesions could jeopardize the mechanics of copulation by interfering with male/female tissues interactions and/or insemination, thus reducing an individual's potential fecundity. Our objective was to describe the morphology and frequency of male penile lesions in juvenile *Caiman latirostris* hatched and raised in captivity for 2 years. We investigated three elements of crocodylian phallus anatomy that intromit into the female cloaca during copulation: the shaft, glans cuff, and glans tip in n=46 males (Average total length: ~1 m long). Sixteen (34.8%) presented phallic lesions (petechiae) on the dorsal or ventral shaft. Similar shaft lesions (petechiae) have been reported on juveniles *Alligator mississippiensis* phalli, associated with herpes crocodile virus HV1. In order to better understand these infection-related lesions, in the future we must perform a histological analysis to evaluate lymphoid aggregates presence and virus detection with PCR. Of those 16 caiman, five also presented structural defects on the glans cuff, an inflatable structure that putatively produces a copulatory lock and seal during mating. The cause of these glans malformations may be related to interactions with enclosure environment or damaging peer interactions. Potential impacts on husbandry and conservation will be discussed.

## Keywords

Broad-snouted caiman; Cloaca; Petechiae.



# Production of pellets based on the Amazonian invasive sailfin-catfish (*Pterygoplichthys pardalis*) for feeding the Mexican crocodile (*Crocodylus moreletii*)

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## Abstract

One of the main environmental problems that seriously affect ecosystems is the establishment of invasive alien species. The fish *Pterygoplichthys pardalis*, of the family Loricaridae, is an invasive species of Amazonian origin that has been established in various bodies of water in Mexico. In the southern of the state of Tamaulipas, the populations of this fish have generated an economic impact for fishermen in the region. Moreover, the complex lagoon system of the Tamesí River is the natural habitat of the Mexican crocodile (*Crocodylus moreletii*), a species whose sustainable use, within Environmental Management Units (UMAs), has become a profitable agribusiness for farmers of the communities of the region. Based on the above, in the sense of taking advantage of local products, and in the search for a diet for captive crocodiles in the neonatal stage, containing the necessary nutrients for their development. Pellets based on fishmeal *P. pardalis* were processed and evaluated. The evaluation of the pellets consisted of the feeding of juvenile individuals ( $n_1 = 16$ ), for six months, under this diet, and the weight and size of their growth was compared against a traditional diet of chicken guts ( $n_2 = 16$ ). The results of the study indicate that crocodiles fed with pellets based on fish meal *P. pardalis* have a significantly higher growth ( $\bar{x}_1 = 22.68$ ,  $SE = 4.78$ ) than the diet based on chicken viscera ( $\bar{x}_2 = 21.43$ ,  $SE = 9.04$ ;  $t(16) = 1.86$ ,  $df = 175.16$ ,  $p < 0.5$ ), so it is concluded that its use is an alternative to control its populations, while local fishermen improve their economy by marketing it.



## Keywords

Pellets, Mexican crocodile, *Pterygoplichthys pardalis*.

## Introduction

One of the main environmental troubles that seriously affects ecosystems is the establishment of invasive exotic species. The fish *Pterygoplichthys pardalis* (Loricaridae) is an invasive species from Amazonian origin that has been established in several waterbodies in Mexico (Fig. 1). In the South of the state of Tamaulipas, populations of this fish have generated an economic impact against fishermen of the region. Moreover, the complex lagoon system of the Tamesi River is the natural habitat of the Mexican crocodile (*Crocodylus moreletii*; Álvarez del Toro and Sigler, 2001), a species whose sustainable use within Environmental Management Units (UMAs) has become a profitable business for farmers of the communities of this region.

Based on the above, in the sense of taking advantage for local products, the search of a diet for captive neonatal-stage crocodiles containing the necessary nutrients for their development is the aim of this study. Pellets produced with the fishmeal of sailfin-catfish (*Pterygoplichthys pardalis*) as a component were processed and evaluated.



Figure 1. Invasive sailfin-catfish at the Champayan Lagoon, Altamira, Tamaulipas.





## Methods

For pellet's production, the raw material was obtained from local fishermen in the Champayan lagoon in the municipality of Altamira. For which three rations were taken every two months. Collecting 10 kg for each serving.

Subsequently, the bromatological analysis of the sailfin-catfish was carried out according to the techniques from AOAC (1984) methods, diets were formulated, pellets were produced with of fish meal obtained with the techniques of the FAO (1986), and finally the diets were evaluated (Fig. 2).

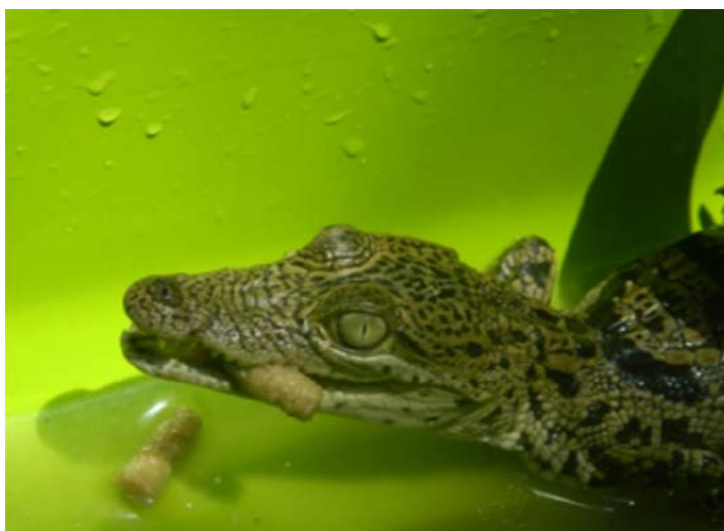


Figure. 2. Crocodile hatchlings feeding on sailfin-catfish pellets.

The conventional diet, based on chicken viscera, was supplied according to the manual for the exploitation of crocodiles in captivity of the FAO (Bolton, 1994).

## Results

Analysis of the pellets consisted of the feeding of juvenile individuals ( $n_1 = 16$ ) during six months under this diet, and their growth (size and weight; Fig. 3 and Fig. 4) was compared with a traditional diet based on chicken guts ( $n_2 = 16$ ). Results of this study indicate that crocodiles fed with pellets have a higher growth ( $\bar{x}_1 = 22.68$ ,  $SE = 4.78$ ) than the traditional diet ( $\bar{x}_2 = 21.43$ ,  $SE = 9.04$ ) with significant difference [ $t(16) = 1.86$ ,  $df = 175.16$ ,  $p < 0.5$ ].



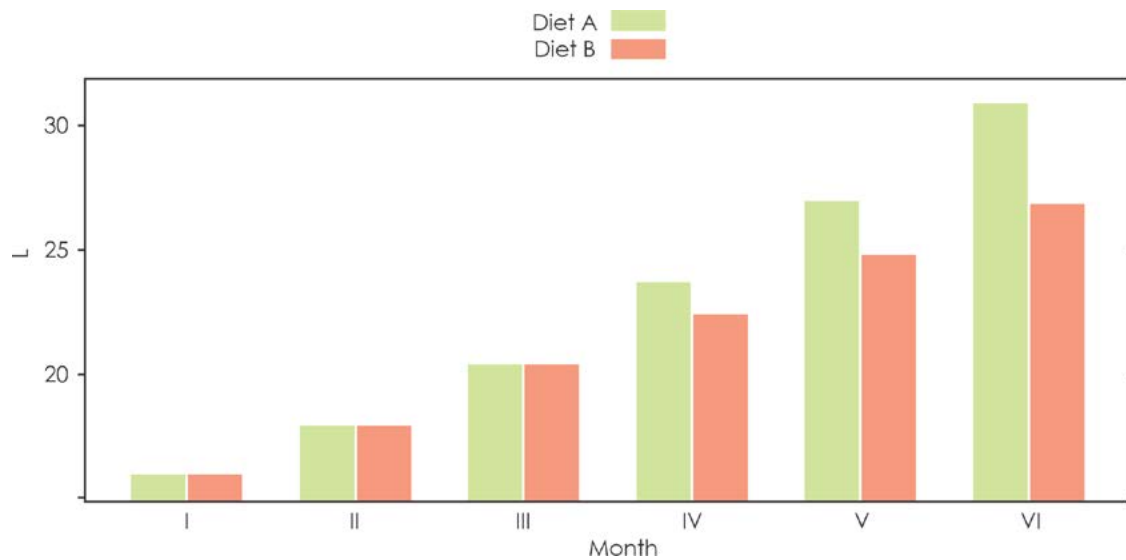


Figure 3. Size increase, comparing a diet based on sailfin-catfish pellets versus a traditional diet. Size increase on L (length by cm) during the study with the pellet-diet elaborate using sailfin-catfish flour (Diet A) and chicken guts (Diet B).

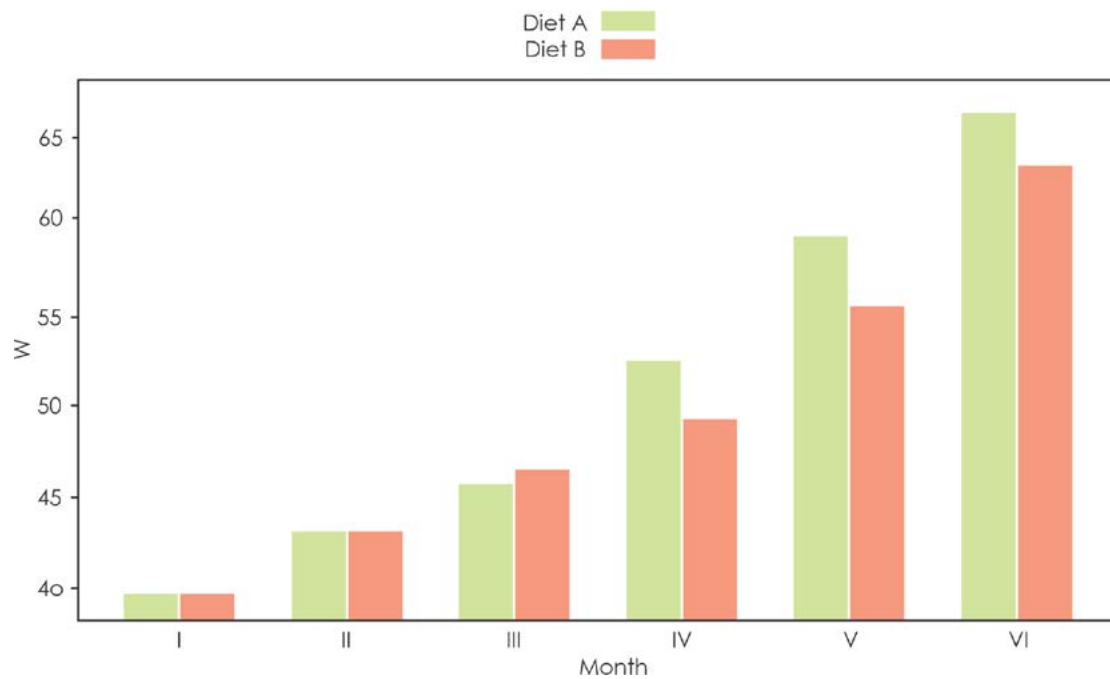


Figure 4. Weight increase, comparing a diet based on sailfin-catfish pellets versus a traditional diet. Weight (w) increase on g during the study with the pellet-diet elaborate using sailfin-catfish flour (Diet A) and chicken guts (Diet B).



## Discussion

As expected, individuals of *C. moreletii* exhibited a higher size increase by the fifth week. In other studies, alligator neonates have been fed with several diets (chicken waste, casein, integral and fish flour), showing that fastest growth increase occurred using fish flour (Jiménez, 2006), as in this study it was found.

## Conclusions

The results obtained show that the growth with both diets for the crocodile. However, in this study was observed that size is greater with a diet based on sailfin-catfish meal pellets than with a typical diet of chicken guts. This work represents a pioneer in the analysis of a compressed food (pellets) for swamp crocodiles in captivity, because the studies carried out so far do not take advantage of a local resource that is also an ecological problem (the invasion of sailfin catfish on lagoons of the complex system of the Tamesi River).

The advantages of presenting the food in this form are as follows:

- a) In a minimum amount of feed are all the necessary components for a balanced feed formulated for the crocodile at the stage of development in which it was provided.
- b) Pelletizing prevents the selection of certain ingredients by the crocodile, prevents food waste.
- c) Storage is less specialized, since it only needs to be kept in a warehouse, inside containers of inert materials, its refrigeration is not necessary, and it has been observed that the protein quality remains around six months.

The use of sailfin-catfish in a productive activity such as the production of flour, has a positive impact on the environment, as a species that has had various repercussions on the native fauna has been removed from the environment (Guzmán, 1997). Therefore, it is concluded that the use of fishmeal pellets is an alternative to grow crocodile populations, while local fishermen improve their economy by marketing them.

## Acknowledgements

"Pescadores Libres de la Laguna de Champayan" who proporcionated the sailfin-catfish; Dr. Cesar Cedillo-Leal for the experimental biomodels replicated. Dr. Velazquez-Narvaez for revision.



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# Ecological drivers of nest temperature variation in the American alligator: predicting the impact of future climatic scenarios

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## Abstract

Species displaying temperature-dependent sex determination – including all crocodilians, many turtles, and some fish – are especially vulnerable to the effects of a rapidly changing global climate due to their profound sensitivity to thermal cues during development. Predicting the effects of climate change on species with TSD, including skewed offspring sex ratios, requires understanding how environmental factors interact with their nesting ecology to shape the developmental environment experienced by embryos in nature. For example, climate change may alter nest temperatures directly through changes to the nest microclimate as well as indirectly through influences on nesting phenology, nest site choice, and nest architecture. To understand the climatic and ecological drivers of nest temperature variation in the American alligator, *Alligator mississippiensis*, we deployed temperature loggers in 86 nests over 9 years at two geographically distinct sites in the northern and southern regions of the species' geographic range. Our findings suggest that alligator nests exhibit considerable thermal variation across multiple spatial. While variation in mean nest temperature across years is largely explained by variation in mean daily maximum air temperature, variation in individual nest temperatures also appears to be related to local habitat factors and microclimate characteristics. With increasing air temperatures, nest temperatures are projected to increase by 1.6°-3.7°C by the year 2100, changes which are predicted to have consequences for offspring sex ratios. Our findings provide insights into how nesting ecology interacts with climatic variables to influence population sex ratios in a species with TSD.

## Keywords

Ecological drivers; American alligator; Climate change.



# Reproductive trade-offs in the Morelet's crocodile, *Crocodylus moreletii*

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## Abstract

The most studied trade-offs focus on the reproductive effort, that is, the proportion of the energy resources of the individual allocated to reproduction, these resources are limited by the environment in which the individual is found and can be influenced by the natural selection, so that the individual seeks to allocate its resources to its different functions, to maximize its fitness. Evolutionary trade-offs in reptilian reproductive effort have focused on optimal egg size. The objective of this study was to evaluate the reproductive trade-offs between egg size and clutch size in the swamp crocodile (*Crocodylus moreletii*). For this, 13 nests were evaluated, 13 post-oviposition females and 434 eggs, of which 292 (67.2%) neonates hatched. No trade-off was found between clutch size and egg size; however, a positive correlation was found between egg size and hatchling size, showing that hatchling size is related to hatchling size. survival of it.

## Keywords

Crocodiles, Reproductive effort, Fitness, Life histories, Energy resources.





# Characterization of the nesting area of the river crocodile (*Crocodylus acutus*) in the estuarine system Boca Negra-Boca de Tomates in the Municipality of Puerto Vallarta, Jalisco, Mexico

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## Abstract

Nesting is one of the periods of the crocodile's reproductive cycle that has the greatest impact on the survival of the species. The objective of this work was to characterize the American crocodile (*Crocodylus acutus*) nesting zone in the estuarine system Boca Negra-Boca de Tomates in Puerto Vallarta, Jalisco, Mexico in the year 2019. Eleven nests were registered distributed in two points ("sand area" with 9 nests, and "airport area" with 2 nests) in an area of 867 m<sup>2</sup>. The field records included coordinates, external measurements (distance from the center of the nest to the nearest tree and the nearest water's edge), and internal measurements from the nest (depth of the nest from top, depth and width of the incubation chamber). The 2019 data was compared with the latest nesting studies in Boca Negra and el Salado estuaries in 2012. This comparison of results gives us data on the nesting of the American crocodile in Puerto Vallarta, placing the Boca Negra estuarine system as the most important for the nesting of the species in the municipality, registering greater number of nests per year and the results obtained suggest a good reproductive status in the region, however, long-term information is necessary to increase the sample size and confirm the reproductive status of the species.

## Keywords

Crocodylians, Nest, Characterize.



# The Crocodyliform PhyloCode Project: formalizing phylogenetic clade names for crocodylians and close extinct relatives

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## Abstract

The practice of defining taxon names on ancestry and descent – phylogenetic nomenclature – has grown in prominence since the 1990's, and such definitions currently exist for most crocodyliform clade names. Phylogenetic nomenclature promotes clarity in the meaning of a clade name, links names to an objective pattern (phylogenetic relationships), and if done collaboratively, strengthens connections between different communities working on the same groups of organisms. Indeed, the clade name definitions within Crocodyliformes are seen as an example of the kind of stability and clarity we can achieve with phylogenetic nomenclature. An international, interdisciplinary effort is underway to formally publish these clade names in accordance with the 2020 *International Code of Phylogenetic Nomenclature* (PhyloCode). The collaboration includes paleontologists and neontologists with expertise in morphology, the fossil record, ecology, molecular phylogenetics, and population genetics. Although the effort is directed toward clades rather than species, we are working closely with the effort to delineate living and extinct crocodyliform species-level diversity. We apply the crown-clade convention, in which names commonly associated with extant crocodylians will refer explicitly to groups based on extant specifiers. We will also use existing clade names and, to a large extent, existing clade name definitions and minimize the establishment of new names. Definitions will account for phylogenetic instability, with specifiers chosen to maximize stability and minimize the chances of destabilizing unintended consequences should our understanding of phylogenetic relationships change drastically. The outcome will be a set of phylogenetically-defined clade names of broad use by the crocodyliform community. Sections on individual clade names will include discussions of nomenclatural history and properties of the clade (e.g., diagnosis, diversity, fossil record, distribution). This will streamline communication among different stakeholders – systematists (modern and



fossil), ecologists, conservation biologists, population biologists, physiologists, and many more – and provide a framework for the organization of newly-discovered species, living and extinct.

**Keywords**

Crocodylia, Crocodyliforms, Phylogenetic nomenclature, Systematics.



# Does confinement period on farms affect the reintroduction of *Caiman latirostris* to their natural environments? Comparative analysis of wild and released individuals

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## Abstract

In “El Fisco” reserve, “Proyecto Yacaré” program has released caimans for about 30 years. *Caiman latirostris* population in this site is composed of wild animals (born in situ) and animals from the same site, released after incubation and breeding in captivity, carried out by the ranching program. Between 2015-2019 both, released and wild animals captured at the site were individually marked on their caudal scutes. A total of 248 individuals were captured, only animals from class size I and II were considered for the study. We measured growth rate in length and weight and distance between captures and recaptures. No differences were observed in growth rates, length ( $p = 0.94$ ) and weight ( $p = 0.31$ ). There were also no differences between capture distances ( $p = 0.07$ ). Therefore, our data support the hypothesis that confinement period of animals on farms, before release, does not affect growth rate in length and weight of animals in wild condition.

## Keywords

Growth rates, Reintroduction, *Caiman latirostris*, Wild-released caimans.



# Contribution of the Zapata Swamp Farm to the conservation of crocodiles in Cuba

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## Abstract

Here, we updated the information regarding the management of the captive population of the Zapata Swamp Farm and its contribution to the conservation of the Cuban crocodile, and the knowledge of the status of the crocodilian species present in Cuba. The aims of the conservation activities are: 1) understanding the species biology, 2) increasing the distribution range of Cuban crocodiles, 3) monitoring their free-living populations, and 4) managing captive populations. Work is currently underway to create a health baseline for captive Cuban crocodile populations, and the wild population presents at Zapata Swamp. Furthermore, we started a project to identify the temperature range for sex determination in *Crocodylus rhombifer*. We show the first results of updating the distribution range of the genus *Crocodylus* in Zapata and of the three species of crocodilians present in the Isla de la Juventud. In addition, we show a summary of several release events of Cuban crocodiles held between 2019 and 2022, and a project on developing to assess the status of the population of *Crocodylus rhombifer* released in 1994 at the Isla de la Juventud.

## Keywords

Cuban crocodile, Body condition, Health evaluation.



# Body condition, growth, and survival of the American crocodile (*Crocodylus acutus*) in the Florida Everglades

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## Abstract

The American crocodile (*Crocodylus acutus*) is a flagship, federally threatened species and ecosystem indicator that directly links responses of crocodiles to hydrologic restoration in the Florida Everglades. Here, a long-term mark-recapture study of American crocodiles was conducted in south Florida from 1978 to 2015. Over the study period, 10,040 crocodiles were captured, with more than 90% of captures being hatchlings. We estimated hatchling survival at 25%, which steadily increased with age to near 90% survival from age six onward. Survival rates decreased with hypersalinity and differed between nesting areas. Body condition and growth of crocodiles were strongly age-structured with younger crocodiles found in lowest body condition but growing fastest and larger crocodiles continuing to grow. Crocodile body condition decreased with more days of hypersaline conditions and low annual salinity had positive effects on body condition. High average salinity conditions during the dry season strongly reduced growth rate. After the first year under high salinity conditions, there was a 13% decrease in crocodile growth, a 24% decrease at 5 years old, and a 29% decrease in growth at 10 years of age. Crocodiles captured in Northeastern Florida Bay where hydrologic conditions have been most altered were in lowest body condition, had reduced growth rates, and had the lowest survival rates relative to other nesting areas of South Florida. These findings support the hypothesis that restoring freshwater flow will reduce hypersaline conditions and will result in crocodiles in better condition, with faster growth rates, and greater survival in the Florida Everglades. American crocodiles are an effective bioindicator and illustrate the need for continued restoration efforts in NE Florida Bay to ensure health of the Florida Everglades.

## Keywords

Crocodylian, Mark-recapture, Salinity, Survival.





# Study of the cytochrome b gene in the genus *Caiman* (Crocodylia, Alligatoridae) in Central and South America: phylogeographic analyses and phylogenetic inferences

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## Abstract

The genus *Caiman* is one of the most taxonomically conflictive among crocodylians due to different views about the phylogenetic position of *Caiman crocodilus* within this genus. In Argentina, *Caiman latirostris* and *Caiman yacare* are present, and they are subject to sustainable use programs although they are scarcely studied at the genetic level. Our study had two aims: 1) genetic diversity, structure, and phylogeny of *C. yacare* and *C. latirostris* in Argentina and, 2) phylogenetic analysis of the genus *Caiman* throughout its entire distribution in America. The results show high haplotype diversity for both caiman species in Argentina but low nucleotide diversity for *C. latirostris* sequences. Phylogenetic analysis shows a clear separation between both species, but surprisingly, a well-differentiated clade belonging to the Chaco region is observed. The phylogenetic analysis that includes all *Caiman* species identified clades made up of the sequences of each species, but with some inconsistencies: in the clade of *Caiman crocodilus*, a sequence of *C. yacare* is included, and a clade is observed that combines sequences from *Caiman crocodilus fuscus* and *Caiman crocodilus chiapasus*. These data indicate the need to undertake



interdisciplinary studies to clarify the taxonomic status of these crocodilian species and inform conservation management.

**Keywords**

Species concept, Conservation genetics studies, Crocodilian systematics.



# Preliminary report: Discovering the ancestral origin of *Crocodylus* in South America: an expedition to the amazing and complex Orinoco Delta

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## Abstract

In 1801, Alexander von Humboldt carried out an expedition to the Orinoco Delta, identifying the presence of *Crocodylus intermedius*. Two centuries later, Medem (1983) mentions that the Orinoco Delta is an area of “exchange” or hybrid zone between *Crocodylus intermedius* and *Crocodylus acutus*. However, no formal expeditions have been made to the Orinoco Delta to confirm the presence of both, or either, species in this amazing and complex environmental system. Evolutionarily, this area is of great relevance because it may be the zone of primary divergence of the most ancestral species of *Crocodylus* in South America and a potential hybrid zone between the two species present in Venezuela. The phylogenetic origin of both species is still unknown, as well as the reason for their distributional divergence: *C. intermedius* is restricted to freshwater habitats of the Orinoco River, while *C. acutus* is a coastal and estuarine species of the Atlantic Ocean and Caribbean. Our principal aim was to explore the Orinoco Delta to discover *C. intermedius* and *C. acutus* and, ultimately, test their evolutionary origins and possible ancestral hybridization or incomplete lineage sorting using molecular, morphometric, and ecological tools. During this work, we will also seek to understand the ethnozoographic relationship that local people (Waraos) have with these crocodylian species. Generally the interaction between wild populations



of crocodiles and local communities can set the stage for conservation interventions and help actions for these species in their different distribution areas. This project was funded by National Geographic and the first stage is already finished.

**Keywords**

Evolution, Crocodilian, South America.



# RNA-seq characterization of blood in the Broad-snouted caiman (*Caiman latirostris*) after pesticide exposure and immunological challenge

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## Abstract

The analysis of expressed genes in a tissue at the mRNA level (transcriptomics) provides much increased insight into biological processes at the molecular level. The aim of this study was to analyze gene expression profile of blood samples obtained from juvenile *C. latirostris* after acute exposure to a cypermethrin-based pesticide formulation and immune challenge with *Escherichia coli*. Eight juvenile caiman were separated in two experimental groups: a negative control (C) and a group exposed (E) to a cypermethrin formulation (25% CYP). Animals were maintained under controlled conditions into plastics containers and the exposure was performed by voluntary immersion in water, at a concentration of 2 µg/l 15 days. After exposure, all animals were immunologically challenged by an injection with *E. coli* suspension (0.5 A) at a dose of 0.1 ml/kg during 96 hs. Blood samples were taken to all animals at the beginning and at the end of the experiment and immediately preserved. TRIzol reagent was used for RNA extraction following protocols previously adapted for the species. Libraries were prepared (DNA 0.1-5.0 µg) and DNA was sequenced using Illumina sequencing Technology (NGS) through a HiSeq3000. We identified 1266 differentially expressed genes in caiman challenged by *E. coli*: 489 (38.6%) downregulated (DR) and 777 (61.4 %) upregulated (UR). When we analyze animals previously exposed to CYP, the number of genes differentially expressed decreased to 592, being 248 (41.9%) DR and 344 (58.1%) UR. These results showed that the previous



exposure of CYP seem to cause a decrease in the immune response of the animals. In order to go further in the understanding of these results, we performed a Functional Annotation analysis using *DAVID Bioinformatic database*, identifying different enriched metabolic pathways in each condition, including lipid and carbohydrates metabolism, immune response and cell adhesion function.

**Keywords**

Differentially expressed genes, Transcriptome, Toxicity, Immune response.





# Social media to promote and support crocodilian conservation

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## Abstract

Gatorland has been the leader in alligator safety and education since 1949. As the trusted name for alligator information, Gatorland is the “go-to” organization for media inquiries on alligator safety, education, and conservation. In 2016, Gatorland made the strategic decision to expand our communication and educational outreach with the general public. To spread our mission to “protect, educate, and conserve,” Gatorland began investing significant human and financial capital into social media platforms to create and distribute groundbreaking content. Our entertaining and educational social media programs were built on a foundation of conservation through the creation of Gatorland Global, the conservation arm of our business. By sharing the beauty and unique behavior of alligators and crocodiles within the park, our social media content has engendered thousands of people to love and respect these often-misunderstood animals, with the ultimate goal of sparking the desire to learn about, protect, and conserve crocodilians around the world. Social media is people power, and support from the millions of people that have joined our social media family has propelled Gatorland Global's mission into a new realm of public awareness. Our social media platforms generate significant dollars, where 100% of social media revenues go directly to support Gatorland Global's conservation projects around the world. These important projects include saving nuisance alligators, *Alligator mississippiensis*, in Florida, research on *Crocodylus acutus* ecology in Florida with Joe Wasilewski, supporting and participating in projects with *Crocodylus rhombifer* in Cuba with Gustavito Sosa and Etiam Perez, relocation work with *Crocodylus acutus* in Jamaica with NEPA and Treya Picking, and supporting *Crocodylus intermedius* with Luis Sigler at the Dallas World Aquarium and Alvaro Velasco of Venezuela. Gatorland's social media is laser-focused on bridging relationships between animal lovers and academia by teaching people to love crocodilians and the amazing world we share.

## Keywords

Social media, Crocodilians, Conservation.



# The return of the Orinoco crocodile *Crocodylus intermedius* to the Venezuelan Llanos

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## Abstract

On 2021, two AZA institutions successfully bred Orinoco crocodiles. In agreement with the Species Survival Plan, all these hatchlings or juveniles can be sent to Venezuela to reinforce the wild populations of the species. More than 10 US zoological institutions are participating head starting a couple of crocodiles in their facilities and using them as ambassadors to raise awareness for the conservation of the species with the zoo visitors. Two fundraisers have been set by CrocFest to raise economical resources to secure the costs of shipping, quarantine, feeding, medical attention, soft-release enclosures, and transportation to the release spot. All the juvenile crocodiles will be scute clipped and tag-numbered for identification, and also will be equipped with satellite and antenna tracking devices to know their movements, dispersion and survival among other parameters after their release. The Crocodile Specialist Group of Venezuela who are also partners of this project have released more than 10,000 juveniles in the wild in the past two decades. Some of the released crocodiles reached maturity and are breeding and producing hatchlings in the Venezuelan Llanos.

## Keywords

Orinoco crocodile, Head-start program, Reinforcement, Venezuela.



# Individual identification of *Crocodylus intermedius* (Orinoco caiman) using pattern of tail dark spot

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## Abstract

The Conservation Action Plan of the Orinoco crocodile (*Crocodylus intermedius*) among its activities is the release or reinforcement of natural populations with captive-bred specimens, by monitoring these specimens in their natural habitat their adaptability is assessed, but an identification system is necessary to recognize the individuals when they are recaptured. 543 Orinoco caiman were photographed and analyzed, generating 464 Swanepoel codes and 537 Boucher *et. al.* codes based on the dark spot pattern of the scales on the right side of the tails. Both methods yielded high code values, however, the one developed by Boucher *et. al.*, with a 98.90% differentiation of the analyzed specimens, worked better. The study confirms that using the method of spots in the tail of crocodiles is an effective tool in identifying individuals.

## Keywords

Orinoco crocodile, *Crocodylus intermedius*, Individual identification, Scales pattern, Venezuela.



# **Citizen science-based radio-telemetry study on the conservation of introduced Philippine crocodiles (*Crocodylus mindorensis*) in Paghungawan Marsh, Siargao Island Protected Landscapes and Seascapes – Initial findings**

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## **Abstract**

A total of 65 Philippine crocodile (*Crocodylus mindorensis*) have been introduced last 2013 and 2017 in Paghungawan Marsh, Siargao Island Protected Landscapes and Seascapes as part of the conservation introduction program of the Philippine government. Citizen science-based radio-telemetry of Philippine crocodiles is currently being conducted to expand the current knowledge on the home range and activity pattern of the introduced *C. mindorensis*, as well as enhance the capacity of local communities in participatory Philippine crocodile research. Five crocodiles have been attached with Holohil R1 2B radio-transmitters and were tracked using ICOM V80 handheld radio transceivers from July 2018 to December 2019. Transmitter detachment has been observed a few months after attachment for some individuals which has been attributed to the size of crocodiles. Both ZoaTrack open-source telemetry software and adehabitat HR package v.0.4.16 in RStudio v.1.2.5033 were used to determine and visualize the home range and core areas via Minimum Convex Polygon and Kernel Utilization Distribution analysis respectively. Initial results showed that one of the introduced Philippine Crocodiles' home range is 5.9ha having a core area of 0.05ha. Individuals have also been observed inhabiting elevated limestone crevices and caverns on steep slopes. This also increased the daytime sightings probability which contributes to the developing community-based sustainable eco-tourism. These novel findings will help in redefining future Philippine Crocodile release programs and in redesigning population survey techniques.

## **Keywords**

Philippine Crocodile, Paghungawan Marsh, Home range, Radio-telemetry.



# Heavy metals in caudal scales of *Crocodylus moreletii* in the southern portion of the Selva Lacandona, Chiapas, Mexico

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## Abstract

Heavy metals are the main contaminants of aquifers due to their high toxicity, persistence, and mobility; they affect important hydraulic loads, such as lagoons and irrigation canals, and because of their physicochemical properties, they are not biodegradable and can become toxic to vertebrates and invertebrates. The objective of this study was to determine the presence of heavy metals in the population of *C. moreletii* inhabiting the southern portion of the Lacantún river in the Selva Lacandona. Samples of caudal scutes were collected by manual captures and with the support of Thompson-type loops from January 2018 to February 2019 in 23 km of the middle sub-basin of the Lacantún river in the Reserva de la Biosfera Montes Azules (REBIMA). Subsequently, the presence of heavy metals such as lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) was determined using the atomic absorption spectrophotometry by flame technique; while for mercury (Hg) and arsenic (As) by atomic absorption spectrophotometry by hydride generation. The presence of five metals was detected: lead (Pb), cadmium (Cd), mercury (Hg), zinc (Zn) and copper (Cu) in the caudal scutes of *C. moreletii* and one metalloid: arsenic (As). With these results, we infer that the pollutants present in the *C. moreletii* scutes flowing at the three sites sampled are indicative of point sources of contamination for the southern border zone of the REBIMA within the complex known as Selva Lacandona.

## Keywords

Morelet's crocodile, Bioaccumulation, Environmental pollution, Ecotoxicology.



# Useful non-destructive tissues for the monitoring of metals in crocodylians and the potential of metallothioneins as a biomarker of metal exposure

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## Abstract

Although crocodylian caudal scutes have been identified as indicators of metal accumulation, the distribution of metals in other tissues and blood fractions, the potential relationships between organs and keratinized tissues and the response of metal binding proteins remain uncertain. In this study, the distribution of Hg, Cd, Cu and Zn in keratinized tissues, blood fractions, and excretory organs, and MTs in blood fractions and excretory organs was determined in captive, semi captive, and wild Morelet's crocodiles and they were compared to select the most effective non-destructive tissues for the monitoring of metal exposure and to assess the potential of MTs as a biomarker. Our results indicate blood plasma, claws, and caudal scutes altogether are suitable for the monitoring of xenobiotic metal exposure, with concentrations in blood plasma being an indicator of recent exposure, whereas concentrations in claws. Results in keratinized tissues suggest they are an important detoxification strategy in crocodiles, and foremost, claws presented the highest concentrations of metals in both captive and wild populations. This latter demonstrates that claws are a recommendable tool for assessing metal exposure in populations, especially in those where scutes clipping as a marking technique is not allowed, and their collection is less complicated than with other tissues. MTs are a suitable biomarker in blood plasma, whereas in erythrocytes detoxification processes might depend on hemoglobin, rather than MTs. Future studies should consider the implementation of these tools for the monitoring of wild populations.

## Keywords

Metallothioneins, Keratinized tissues, Hemoglobin, Metal detoxification.





## Knowledge and perception of tour operators on crocodiles (*Crocodylus moreletii*) as a tool for dissemination and conservation

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### Abstract

The correct interaction between humans and wildlife has been basic in the conservation of species, a strategy to promote it, is the ecotourism, which has been successful around the world having benefits for wildlife and people. The Catemaco Lake (Veracruz, Mexico), has a population of *Crocodylus moreletii* that has been included as one of the tourist attractions of the place, however service providers do not have the necessary information to offer tourists an optimal service that promotes species conservation. This study aims to analyze the knowledge and perception of tour operators of the Catemaco Lake about crocodiles as a tool for the conservation of the species. A semi-open survey of 15 questions was applied to the tour operators of the Catemaco Lake boardwalk. Forty-seven percent of respondents know at least one way to exploit crocodiles, mainly skin and tourism; 95% believe they are important in ecosystems, however only 26% know a particular important role of crocodiles, the rest of interviewed partially or totally unknown any role of crocodiles importance; 75% recognize some risks that crocodiles face in the lake. Regarding tourist activity, 95% of respondents receive questions from visitors about crocodiles, however only 63% say they know how to answer these questions, in the same way 95% of respondents are interested in receiving more information about crocodiles. The level of knowledge that tour-operators possess about crocodiles is insufficient to satisfy both tourist inquiries and the need of knowledge and awareness for



conservation. Nevertheless, interest of tour-operators and tourists, to increase crocodile background information, crocodile observation as part of the tours is a promising tool for science communication and conservation not only of crocodiles but also of its environment, aimed at a wide audience.

**Keywords**

Ecotourism, Human-crocodile interactions, Science communication, Local ecological knowledge.



# A review of 25 years of research and management efforts for the conservation of the American crocodile (*Crocodylus acutus*) in the Mexican Caribbean

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## Abstract

The population of *Crocodylus acutus* in the Yucatan Peninsula is one of three that are separated by geographical barriers in Mexico, the other two populations are found along the Pacific Coastal Plain and in the Grijalva - Usumacinta rivers drainage system. In the State of Quintana Roo *C. acutus* is circumscribed mainly to saline environments along the coast, consisting essentially of communities dominated by mangroves, coastal lagoons, rivers, cays and islands and typically nesting in sandbars. This coastal strip, where the critical habitat for the reproduction of the species is found, is subject to one of the greatest touristic developments and urban growth pressures in the world. Here we present a 25-year review of efforts for species conservation and its habitat, sympatry with *Crocodylus moreletii*, population trends, institutional management and human crocodile interactions. Finally, we provide guidelines for future research and adaptive management for the conservation of the American crocodile in the state of Quintana Roo along the Mexican Caribbean.

## Keywords

*Crocodylus acutus*, Conservation, Management, Mexican Caribbean.



# Wildlife tourism value of crocodilians in relation to consumptive values

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## Abstract

Wildlife tourism can provide economic benefits to local communities and conservation benefits to species if carried out in a responsible and sustainable manner. Large predators have received increasing interest from the wildlife tourism industry in recent years and some populations/communities have been assigned high tourism values in the literature. One group of large predators that has not been studied in this regard is the crocodilians, even though they have been the focus of dedicated wildlife tourism operations in many countries for decades. We conducted the first analysis of the wildlife tourism value of crocodilians using a unique dataset of financial information from a wildlife tourism operation in South America coupled with data from a long-term mark-recapture study. We also compared the estimated monetary values of individual crocodilians from our study with the values of individual crocodilians estimated from publicly available data provided by the crocodilian farming and hunting industries. We found that between 2009 and 2014, farmed *Alligator mississippiensis* in Florida, Louisiana, and Texas had average individual gross values of US\$140.98-\$583.06, while farmed *Crocodylus niloticus* in Zimbabwe were valued at US\$312.25-\$558.97. Meanwhile, hunted *A. mississippiensis* in Florida and Louisiana were valued at US\$173.03-\$392.19. During the same time period, *Melanosuchus niger* that were the focus of wildlife tourism near a village in Guyana were valued at US\$385.53-\$1051.69. Our results demonstrate that non-consumptive crocodilian tourism is capable of generating, at a minimum, comparable amounts of money per individual relative to consumptive crocodilian industries, and may even generate much more money in certain contexts. Further developing crocodilian tourism where crocodilian are threatened or endangered could therefore be a viable method of supporting conservation efforts.

## Keywords

*Melanosuchus niger*, Guyana, Farming, Hunting.



# Using past archives to better constrain the future of *Alligator sinensis*

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## Abstract

Species distribution modelling is a widely applied tool for forecasting future distributions of species under different climatic scenarios, informing conservation strategies and rewilding programmes. However, forecasting is typically based on very recent species' records (last ~50 years). This is problematic, given that these records are strongly affected by human interactions, and we do not know whether current distributions reflect the full suite of environmental parameters a species can inhabit. If we only model data from current distributions in future projections, we are thus likely to get misleading predictions that might misdirect conservation planning. The Critically Endangered Chinese alligator is currently restricted to a single Chinese province. Historical, zooarchaeological, and fossil records demonstrate a greater range across mainland China, extending its past distribution even further, to Taiwan and Japan. Species distribution models (SDMs) based only on the present-day distribution of the Chinese alligator are poorly constrained, whereas incorporation of past archives improves model fit and changes projected suitable habitat. By combining past and present data, we can provide a closer approximation of the full ecological niche of a species. For endangered species with restricted present-day ranges, additional occurrence data from past archives is critical for constraining SDMs, with potentially major misinterpretations of suitable habitats for conservation and rewilding. This research is the principal case study for an IUCN Green status of species/Conservation Paleontology Network working group; forming the framework for the inclusion of past archives in the development of species recovery baselines and it is planned that Crocodylia will have the first order-wide assessment.

## Keywords

Species distribution model, IUCN Green status, Past archives.



# Phylogenomic data support a non-bifurcating speciation history within the *Paleosuchus palpebrosus* species complex (Alligatoridae: Caimaninae)

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## Abstract

In our previous study we detected three Evolutionarily Significant Units and proposed that *P. palpebrosus* is a species complex. In the present study, we expanded our genomic sampling to 6,733 loci to delimit lineages, test monophyly and resolve phylogenetic relationships between lineages. Cluster analyzes were consistent in indicating four deeply divergent groups - "Amazon" (A), "Madeira" (M), "Bolivia" (B) and "Pantanal" (P). Species tree estimated with SNAPP (A,(M,(B,P))) was well supported and different from that estimated from the mitochondrial cytb gene (A,((M+B),P)). Supertree estimated in ASTRAL-III was consistent with the SNAPP results and confirmed the monophyly of A, P and B+P, although B and M were both not well supported as monophyletic. Additionally, the topology resulting from SNAPP was analyzed in G-PhoCS, which estimated three unidirectional migration bands: ancMBP→A, A→M and M→B. Delimitation of species using the Bayes Factor Delimitation method in SNAPP indicated the existence of four species, since models containing four species were more likely than models with three or less species. Although our results are robust in terms of the number of species in the complex, phylogenetic relationships among them are less certain. The non-monophyly of M and B in ASTRAL-III, the apparent inconsistency with the mitochondrial topology and the need to include gene-flow/hybridization to explain lineage divergence of this group indicates a more complex speciation history than explained by simple branching process. It is possible that the mtDNA phylogeny reflects the true sequence of divergences, and that subsequent introgressions made it difficult for analytical methods that account only for Incomplete Lineage Sorting to estimate the correct phylogenetic relationships. Although they appear inconsistent, the phylogenetic signs of the mitochondrial and





nuclear markers are complementary and help us to delimit a small number of alternative hypotheses of diversification with reticulation and/or hybridization that can be explicitly tested.

**Keywords**

Dwarf caiman, Species complex, Species tree, Forensic genetics.



# Hybrid a Salt: Genomic investigation of salinity tolerance as an adaptive phenotype in *Crocodylus acutus* x *C. moreletii* hybrids in Belize and its conservation conundrum

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## Abstract

Incorporating alleles from one species into the gene pool of a second—or introgressive hybridization—is a subject of controversy due to its constructive and destructive force. It can enhance adaptability and facilitate rapid radiation by introducing genetic variation, but it can also drive rare taxa to extinction through loss of local adaptation or genetic swamping. While natural hybridization is a known evolutionary process, anthropogenically induced hybridization has been established as a threat to biodiversity. High levels of introgression between the saltwater-adapted American crocodile (*Crocodylus acutus*) and freshwater-adapted Morelet's crocodile (*Crocodylus moreletii*) have been recorded in sympatric areas throughout Central America, revealing evidence of multigenerational hybrids across the Gulf of Mexico and parts of the Caribbean. While this hybridization has been established as an ancient process, anthropogenic impact has been proposed to be speeding up and spreading the hybrid boundaries beyond historical hybrid zones and farther than the boundaries of any one species. In Belize, escalating reports of hybridization has raised concerns among conservation stakeholders regarding the preservation of each species' genetic integrity. With both species being listed as highly threatened in Belize, decreased protection due to ambiguous conservation laws for hybrids increase the vulnerability of both the animals and their environment. The goal of my study is to investigate what may be facilitating this hybridization in order to understand its evolution and conservation implications. Using a genome-wide association study, I aim to conduct a population genomic analyses to reconstruct the magnitude and timing of introgression, as well as to identify potentially adaptive phenotypes exhibited from introgressed genomes – particularly involving salinity tolerance. In preliminary analyses, significant differences were found in environmental salinities taken at capture locations across Belize between morphologically distinguishable *C. acutus* and *C. moreletii*, and between *C. moreletii* and putative hybrids.

## Keywords

Hybridization, Introgression, Evolution, Genomics.



# Knowledge of locals and interaction with crocodiles in the Sian Ka'an Biosphere Reserve, Mexico

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## Abstract

Contact between wildlife and humans has become frequent due to the displacement and growth of the human populations; therefore, it is necessary to work with locals to know their relationship (knowledge and interaction) with wildlife and strengthen the information they have, to guide people to a satisfactory co-existence with wildlife. This study aimed to document and analyze the knowledge and interaction that residents of two villages at Sian Ka'an Biosphere Reserve (SKBR) have about crocodiles. Semi-open interviews were conducted in Punta Allen (n = 71) and Punta Herrero (n = 13) during August-October 2019 and November-December 2020. Local in both villages tend to be unaware of the existence of the two crocodile species (*Crocodylus moreletii* and *C. acutus*) that live in the SKBR. In most cases they do not know their differences; 100% of respondents refer the presence of crocodiles (regardless of species) in the mangroves of lagoons and canals, followed by savannas and the beach. According to more than 50% of respondents, crocodiles are visible throughout the year, however particular cases remarks some months more regularly. The tourist activity targeting crocodiles is mainly carried out in Punta Allen, but it is not offered regularly; close to 70% of respondents say it is not a relevant activity and do not believe that this activity can be improved. Likewise, the interviewed people believes that crocodiles are dangerous or not attractive to them, despite this 70% know that they have an



ecological importance. In addition, 85% assures that the population of crocodiles is currently greater than in the past. The villager's knowledge about crocodiles seems to be fairly good, however there is a need to strengthen and offer more broadly information about their biology, importance and conservation.

**Keywords**

*Crocodylus acutus*, *Crocodylus moreletii*, Human-crocodile interactions.



# Conservation of *Crocodylus acutus* based on environmental education, art and interculturality in an indigenous paradise on the coast of Oaxaca

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## Abstract

The actions of conservation of wild species in Mexico and the participation of society in these have had an increase in recent years, some cases have been documented and published. Within these conservation actions we find environmental education, which is mainly characterized by being interdisciplinary and multidisciplinary, as well as having a range of possibilities and resources. Since 2016, an inclusive, dynamic and participatory synergy has been promoted on the coast of Oaxaca between environmental education, art and interculturality aimed at the conservation of species that inhabit the mangrove of La Ventanilla, municipality of Santa María Tonameca. The actions carried out have as a central point the conservation of the *Crocodylus acutus* source of income by means of responsible tourism and non-extractive use by the Cooperative Society of Ecotourism Services of La Ventanilla S.C. de R.L. de C.V. Work has been done to systematize and analyze the results of the actions carried out, in coordination with the Universidad Juárez Autónoma de Tabasco (UJAT) and the University of Guadalajara (UdG) to propose conservation strategies and future use of this species. The participation of the community has been fundamental for the continuity of the work carried out, as well as a dialogue and exchange of knowledge between different communities, scientists and artists of the Mexican territory.

## Keywords

Conservation, Environmental education, Indigenous paradise, Oaxaca.



# **A community-based participatory research experience on Proyecto Yacaré-Broad-Snouted Caiman Sustainable Use Program (*Caiman latirostris*)**

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## **Abstract**

Proyecto Yacaré, *Caiman latirostris* Program, has been operating in the city of Santa Fe, Argentina for 30 years, however, the relationship with the society in which its activities are carried out was maintained until 2015 within the academic field (research and teaching) in addition to the work with local people who participate in the collection of eggs. Since 2015, extension activities have been started in the field of Environmental Education, planned for the time of births. Through social networks and media, citizens of Santa Fe and the region are invited to join the Project's facilities on certain days of the week, upon confirmation that births were taking place. There they are welcomed and guided by researchers and interns of the same who give a small talk about the activities, the value of the incentive driven conservation of the program and a video is projected about it. Then, children and adults are allowed to participate directly in the hatching of the eggs, after a brief talk on the correct way to do it. Since the beginning of these activities more than 1200 people have participated in the six seasons, and the opinions and perceptions of the public was recorded, plus the reception of the suggestions of the visitors on the most effective way to promote the understanding of the sustainable use programs. Since November 2019 this experience of Community Participation is complemented with a survey of alligator populations in peri-urban wetlands of the city of Santa Fe with neighbors and island settlers, which has so far resulted with 10 records of the species in the vicinity of Ciudad Universitaria by mean of a Community-based participatory research which is just starting now.

## **Keywords**

Citizen participation, *Caiman latirostris*.





# The crocodile in the pre-hispanic cosmovision of Mexico

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## Abstract

The pre-Hispanic myth tells us: "In the beginning, there were only chaotic waters, home of a large crocodile, who was sacrificed by the solar gods, from his body, the world was created, and the time began, however, he will destroy the world at the end of time". This fundamental myth has the clue to understand, the role of the crocodile in prehispanic cultures, role that has mostly studies by an anthropological perspective. So, using that information we propose a theoretical approach to their understanding. The myth state that the violent confluence between two opposite qualities, to create a third unifying one, it is this union that creates life and therefore death, it is the union of the hot with the humid, of the masculine with the feminine, of the divine with the material, the sun whit the earth, fundamental stone of the pre-Hispanic cosmovision. With this key, the role of the crocodile emerges as a symbol of fertility, of the humid, of earth, of the nocturnal and also of dead; this is antagonist with the sun, which is warm and dry, but indispensable to create life, reason why we can see the crocodile as the beginning and end of the sunstone. Thanks to this decoding, we can understand the other mythical representations, like the relationship between the crocodiles and the corn (as we can see in the Codex Borgia), with Tlaloc and with the Earth goddesses (like Tlaltecuhli). Also allows us to know the relationship whit the Mayan cosmic tree, the place of communication between the underworld and the overworld. In conclusion, the role of the crocodile must be re-interpreted to give him her true place in the pre-Hispanic cosmovision, a place it shares with such important animals as the eagle or the jaguar. This mythological analysis gives us an important tool to create identity, an indispensable condition for cultural and biological conservation.

## Keywords

Cipactli, Ain, Mythology, History.



# Human dimensions of crocodile conservation in the southeast of Mexico

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## Abstract

The human dimension of wildlife conservation emphasizes understanding human thought (public values or preferences) and actions toward wildlife. One approach to analyze people's perceptions about wildlife is Wildlife Value Orientations (WVOs), a conceptual framework to study human values and understand people's beliefs and actions towards wildlife. This study applied the WVOs approach to explore human values, beliefs, and attitudes towards crocodiles in Mexico. A 20-item, semi-structured questionnaire were applied to interview 59 persons in three rural villages in Campeche, Mexico (Hampolol, Miguel Colorado and Silvituc). Exploratory Factor Analysis (EFA) were applied to elucidate the latent variables. To determine whether the data set in this study was appropriate for a EFA we applied Bartlett's sphericity and Kaiser-Meyer-Olkin factorial adequacy tests. The results (Bartlett's test of sphericity  $\chi^2 = 242.23$ ,  $p < 0.001$ , a positive determinant value  $\det = 0.010$  and the Kaiser-Meyer-Olkin factorial adequacy test overall MSA = 0.75) indicate that the data set of this study was appropriate for an EFA. Three latent variables or factors explained 52% of the variance, these were interpreted as 1) coexist/management factor; 2) harvest factor and 3) risk factor. All three factors were internally consistent, (Factor 1 (Coexist/Management)  $\alpha = 0.77$ , Factor 2 (Threat/Danger)  $\alpha = 0.78$  and Factor 3 (Harvest)  $\alpha = 0.72$ ) which indicated that its items were measuring the intended latent variable. Results suggests that Silvituc participants have the highest risk perception (Factor 2) and are willing to harvest crocodiles under an utilitarian scope (Domination value) (Factor 3), whereas the residents of Hampolol are more involved in Factor 1 (Coexist/Management). With respect to Miguel Colorado participants, analysis suggests they have a similar risk perception as Hampolol but have lesser Mutual/Domination and Domination values. These results provide insights into rural communities' wildlife values, it also offers a theoretical contribution and illustrates how WVOs may be applied in rural Latin-American context.

## Keywords

Wildlife-value-orientations, *Crocodylus moreletii*, Mexico



# **Current status of the Crocodile Management and Conservation Program in Cancun, Quintana Roo, Mexico**

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## **Abstract**

The work developed in the last seven years is presented, where an attempt has been made to permanently establish the Crocodile Management and Conservation Program in Cancun (PMCCC for the name in Spanish), partially carrying out activities in the various subprograms such as: population monitoring, attention to conflicts and environmental education. These activities include: the decrease in relative densities, the decrease in the number of encounters with adult specimens, the attention to conflicts between humans and crocodiles, the development of a database of negative human crocodile interactions and their respective analysis, the discovery of plastics in stomachs of run-over crocodiles and the ignorance of the residents and visitors about the true behavior and importance of crocodiles, as well as the population size present.

## **Keywords**

Conservation program, Crocodiles, Cancun.



# Unveiling the mystery: assessing the evolutionary trajectory of the Apaporis caiman population (*Caiman crocodilus apaporiensis*, Medem 1955) via mitochondrial molecular makers

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## Abstract

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

## Keywords

Crocodylians, Phylogeography, Systematics



# Molecular characterization of the spectacled caiman (*Caiman crocodilus*) in the Upper Magdalena River Basin, Colombia: demographic and phylogeographic insights

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## Abstract

Maintenance of high levels of genetic diversity is crucial for the recovery of overexploited species and acquiring knowledge of genetic diversity of natural populations is crucial to define effective conservation strategies. Spectacled caimans (*Caiman crocodilus*) were unsustainably exploited for decades in Colombia causing drastic population reductions with unknown effects on genetic structure. We molecularly characterized three spectacled caiman populations from the Upper Magdalena River Basin (UMRB), analyzing them within the context of the trans-Andean *C. c. fuscus* sensu stricto lineage, assessing nucleotide and genetic diversity, demographic history, and phylogeography at different scales. Seventeen of the 23 mitochondrial haplotypes currently described for Colombia are present in the UMRB, showing high levels of genetic diversity even when compared with the trans-Andean region (uncorrected genetic distances 0.00-0.87%). Mutational steps between closest haplotypes ranged from one to four while the most differentiated haplotypes were separated by 19 mutational steps across the whole trans-Andean region. Distribution of pairwise nucleotide differences and raggedness tests showed unimodal patterns of mismatch distribution curves fitting the sudden expansion model. Intriguingly, samples from Tolima were overall more related to those collected from Panama and Costa Rica ( $0.34 \pm 0.15\%$ ) than the ones collected across Choco ( $0.45 \pm 0.15\%$ ), Cauca ( $0.70 \pm 0.09\%$ ), and Nariño ( $0.60 \pm 0.14\%$ ) departments. We discuss our genetic findings in the context of the management policies



carried out in the country during the last decades (unsustainable and sustainable use, and population restocking), evaluating the implications of these events for the genetic integrity and conservation of the species.

**Keywords**

Conservation genetics, Colombia, Wildlife management, Genetic diversity.



# Mitochondrial DNA analyses reveal mainland-insular dispersal of American crocodiles across the Caribbean

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## Abstract

The American crocodile (*Crocodylus acutus*) is one of most widely distributed true crocodile species in the new world. However, *C. acutus* is currently categorized as “Vulnerable” by the IUCN Red List due to an extended unsustainable use and habitat transformation across its range. Conservation efforts have allowed populations to recover to the point dispersal movements began to be documented. In 2012 and 2018 the environmental authority of San Andres, Providence, and Santa Catalina archipelago reported the arrival of two *C. acutus* from unknown localities. The former animal was sacrificed due to a potential human-wildlife conflict with tourist/locals and no samples were collected. The latter animal was captured and kept to determine the potential origin of it. To this end, we used wildlife forensics to establish the most likely origin of this individual based on phylogeographic analyses. We amplified, sequenced, and analyzed two mitochondrial genes (Cytochrome Oxidase I-*COI* and Cytochrome B-*CytB*) from a sample collected in 2018. Phylogenetic and phylogeographic analyses were performed including existing sequences from the NCBI database and samples collected from Tayrona (TNNP) and Salamanca Island (SINNP) national natural parks. Reconstructed phylogenies derived from Bayesian Inference and Maximum Likelihood analyses showed that the American crocodile found in San Andrés belongs to an evolutionary lineage endemic from Colombia (Magdalena-Buritaca). The TCS haplotype network analysis showed a strong genetic similarity between the San Andres individual and those from SINNP. Thus, the most likely origin for the *C. acutus* that arrived to San Andres is somewhere around the Magdalena river area, which is located ~700-km from the island, highlighting the capacity of *C. acutus*





to perform sea incursions, opening up the possibility of active dispersal events across the Caribbean, and suggesting the potential of these type of analyses to be used as a conservation strategy.

**Keywords**

Crocodylians, Wildlife Forensics, Genetics, Conservation.



# Mitochondrial markers as a tool for the management and conservation of American crocodiles (*Crocodylus acutus*) in Colombia

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## Abstract

The American crocodile is the most widely distributed crocodile species in the neotropics, and it is essential in aquatic ecosystems given the ecological roles it plays. In recent decades, unsustainable exploitation along with different types of anthropic intervention, led to the decimation and local extinction of many of this species' populations. In Colombia, this situation gave rise to a legislative framework for its protection, including a hunting ban and the establishment of breeding programs intended to promote sustainable use and contribute to its conservation. However, to fully comply with these programs, it is essential to obtain information about genetic diversity, integrity, and distribution, in wild and captive populations, considering the impact these variables have for the species survival. This study evaluated the genetic diversity and phylogeographic patterns of the American crocodile in Colombia based on 3 mitochondrial markers (*CO1*, *CytB* and *TrnP/trnF/D-Loop*), analyzing potential actions for management and conservation. To this end, 33 individuals belonging to natural and captive populations in the Caribbean and Andean regions of Colombia were genetically characterized, assessing their genetic variability, phylogenetic and phylogeographic patterns as well as performing neutrality tests. Our analyses included sequences that had been previously reported in Colombia and across the species' distribution. Consequently, we found evidence of a high genetic variability in Colombian populations from nucleotide diversity values (0,001 to 0,004) and haplotype diversity values (0,710 to 0,900), the existence of



phylogenetic clades that might represent evidence for evolutionarily significant units (ESUs) in Colombia supported by genetic distance values (0,040 to 0,630 between haplogroups), phylogenetic reconstructions and haplotype networks (3 to 11 mutational steps between haplogroups), and events of demographic variation. Based on these results, dispersal events along the Caribbean and in the Magdalena River basin were evidenced. We establish a genetic baseline to propose management recommendations when releasing individuals into the wild. Finally, we suggest the assignment of Management Units (MUs) to Colombian populations and the identification of research priorities in the species.

**Keywords**

Crocodylians, Phylogeography, Genetics, Breeding.



# The crocodile's population of La Manzanilla, Jalisco, Mexico

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## Abstract

La Manzanilla is a coastal village in the municipality of La Huerta, Jalisco, México, where there is a coastal lagoon of 200 hectares with a main channel of 3.5 km, dominant vegetation is mangrove forest and topical deciduous forest. The population is 1500 people, and the land is administrated by the community through Ejido La Manzanilla. In this research the crocodile's population was estimated during two periods, first one was from 2001 to 2002 and the second was from 2017 to 2018. In the first period the population was estimated as  $N=103.13$  and average meeting rate of  $15 \text{ org} \cdot \text{km}$ , in the second period the estimation was  $N=709.23$  and average meeting rate of  $78.77 \text{ org} \cdot \text{km}$ . Six size classes were found every 60 cm, Classes I, II, III, IV, V and one undetermined. There were not differences between periods ( $P=0.69$ ), however, in the period 2017.2018 were differences ( $P=0.0003$ ) among classes, the Tukey test showed that Class II is different ( $P<0.05$ ) from Classes I, III, IV, V and the unterminated one. Biologically this Class II reflects the new recruits of the population, and also the largest ( $N=417.8$ ). The crocodile's population increased due the management and conservation actions made by the community of La Manzanilla, some of the activities are protection of nests and offspring during last 20 years beside the restrictions to use in the crocodile's habitat and the ecotourism that visits the area.

## Keywords

Crocodylians, Abundance, Population structure.



# Sinking your teeth into crocodile conservation

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## Abstract

Conservation is not just about wildlife, it is about people. The success of any wildlife conservation program relatively parallels the involvement and support from local communities, thus working alongside communities and partner organizations is imperative to empower people with the knowledge of coexistence and sustainability to ensure long-term conservation efforts. Moreover, continuous collaboration and communication with local and national governments can ensure data collected from one's scientific investigations will be prioritized in regard to policy decisions regarding wildlife and their habitat (= translational ecology). In this presentation, I will be discussing the conservation efforts of the Crocodile Research Coalition (CRC), a Belize based non-profit that works with local, national and regional stakeholders to ensure long-term conservation and management of crocodiles and their habitat. Our program can be generalized into 2 components: 1) research projects that not only focuses on crocodiles, but the surrounding flora and fauna that range from conservation biology, genetics, eco-toxicology, and population ecology, and 2) educational outreach that consists of active media and social media presence, participating in community events and reaching out to schools, educational material, and the creation of games and displays to creatively reach out to people of all ages to provide the facts of the two species of crocodiles in Belize, the American crocodile (*Crocodylus acutus*) and Morelet's crocodile (*Crocodylus moreletii*). This holistic approach of crocodile conservation and management has furthered assisted us in identifying wildlife champions, especially through mentorship programs such as Next Gen Croc. Moreover, the aforementioned efforts have proved successful in local community stewardship of protecting crocodiles and their environment in our location, Placencia Lagoon.

## Keywords

*Crocodylus acutus*, *Crocodylus moreletii*, Wildlife education, Community outreach.



# Caiman and fishermen: negative interactions between crocodilians and riverside communities in northeastern Brazil

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## Abstract

Exponential anthropic growth over the last decades associated with the suppression of natural environments has intensified the competition for space and resources between fauna and humans is becoming increasingly evident and common. Crocodilians and riverside populations, for example, overlap their areas of use in various regions of the world and are closely related. This research aims to identify the relationship between *Caiman latirostris* and fishing communities in a dam in northeastern Brazil. The field activities were carried out in Tapacurá river reservoir, located in São Lourenço da Mata municipality, Pernambuco, between 2015 and 2018. In this locality, there are Atlantic Forest Conservation Unit and areas with housing, agriculture and open fields of livestock. We identified 53 residences adjacent to the dam, with frequent fishing activity practiced by local families. Between April 2015 and March 2016, 101 fishing nets were identified distributed throughout the reservoir at the same time, as well as two caiman traps. Five animals were found trapped in fishing nets, two young and three adults. Smaller animals had limb injuries, with strangulation observed in the forelimbs due to entanglement with the nets. Adult animals, in turn, did not present external lesions, two of them being detached from the nets and one coming to death due to the aspiration of nylon gillnet, with 21 cm of material in the individual's trachea. A large distribution of fishing nets has been observed, often not respecting the boundaries of protected areas, sometimes turn into ghost nets increasing the already existing bycatch and endangering the conservation of the region's aquatic fauna. Environmental education works are being carried out in the region to elucidate the need and importance of wildlife conservation associated with fishing resources maintaining, including crocodilians.

## Keywords

*Caiman latirostris*, Conservation, Environmental education, Fishing.



# Human-crocodile conflict history in Mexico

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## Abstract

An historic analysis of the Human-Crocodile Conflict (H-CC) in Mexico is presented. Historic cases of H-CC were studied since the Spanish had arrived to Mexico, based on the manuscripts from that time, up to date. This resulted in six different stages, information which have been related to Mexican history. In a qualitative way, crocodile abundance, declination and recovery is related to the historic process of HC-C, based on the comments of the old manuscripts, skin exportation, law protection and the actual abundance of large crocodiles. Some H-CC cases were recovered from XVI century in Mexico and South America. The oldest case registered in the country, seems to be occurred with Morelet's crocodile in the year 1566 in Yucatán, where an indigenous man lost its life. The oldest case recorded here for an American crocodile, in the American continent, was in the year 1565 in Colombia, which occurred to an African man. Systematic information related to H-CC started in early nineties in the state of Jalisco and then in Quintana Roo at the middle of the decade. Some researchers, started to be involved since the year 2000 and this effect increased in the late 2000's, up today. H-CC protocol process is mentioned until the last protocol was presented in 2018. The law protection process of Mexican crocodilians is mentioned and related to adult crocodile population recovery in the country. A list of actions and strategies to diminish HC-C in the country is presented. It is important to know that H-CC have decreased significantly in the last two years. The highest frequency of H-CC in Mexico was in the year 2017.

## Keywords

Human-crocodile conflict, History, Mexico.





# Human–crocodile conflict attention protocol and its application in Chiapas, Mexico

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## Abstract

Due to the increase in human-crocodilian conflict, there is a need to implement strategies to address and prevent this problem. In 2010, a Workshop on Development and Management for UMAs in Ciudad del Carmen; Campeche was organized; the Human Conflict - Crocodile was discussed, taking as reference the version called “Protocol of Attention to Conflicts Man-Crocodile” in Mexico. In 2015, a second version was prepared compiling contributions from different specialists in the country. After a non-fatal incident in Chiapas in 2011, municipal, state and national meetings were held to address the issue. It was through efforts and budget of the National Commission of Natural Protected Areas and the La Encrucijada Biosphere Reserve that in 2016, in collaboration with the Group of Crocodile Specialists in Mexico, that the Human Interaction Review and Analysis Workshop was held entitled “Crocodile and Management Strategies for the Sustainable Use of Crocodylia of Chiapas” through intersectoral work for the conservation of crocodilians in Mexico. After nine years and 11 meetings in Chiapas, it was possible to generate an Action Program for the Conservation of Species (PACE): Crocodylia and a Protocol of Attention to Human-Crocodilian Contingencies (PACH-C), which were published officially in 2019, with a validity of 3 years for its application, update and improvement of actions. Derived from this protocol, intersectoral meetings have been held to launch the SOS - Crocodile group for the State of Chiapas. Although the PACH-C is mainly operative, it is expected to complement a preventive protocol that allows to inform, raise awareness and mitigate the incidents with crocodilians in Mexico, achieving a harmonious and sustainable coexistence with the Crocodylia.

## Keywords

Crocodilians, Human-crocodile conflict, PACH-C, Chiapas.



# Protocols for management of human-crocodilian interactions in Costa Rica

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## Abstract

In recent years, the report of interactions between humans and crocodiles has increased in Costa Rica, which has generated concern in the human population. This concern increases due to the lack of information and protocols that allow for proper management of those interactions by the competent authorities. Because of this, wildlife authorities in Costa Rica prioritized the construction of protocols for handling these situations. In a participatory process, three protocols were created: Immediate management of crocodilians, Management of interactions between humans and crocodilians, and Economic valuation of damages. We work between February to December 2019. The process for the construction of the protocols included: 1- Review of the existing information on the crocodilian populations of the country, and the relevant initiatives to generate the protocols. 2- Meetings with crocodilian specialists and wildlife officials, 3- Workshops for consultation and construction with key actors in the field: tourism, NGOs, red cross, police, coast guard, government wildlife officials. These protocols detail the steps that wildlife officials must follow, in response to reports of human-crocodilian interactions. The process was constructed according to what is established in the regulations to the Wildlife Conservation Law and its regulations, participatory and exhaustive. The protocols obtained are easy to implement for wildlife officials in the country.

## Keywords

*Crocodylus acutus*, *Caiman crocodilus*, Attacks.



# Human–crocodile interactions in La Encrucijada biosphere reserve, Chiapas, Mexico

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## Abstract

In the last 9 years, the La Encrucijada Biosphere Reserve has presented interactions between Humans and Crocodilians limiting a harmonious coexistence in wetlands. Five types of interactions were identified as the result of environmental and anthropogenic factors: 1) Risk crocodilians, 2) Predation of domestic fauna, 3) Illegal hunting, 4) Non-fatal incidents and 5) Fatal incidents. Each case is verified and attended with planning and programming of activities from 3 to 18 working days using cars, boats, outboard motor, networks, ropes, traps, electric tapes, GPS, field notebook, camera, among others. From 2011 to 2019, 133 reports have been documented, of which 2 correspond to fatal cases, 10 non-fatal cases and the rest were cases at risk, captivity, illegal hunting and rescued crocodilians. Most cases occur between March and July, and were originated from hunting, swimming, diving, fishing and neglect of people. With a communitarian and technical work group, care and prevention strategies have been designed to raise awareness among residents, placing signs, promoting sustainable use alternatives, and capacitating community groups. In addition, the possibility of creating natural physical barriers as protection measures, generating agreements between fisheries cooperatives for the management of their fishing waste, management of domestic fauna, promotion of culture of prevention, as well as avoiding the capture of wild specimens for sale as pets, is being evaluated. We recommend to continue monitoring wild populations of crocodilians in La Encrucijada Biosphere Reserve.

## Keywords

Human-crocodile interactions, REBIEN, Non-fatal and fatal cases.



# Removal of Spectacled caiman (*Caiman crocodilus*) in South Florida, USA

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## Abstract

Spectacled caiman (*Caiman crocodilus*) occurs from Mexico to South America and reaches over two meters in length. It has been introduced in the United States, Cuba, and Isla San Andres, Colombia. Spectacled caimans have been established in South Florida since the 1970s. As an invasive species with a broad diet, they have the potential to impact biological resources. Caiman may prey upon protected species in South Florida, such as eastern indigo snakes (*Drymarchon couperi*) and young American crocodiles (*Crocodylus acutus*). They may also compete for food and space with native crocodylians, the American alligator (*Alligator mississippiensis*) and the American crocodile. Caiman in the USA appear to tolerate disturbed and urban habitats, increasing potential for human-crocodylian conflict. Past removal efforts have failed to extirpate them. Yet, these efforts have varied greatly, and their efficacy has not been well evaluated. Our project's purpose was to remove spectacled caiman and perform necropsies: (1) to improve removal rates; (2) to determine seasonal reproductive activity; (3) to augment caiman diet information in Florida; and (4) to test the management hypothesis that caiman removals will decrease their encounter rates and may increase native crocodylian encounter rates and occupancy. We began opportunistic caiman removals in 2012, and systematic efforts have been ongoing since October 2017. From December 2012 to January 2020 we removed 187 caimans. Necropsies revealed that their reproduction in Florida may be earlier than in their native range and overlaps the American alligator. Diet analysis yielded 24 insects, 18 plants, 15 reptiles, 10 gastropods, eight crustaceans, six fish, three mammals, three gastroliths, two amphibians, and one occurrence of plastic. We documented eleven unreported prey species in Florida, eight of which are native. Our analysis results suggest that caiman removals decreased encounter rates but did not increase native crocodylian encounter rates or occupancy.

## Keywords

Invasive species, Caiman, Removal, Florida.



# Distribution of American alligators across an urban landscape

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## Abstract

Urbanization is an ever increasing threat to wildlife and their natural habitats, yet research has been limited to a small number of taxa. Filling this knowledge gap, while effectively educating people about urbanization and its effects on wildlife, will require new research projects that target charismatic species which naturally capture the public's attention. One such species, the American alligator (*Alligator mississippiensis*), is an apex predator across the southeast United States and has surprisingly received minimal attention within urban areas. To investigate the potential effects of urban land cover on alligator habitat use, we conducted surveys of relative alligator abundance in nine tributaries with varying levels of urban influence surrounding the St. Johns River in northeast Florida, USA. For each animal sighted, several environmental variables were measured and global positioning system coordinates were recorded. These data were then incorporated into geographic information system analyses to determine the potential effects of urban development on alligator spatial distribution at a coarse scale. Habitat selection preferences at a fine scale were then determined using observed habitat data. At the coarse scale, we found that there is no correlation between percent developed land and relative alligator abundance. Instead, salinity is the primary driver of relative abundance across tributaries. However, only two out of 93 sighted individuals were adults, suggesting that adults avoid urbanized areas while juveniles are forced to occupy these potentially more marginal habitats. At the fine scale, the data showed that alligators prefer habitats characterized by more open water and highly vegetated shorelines and avoid anthropogenic structure. Further urbanization may therefore degrade favorable habitat and limit the distribution of breeding adult alligators in once suitable areas, potentially leading to local population declines.

## Keywords

Urbanization, Distribution, Habitat selection, *Alligator mississippiensis*.



# High lead exposure and clinical signs of toxicosis in wild Nile crocodiles (*Crocodylus niloticus*) from a World Heritage Site: Lake St Lucia estuarine system, South Africa

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## Abstract

Lead (Pb) exposure is a widespread wildlife conservation threat, but impacts on reptile populations remain poorly documented. In this study, we examined Pb exposure and accumulation in a wild population of Nile crocodiles (*Crocodylus niloticus*) at the Lake St Lucia estuarine system, South Africa. Recreational angling has occurred in the area since the 1930s and incidental ingestion of Pb fishing weights has previously been identified as a major source of Pb poisoning in the local crocodile population. In 2019, we sampled blood and tail fat tissues from wild ( $n = 22$ ) and captive ( $n = 3$ ) crocodiles at Lake St Lucia to investigate potential impacts of chronic Pb exposure on crocodilian health. Lead was detected in blood samples of all wild crocodiles, although concentrations varied widely between individuals (86 - 13100 ng ml<sup>-1</sup>). The incidence of Pb poisoning was higher in male crocodiles, with mean blood lead (BPb) levels in males ( $3780 \pm 4690$  ng ml<sup>-1</sup>) significantly ( $p < 0.001$ ) higher compared to females ( $266 \pm 230$  ng ml<sup>-1</sup>). Blood Pb levels were correlated with concentrations measured in tail fat tissue (n.d - 4175 ng g<sup>-1</sup> wet wt.). Although most of the crocodiles sampled appeared to be in good physical condition, highly elevated BPb levels ( $> 6000$  ng ml<sup>-1</sup>) were associated with markedly suppressed packed cell volumes (4.6 - 10.8%) and severe deterioration in tooth condition. These findings suggest that anaemia and tooth loss may be clinical signs of long-term environmental exposure to Pb. Although previously undocumented in crocodilians, these symptoms are consistent with Pb poisoning observed in birds and mammals, and suggest that crocodilians may be more susceptible



to the long-term toxic effects of Pb than previously thought. In light of these findings, we suggest that the impact of accumulated Pb on crocodilian fitness, reproduction and mortality requires urgent attention.

**Keywords**

Pb, Nile crocodiles, Lake St Lucia.





# Exploring an Amazonian species in recovery process: defining conservation areas for *Melanosuchus niger*

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## Abstract

For the conservation of biodiversity, it is essential to know the distribution of genetic variability of the species and understand their demographic dynamics, which allows to identify appropriately, taxonomic and population units for their protection and management. Considering populations as functional units in an ecosystem, it is necessary to identify and protect genetically distinct local populations, to maximize their evolutionary potential and reduce the risk of extinction. In this way, it is possible to delineate intraspecific conservation units considered as biologically significant entities for conservation, and thus apply management and monitoring programs more efficiently, plan harvest quotas, carry out reintroductions of individuals, prioritizing the use of limited financial resources for conservation. In this study, we define the conservation areas for the Amazonian crocodilian species *Melanosuchus niger*, through the use of molecular markers (Cyt B mitochondrial gene and SNPs), for its entire range. We took into account the patterns of distribution of genetic variability and genetic differences between locations to identify genetic units. It was possible to delimit four management units (MUs) with discrete patterns of distribution, corresponding to the populations of the Araguaia, Guaporé, Uraricoera and Napo river basins, all differentiated from the main population, which is broadly distributed along the Amazon River plain. These MUs showed divergence in haplotypic and allelic frequencies, but no reciprocal monophyly in the mitochondrial DNA. The population from Amazon river plain presented a continuous pattern, compatible with isolation-by-distance model, so we estimated independent geographical intervals and based on that defined three areas as operational units for management: Western, Eastern and Central regions of the Amazon basin. Although the species is cataloged in Low Risk, as a result of its recovery in some places, it is still dependent on conservation due to illegal meat hunting and destruction of its habitat, so the definition of these seven areas is very important for conservation and management planning.

## Keywords

Amazonian, Alligatoridae, Conservation Units, Population Genetics.



# Towards a socio-ecosystem perspective on the role of *Crocodylus acutus* in coastal ecosystems

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## Abstract

The study of socio-ecosystems has become increasingly important in recent decades, because the scientific community has recognized that transdisciplinary approaches are required to try to understand the growing complexity of socio-environmental problems, proposing integral solutions that are indispensable to mitigate the ecological and civilization crisis in which we live. This theoretical-methodological paradigm, however, is incipient in crocodilian studies, so this research proposes a first approach of a transdisciplinary perspective of a socio-ecosystem studies where the crocodile has a central role. Current research on crocodiles shows a trend in Mexico and Latin America to the biological sciences, while sociological research is scarce and poorly diverse, focuses on topics as local knowledge of biological theories, the benefits obtained by local people or the human-crocodile conflict. With the analyzed bibliography, we proceeded to build the theoretical framework of the socio-ecosystem, the biological component was based on the trophic role of the crocodile and in their autecology, while for the social component, the research reviewed was not enough. Therefore, sociological bibliography was consulted, creating a social theoretical framework under an eclectic approach. However, the information about the benefits and conflicts generated by the coexistence of humans with crocodiles was used to unite the social dynamics with the ecological dynamics, these approaches allow to join both paradigms through their pragmatic relations, that is: the effects of the social in the ecological and vice versa. As a result of this, the socio-ecosystem was formed by the ecological component (the crocodile's ecology), that produces the material conditions that local actors can alter or reproduce, according to their management practices, relaying on the material conditions themselves



and on the perception and knowledge of the ecological component of the actors, which are dependent on the nature socialization (the social component).

**Keywords**

Socioecology, Transdisciplinary, Socio-ecosystem.



# Characterization of heavy metals found in *Crocodylus acutus* from Coiba Island and Gulf of Montijo, Panama

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## Abstract

Heavy metals have a relatively high density compared to other components such as water. The environmental sources of metals can be from Industrial, agricultural and pharmaceutical, mining smelters among others. Metals are bioavailable and can have toxic effects on organisms when they surpass limit concentrations. Therefore, is important to establish a direct connection of these disruptive contaminants in the marine coastal environment and their impact on ecosystem functioning. This relationship can be established using an apex predator, the American Crocodile (*Crocodylus acutus*), as a bioindicator. For over 2 years in different seasons (rainy and dry) 141 American Crocodiles were captured and morphological measurements were taken such as rostrum, total body, and tail lengths, head, occipital bone, eye, and nose widths, as well as gender and habitat from which the individual was captured. Scutes were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) to determine the concentrations of heavy metals in the study areas (Coiba Island and Gulf of Montijo, Panamá). We did find a significant difference between study sites, groups ages and seasons. The study sites showed a difference in a higher concentration of metals in the Gulf of Montijo and a lower concentration of metals in Coiba Island. Juveniles presented higher metal concentrations followed by sub-adult and adults. However, we did not find a significant difference between sexes. This project should generate clear conservation strategies for the population of *Crocodylus acutus* located in Coiba Island, and the Gulf of Montijo Gulf, and ultimately contribute to the development of future strategies for fisheries and other activities that affect the marine coastal environment.

## Keywords

Heavy metals, Contamination, American crocodile, Coastal environment.



# Caimans population trends in the Anavilhanas National Park, Central Amazonia, Brazil

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## Abstract

*Melanosuchus niger* (Black caiman) and *Caiman crocodilus crocodilus* (Spectacled caiman) are among the largest Amazonian vertebrates. Unregulated harvesting for their skins and for their salted meat has threatened both species, with a more severe impact on the Black caiman, which, until 2000, was considered an endangered species. Conservation of these species is controversial, given the potential risk that they may represent to humans and their domestic animals. Hence, a very well-planned management strategy is needed to maintain wild populations of these apex predators. In this perspective, tourism to see caimans could be as a potentially effective conservation action, by generating profit to stakeholders involved and reducing the number of crocodilians killed. From September-December 2019 we conducted spotlight surveys on relative abundance, size structure and sex ratio of both species in the Anavilhanas National Park located in Central Amazonia, Brazil. We counted 2726 caimans in 516 km of shoreline of canals and lakes, 158 of which were *M. niger*, 383 were *C. crocodilus* and 2185 were only eyes. We captured 66 *M. niger* ( $20 \leq \text{SVL (cm)} \leq 118$  cm, mean = 32.2) and 71 *C. crocodilus* ( $20 \leq \text{SVL (cm)} \leq 95.5$  cm, mean = 43.9), of which 70% and 54% were males, respectively.



Our partials results indicated an increase in caiman population parameters when compared with data collected for the same populations in the 1990s.

**Keywords**

Alligatoridae, Populations trends, Conservation.



# Effect of protected areas type and repetitive surveys on two West African crocodiles: *Mecistops cataphractus* and *Crocodylus suchus*

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## Abstract

Protected areas (PAs) are one of the most common conservation strategies to halt biodiversity loss. Different types of protected areas, which vary in the level of protection afforded, exist and their effect on biodiversity loss has been largely investigated only for terrestrial species. For aquatic or semi-aquatic species, such as crocodiles, few studies have examined their protection efficacy. We investigated the extent to which protected area type influences *Mecistops cataphractus* and *Crocodylus suchus* populations. We implemented repetitive surveys in 6 national parks, 7 classified forests, 2 community protected areas, and 5 sites completely outside protected areas in Côte d'Ivoire over the period 2015 to 2019. We noted all *M. cataphractus* and *C. suchus* sightings, as well as anthropogenic threats like fishing, artisanal mining, plantations, etc... We used mixed models to assess the effectiveness of each protected area type and to assess the impact of repeated surveys on crocodile wariness. On average national parks, which have a high level of protection, provide the most conservation advantage for both species, followed by community protected areas and classified forests. We found that the use of repetitive surveys for monitoring crocodiles has a mixed effect on their wariness – where a trend is difficult to detect. These results highlight the importance of action-based interventions in protected areas for species conservation and to ensure the future of West African crocodilians, and the need to consider the effects of increasing wariness when using repetitive surveys for crocodile monitoring.

## Keywords

Effectiveness, Protected areas, Multiple surveys, Crocodilians, Côte d'Ivoire.





# Evaluating a Head-Starting Programme for Gharial in Chitwan National Park, Nepal

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## Abstract

The Critically Endangered gharial declined exponentially over the 20th century, and now only remains in a few locations in India and Nepal. Head-starting (population reinforcement) has been a widely used gharial conservation strategy, however most programmes have not included a post-release monitoring component, and therefore the efficacy and effectiveness of these interventions hasn't been determined. Chitwan National Park is one of just six remaining gharial populations with recorded reproduction, and since 1978 the conservation strategy has centred on head-starting, with eggs collected from the wild hatched in captivity at the Gharial Conservation Breeding Centre (GCBC). Gharials are reared in captivity until they reach more than 1.5m, at which stage they are released back into the wild. More than 1200 gharials have been released in Chitwan through this programme, and after nearly 30 years of negligible population increases, the population has slowly climbed to over 200 gharials over the last decade. The improving success of this programme in Chitwan provides an excellent setting to investigate both how to monitor the output of reintroduction programmes, and to provide vital insights on what leads to their success or failure. In this presentation we discuss the results of our ongoing 4-year study to determine the efficacy of the head-starting programme. We will discuss the methodology and technology utilised by the programme, including VHF and GPS telemetry of both recently released and free-living recaptured gharial, and a range of survey techniques. We will share the results these have yielded to explain why the majority of released gharial have not been recruited into the wild population. We discuss our recommendations for the conservation of the gharial in Chitwan, and how our methodology and results could be applicable to other post-release monitoring programmes.

## Keywords

Gharial, Head-starting, Telemetry, Conservation, Reinforcement.



# Current status of the population of the American crocodile (*Crocodylus acutus*) in the Sumidero Canyon National Park (SCNP), Chiapas, Mexico

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## Abstract

Monitoring is a relevant activity to know the status of certain populations. The objective of this study was to know the current status of the population of the American crocodile (*Crocodylus acutus*) in the Sumidero Canyon National Park (SCNP), Chiapas, Mexico; which had more than five years without being monitored. Two transects for day trips and night counts were established on a monthly basis during 2017 (seven months) and 2018 (six months). The abundance and population structure were determined, the nesting areas and spatial distribution of the American crocodile in the SCNP were identified. 31 active nests were located during the incubation season, (2017 = 14 and 2018 = 17). In the Puente-Cave transect, 266 individuals were observed and the encounter rate of 1.97 crocodiles / km (without hatchlings) was recorded with an estimated population (N) of 70 crocodiles and in 2018, 361 individuals were observed, encounter rate of 3.22 crocodiles / km (without hatchlings) and an estimated population (N) of 80 crocodiles. In the Cueva – Cacao Usumacinta transect, 192 individuals were observed in 2018, the registered encounter rate was 0.26 crocodiles / km (without hatchlings) and an estimated population (N) of 30 crocodiles. For both transects, the best represented class was II, III and IV (juvenile, sub adult and adult stages). In 2017, 86 individuals were captured (between 20.5 to 246 cm of total length), 7 were females and 80 hatchlings without determining sex. In 2018, 188 (between 26.5 to 243.5 cm of total length) were captured, 2 were female, 1 male and the rest were hatchlings. It is suggested to continue monitoring in both transects, to carry out the evaluation of habitat and nesting areas. Foster protection and surveillance in the reproductive period, promote



intersectoral participation, conduct environmental education activities and disseminate on the conservation of river crocodiles.

**Keywords**

American crocodile, SCNP, Encounter rates, Nests.

\*A portion of the support of the Student Research Assistance Scheme program of the IUCN-SSC Crocodile Specialist Group (CSG) in 2017 was used for the development of this project.



# Strategies for care and conservation of crocodilians product of the human–crocodile conflict in natural protected areas of Chiapas, Mexico

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## Abstract

There are reports of incidents with crocodilians since the 1940s in Natural Protected Areas (NPAs) in Chiapas, Mexico; despite crocodilians coexist with human populations, interactions have increased due to human recreation, habitat decline, traditional fishing (diving), poor management of domestic fauna, and hunting among others. The attention to the interaction is validated by telephone and they are officially reported to the environmental authorities. Depending on the type of interaction, the planning and programming of activities is carried out for: Diagnosis of the case, monitoring actions, capture, handling and transfer of risk specimens, data collection, photographic registration and environmental education. From 2011 to 2019, 40 reports of interactions were attended at the La Encrucijada Biosphere Reserve; in 2014 and 2015, 7 for the Puerto Arista Estuarine Sanctuary; and in 2017 and 2018, 10 for the Sumidero Canyon National Park and one for the Montes Azules Biosphere Reserve. The given attention was: a) sighting of risk crocodilians, b) predation of domestic fauna, c) hunting and illegal exploitation, and d) interactions with the humans (non-fatal and fatal). As a result, it has been possible to generate a Program of Action for the Conservation of Species (PACE: Crocodylia) and a Protocol of Attention to Human-Crocodilian Contingencies (PACH) as a baseline, which allows the formation of community and technical groups in Natural Protected Areas (NPAs) in conjunction with Environmental offices from the three levels of government, NGOs, and the academy; to train community members in the prevention, attention to interactions, crocodilian surveys, signage to raise awareness and avoid incidents, to generate alternatives for sustainable management and exploitation at the community level promoting gender equity as well as research to conserve crocodilians in the wetlands of the Chiapas NPAs.

## Keywords

Human-crocodile conflict, NPAs, Community, Chiapas.



# Successful hatching and survival of the American crocodile *Crocodylus acutus* at Sumidero Canyon National Park (SCNP), Chiapas, Mexico

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## Abstract

The nesting process is the most vulnerable stage of the life cycle of crocodiles, therefore, it is important to consider the reproductive phase and reproductive success, since it can be affected by natural and anthropic factors. The objective was to identify and characterize the nesting areas of the American crocodile (*Crocodylus acutus*) in the Sumidero Canyon National Park (SCNP), Chiapas, Mexico. The activities were carried out in 2017 and 2018. The coordinates of each nest, diameter (cm), incubation chamber depth (cm), egg chamber temperature (° C), distance from the nest to the shore of water (m) and percentage of shade were recorded. For the reviewed nests, the total number of eggs, major and minor diameter (mm), weight (gr) and conditions of each egg (fertile, infertile or cracked but viable) were counted. In 2017, 14 active nests were located, 9 in the "El Tomatal" zone totalizing 47 eggs (25 fertile, 14 infertile and 8 cracked but viable). The remaining five nests were located on the banks of the river by detecting groups of hatchlings. In 2018, 17 active nests were found, 8 in the "El Tomatal" zone totalizing 146 eggs (121 fertile, 12 infertile and 12 cracked but viable), one nest on the Island of Cahuaré with 45 eggs (29 fertile, 2 infertile and 14 fissures but viable) and the remaining eight located on the banks of the river by detecting groups of hatchlings. Hatchlings were captured and marked every year: 82 in 2017, and 178 in 2018; 13 hatchlings had atypical coloration. Although the nests were active, productivity was low compared to previous years, looted nests and infertile eggs were found. The decrease in hatchlings is affected by predation, waves produced by tourist boats and illegal looting. It is recommended to continue monitoring crocodiles and strengthen surveillance in nesting areas.

## Keywords

American crocodile, SCNP, Nests, Fertile, Infertile.



# Designing, constructing and maintaining crocodile sanctuaries in the USA and Jamaica

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## Abstract

From the 1960's to the 1980's, the American crocodile (*Crocodylus acutus*) population in south Florida was estimated at  $250 \pm 78$  non-hatchlings. In 1978, Florida Power & Light (FPL) joined the recovery efforts by initiating an American Crocodile Management Program on their Turkey Point Property in Florida City, Florida. In 2006 FPL made plans to design and construct additional crocodile nesting habitat in an area south of the power plant. The restoration project involved removal of the invasive vegetation, followed by the removal of rock fill and replacing it with substrate suitable for crocodile nesting. The construction was complete in January 2008 and the first successful crocodile nest hatched in June of 2008. The crocodile population in Jamaica is in decline. Jamaica is a tourist destination and resorts take up much of the islands' beaches. Habitat destruction on different levels is happening island-wide. Much of the coastal habitat is under pressure by charcoal producers. The Holland Bay Crocodile Sanctuary is located in agricultural land in St Thomas. Several dedicated people, both Jamaican and international, have put their resources, time, energy, expertise and funding into developing designing, constructing, maintaining, and operating this sanctuary. The facility is off the grid and self-sufficient, solar powered, features wells with treated water and a septic system. It has a room for short- and long-term scientists, students or volunteers.

## Keywords

Restoration, Sanctuary.



# Outcomes of evaluation of the social, economic and cultural impact of the sustainable use program “Proyecto Yacaré”

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## Abstract

The use of natural resources is an important activity for local communities, since it generates an important economic income. Historically, the positive impact of sustainable use programs on species recovery and regional economies has been assumed, but it was necessary to quantify their effects on those variables related to local people such as their families' structures, their community, and the ecosystem. To evaluate the effects on the people living in rural areas where Proyecto Yacaré ranching program work, interviews and structured surveys were designed for gathering information and generate a system of indexes. Using some specific tools, we were able to know many aspects about local people like the main and secondary occupation of the members of the families, medical insurance, education, the average of incomes, among others. We also obtained an overview of other specific needs in this area like type housing, elemental services, and their conditions, mechanisms to get water for consumption, electricity, and gas services, among others. Finally, the interviews gave us information about their knowledge about caiman, their vision and representation around the Proyecto Yacaré sustainable use program.

## Keywords

Local communities, Ranching, *Caiman latirostris*, Social and economic impact.





# Spatial ecology of the two African Slender-Snouted crocodiles *Mecistops cataphractus* and *M. leptorhynchus*

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## Abstract

Despite the high conservation priority of the genus *Mecistops*, and its recent split into two distinct species (*Mecistops cataphractus* and *Mecistops leptorhynchus*), crocodiles of this genus remain the least known crocodylian species in the world. Given the conservation status of these two species (Critically Endangered and Endangered, respectively), gaps in knowledge on their ecology need to be filled to ensure adequate protection. Studies of species movements are vital to understand spatial requirements of individuals. Moreover, space use and ranging patterns can help to understand the social organization of animals through space and time, and can be used to enhance effective management and conservation action. We conducted a telemetry study on 26 *Mecistops cataphractus* and 30 *Mecistops leptorhynchus* in Taï National Park (Côte d'Ivoire) and Loango National Park (Gabon), respectively. We used minimum convex polygon (MCP) methods to determine home range (95% MCP) and core area (50% MCP) size, as well as social interactions. Home range size varied from 5.13 to 1,418 ha and 3.03 to 164.83 ha, respectively for *M. cataphractus* and *M. leptorhynchus*. The two species exhibited approximately the same daily rate of movement (ROM). Mean overall activity levels were up to 90% for both species. Both home range and core area size were greater than those reported for another forest-dwelling crocodile species, *Tomistoma schlegelii*, but smaller compared to other more "typical" crocodylians, like the saltwater crocodile *Crocodylus porosus*, American alligator *Alligator mississippiensis*, and the Nile crocodile *Crocodylus niloticus*. These findings provide a first step towards understanding movement patterns for *M. cataphractus* and *M. leptorhynchus*, and will hopefully help to define management strategies



for the species in-situ conservation. For *M. cataphractus*, these data will additionally be useful for monitoring post-release success of reintroduced, captive-produced juveniles.

**Keywords**

Movement patterns, Radio tracking, Genus *Mecistops*, Crocodilians, Africa.



# **Sustainable management of Yacare as a strategy for conserving biodiversity and for improving livelihoods of indigenous people and rural communities in Eastern Bolivian Amazon**

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## **Abstract**

The use of *Caiman yacare* in Parque Iténez begins in 2007 with the allocation of an experimental harvest quota granted to farmers and to Bella Vista community. In 2010, the Yacare Management Plan of the Departmental Park and Integral Natural Management Area (PD ANMI) Iténez was prepared and assigned - for two years - an official quota of 680 Yacares to Bella Vista Canton, within the framework of the National Program for the Conservation and Use of this specie. Since 2013 WWF Bolivia begins technical support for Yacare hunters with the aim of improving the effectiveness of the harvesting system and achieving a more comprehensive use of the hunted specimens. After 8 years of support for the activity (2013 to 2019) there is monitoring evidence ensuring that the use of the species is carried out in a sustainable manner. Yacare populations currently have an average abundance value of 36.15 ind/km of shore, with maximum values of up to 132 ind/km of shore in streams and minimum values of 6.93 ind/km of shore in lagoons of tectonic origin. The population structure presented by the species is composed of 46.37% of Class II individuals, 33.27% of Class III individuals and 20.35% of Class IV individuals, complying with the criteria established in the national standard for continuing to carry out selective harvests of adult males. The incorporation of meat in local commerce has significantly improved the income of hunters, with years in which they have obtained more than US \$ 20,000 from the sale of skins and meat from sustainably hunted Yacares. Despite this situation, in recent years the wild fur market has been gradually reducing, which has significantly reduced the income obtained by hunters and jeopardizes the continuity of an activity that has been generating incentives for the conservation of aquatic ecosystems.

## **Keywords**

Yacare, Sustainable, Indigenous, Iténez.



# **Liberando Esperanzas: a conservation program of *Caiman latirostris* populations in Santa Fe, Argentina**

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## **Abstract**

Since Proyecto Yacaré creation (1990) *Caiman latirostris* populations from Argentina successfully has been recovered and in the following years, the species was transferred from Appendix I to II of CITES. From there the ranching program has notably improved the population situation of wildlife caimans. However, in early life stages, broad-snouted caiman exhibits greater sensitivity than adults, because of body size immaturity, and can increase the susceptibility of some neonates to natural factors added to overexploitation by anthropogenic activity (predators, high temperatures, extreme cold, droughts, floods, overcrowding, contaminants, lack of shelters or food, among others) that affect their survival. That's why we need to do more to protect and save our wildlife and their natural habitat for future generations by promoting conservation actions. In this context, through the *Liberando Esperanzas* program a non-profit organization dedicated to the conservation of the broad-snouted caiman population in Argentina, which consists of symbolic adoption of caimans (or sponsorship) with the consequent monitoring of some individuals in the natural environments, which adds the possibility of controlling the activities of the captive breeding period first, and then the chance to monitor their return to nature and their performance there. This is offered as a strategic alternative to reinforce the possibilities of conservation of the species with the early harvest of eggs, artificial incubation, and controlled rearing during the first year of life. This prevents the high natural mortality, generating a large number of surviving animals to return to nature. Funds from this program through symbolic adoption go toward efforts to help protect the



wild broad-snouted caiman populations from Argentina, their habitats and at the same time inspire and promote the conservation of wild species around the globe with community support.

**Keywords**

Broad-snouted caiman, Conservation program, Husbandry care, Symbolic adoption.



# Current situation of the National Program for the Conservation and Sustainable Management of Yacare in Bolivia

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## Abstract

During the last five years, the harvesting quota authorized under the National Program for Conservation and Sustainable Use of *Caiman yacare* vary from 36,287 (in 2015) to 39,652 individuals (in 2017). The authorized quota in 2019 was 38,466 individuals. The National Program still benefits approximately 800 families of indigenous and peasant communities that belong to 19 Indigenous Territories, 25 indigenous communities and 14 peasant communities. As part of the updating of some management plans, new information has been produced on the population status of both *Caiman yacare* and *Melanosuchus niger*, (sympatric species in the Bolivian Amazon). With the focus of achieving an integral use of the species, the use of meat has been supported. In this framework there are some organizations such as Loreto, Bella Vista and Tacana I, who since 2009 have been trained to perform a good management of meat. Work has been done with the national authority on sanitary issues to have a regulation that allows obtaining sanitary registration to communities that produce yacare meat, complying with good handling and hygiene practices. Despite these advances, the sustainability of the program is threatened by the international decrease in the demand for wild hides, which in turn has produced a reduction in prices offered by national tanneries to local communities. This situation has discouraged hunting in recent years and there is a risk of losing one of the few incentives that exist for the conservation of extensive aquatic ecosystems.

## Keywords

Yacare Program, Sustainable, Indigenous, Bolivia.



# National survey of Orinoco Crocodile (*Crocodylus intermedius*) in Venezuela: final report

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## Abstract

The main goal of the national survey of the Orinoco crocodile in Venezuela was to determine the abundance, density and size class structure, in high-priority locations, including geographical places where the possible presence of this species has been informed, but there are not recent available data. The study area was selected based on historical reports on literature, comparing the first report by Goldshalk and Sosa (1978) and places suggested by Balaguera-Reyna *et al.* (2017); as priority areas for conservation of the Orinoco crocodile. The surveys were carried out in 14 localities. Some of these localities were separated in small survey areas (transects) due to its large aquatic surface resulting in 36 surveyed areas, some of them were visited more than one time due to the necessity of preliminary approach as to evaluate logistic matters, like figuring out the feasibility of carrying out the survey the navigable extension, camping location areas, and identification of local collaborators. About more than 1,000 km of both river and creeks banks were surveyed, and the data is reported on the basis of water surface. There were observed 260 Orinoco crocodiles on 515.10 km of river navigated. All individuals were classified in size classes, Class II: 33; Class III: 36; Class IV: 35; Class V: 83; only eyes 73 and 56 hatchling. Three important discoveries have been found, the first is the establishment of a third reproductive population in Estero de Camaguán, Guárico state at Santa Rosa's ranch, as a result of the reintroduction program, particularly from those liberated on the period 2008-2009; the second is, the increase number of nest in Capanaparo River, and finally the confirmation that Orinoco crocodile is present in Zuata and Quitaparo Rivers. This study has been made possible thanks to the support of the Crocodile Specialists Group (CSG) of the World Union for the Conservation of Nature (IUCN), CrocFest and Río Verde, as well as of all the local inhabitants, guides and boat drivers who have supported the field work.

## Keywords

Survey, Orinoco crocodile, *Crocodylus intermedius*, Venezuela.





# Evaluation of the use of drones to monitor a diverse crocodylian assemblage in West Africa

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## Abstract

In West Africa, crocodylian populations are declining and in need of conservation action. Population surveys and other monitoring methods are critical components of crocodile conservation programs; however, survey efforts are often hindered by logistical, financial, and detectability constraints. Drones are increasingly used in wildlife monitoring programs, including for crocodylians in some places. We evaluated the potential of drones as tools in survey and monitoring programs for the diverse crocodylian assemblage of West Africa. We surveyed crocodile populations in Benin, Côte d'Ivoire, and Niger in 2017 and 2018 using both drones and traditional diurnal and nocturnal spotlight surveys. We first sought to objectively evaluate the impact of drones



on crocodylian behavior and establish a standard protocol for drone flights to optimize detectability. We then compared drone survey results to those from traditional crocodylian surveys. We found that crocodiles can be approached very closely (< 2m) and that drones cause only minor disturbances to wildlife in general, including to very sensitive species (e.g., elephants and buffalo), at altitudes of > 40 m. We also found that altitude and other flight technical parameters did not impact detectability because high quality photos allowed accurate counting of crocodiles. Though, observer experience and motivation, as well as field conditions (e.g., wind and sun reflection) and site characteristics (e.g., vegetation, homogeneity, etc...) all impacted detectability. Ideally drone surveys should be implemented from 40 m altitude and in the first third of the day. When comparing drone survey results to traditional methods, we found that drones performed better than diurnal surveys, but worse than nocturnal spotlight counts. The latter not only captured more individuals, but also a greater size class diversity. And, while drone surveys did not detect any Critically Endangered *Mecistops cataphractus* or *Osteolaemus sp. nov. aff. tetraspis*, nocturnal spotlight surveys did. However, drone surveys provide advantages such as accurate size estimation and identification of hard to see individuals, less disturbance, and the ability to cover greater and more remote areas compared to traditional methods. Photos resulting from drone surveys also more readily allow for repeatable and quantifiable habitat assessment, including encroachment and other illegal activities in national parks. Overall, drones offer a valuable and cost-effective alternative for surveying crocodilian populations with compelling secondary benefits, though they are not suitable in all cases and for all species.

### Keywords

Drone, Surveys, *Mecistops cataphractus*, *Crocodylus suchus*.



# Hato Masaguaral: a conservation and education experience about the Orinoco crocodile

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## Abstract

In 1960, Tomás Blohm created Hato Masaguaral at Corozopando, Guárico state, Venezuela. In 1978, concerned about the situation of the *Crocodylus intermedius* species, he began to raise adult specimens with the aim to reproduce them at the Hacienda El Paraíso near Camatagua (Guárico state). In 1984, he moved these specimens to Hato Masaguaral, establishing a hatchery for them. In 2000, Hato Masaguaral and the Foundation for the Development of Physical, Mathematical and Natural Sciences (FUDECI) signed a technical cooperation agreement with the objectives of strengthening captive breeding, population reinforcement and promoting scientific research. In 2004, FUDECI establishes another Orinoco crocodile farm at the Experimental Station in Amazonas. In addition, since 2005 both institutions together with the Group of Specialists in Crocodiles of Venezuela (GECV) provide technical assistance, to teach at Hato Masaguaral the "Ecology and Conservation Course of the Crocodylia of Venezuela", given to university students (155) and officials (77) of the environmental area, which has reached its 11th edition. Since 1990, Hato Masaguaral has released a total of 3,987 young Orinoco Crocodiles and FUDECI 1,601 for a total of 5,588, which currently represents 53% of all the Orinoco Crocodiles released by the 10 "zoocriaderos" that have participated in the National Program for the Conservation of the Orinoco Crocodile. In Venezuela, the releases of both hatcheries have been made in areas of distribution of this species located in the Hato El Cedral, Hato El Frío, Hato Garza, and in the Aguaro-Guariquito and Santos Luzardo National Parks, in the wildlife refuges Caño Guaritico and Tortuga Arrau, at the "Estero de Camaguán Wildlife Reserve" and at the Cojedes River. In the same way, these organizations have supported university pre-degree and master thesis



referred to natural populations and captive breeding. The hatchery of Hato Masaguaral has been an open school for thousands of students national and international, as well as tourists who visit it.

**Keywords**

Conservation, Education for sustainability, Privately protected areas, Crocodylia.



# Acoustic communication in Gharial (*Gavialis gangeticus*)

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## Abstract

Living crocodylians communicate using visual, acoustic, chemical, and/or tactile signals. As adults, gharials (*Gavialis gangeticus*) vocalize rarely. Detailed behavioral observations, with 24hr acoustic recordings and still/video imagery, on the Chambal River in 2017-2019, have documented complex social interactions, including acoustic signaling amongst adults, as well as young. Gharials breed at well-defined arenas established by dominant males, and then reproductive females assemble and nest in large colonies nearby. Male gharial produces an explosive, concussive “pop” signal underwater, in 1-3 short, loud audible bursts. A “pop” resembles a stoppered bottle being opened rapidly, like a wine bottle being uncorked. We used hydrophones and aerial mics, to record the “pops” of 15+ male gharial, > 700 samples. Spontaneous recordings were obtained as gharials behaved normally under natural conditions. Each male gharial produces a stereotypic and distinctive pattern of 1, 2, or 3 pops. Temporal components, rather than frequency differences, appear to facilitate individual recognition. The “pop” or syllable duration ranged from 0.013 to 0.023 seconds, and the time interval between syllables ranged from 0.103 to 0.555 seconds. Distinctive low and high frequencies were characteristic of each pop, ranging from >100-2400 Hz to >10,000-22,000 Hz. Immediately preceding a pop, infrasound is produced. At one site frequented by a breeding male, with few females (<10 in 2017) vs. many (>30 in 2018), “recruiting” pops directed at females predominated in 2017 and in 2019, whereas “challenging” pops were frequent in 2018, when other males were present. At this site, overall pop frequency almost doubled in 2018 (182 vs 101), relative to 2017; then in 2019, frequency declined (120 vs. 182). Peak “popping” frequency appears to coincide with breeding intensity, varied from year to year, and appears to be a good indicator of peak breeding, which in turn, provides an accurate prediction of nesting (5-6 weeks later) & hatching (~60-75 days incubation).

## Keywords

Acoustic signal, Gharial, Individual recognition, Infrasound.



# Gharial population and nest counts in Chambal River, India, 2017-2020

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## Abstract

Field reports (GEP 2017, 2018) indicated adult *Gavialis gangeticus* population was 75 mature males (with ghara), 464 reproductive females plus 52 “near reproductive” females, 462 subadults, 366 juveniles, and 208 yearlings. In 2017, in the National Chambal Sanctuary (NCS), we tallied 417 nests at 28 sites, of which 358 hatched and 59 were lost. In 2018, a total of 443 nests at 37 sites were observed; 318 hatched and 115 were lost. Consequently, this is the largest extant population, by a factor of ten, and the only open-river, self-sustaining remnant of this CR species alive today (Lang et al. 2019). In 2019, additional counts were made. In the upper Chambal, there were 400+ gharial, specifically 35 males, 285 females, 25 subadults, 48 juveniles, and 23 yearlings. In the lower Chambal, 1274 gharial were observed, namely 66 males, 415 females, 428 subadults, 261 juveniles, and 104 yearlings. Adjusted for into size categories, there were 80 mature males (with ghara) plus 59 “near-mature” males, 525 reproductive and “near reproductive” females, 435 subadults, 295 juveniles, and 151 yearlings, in the NCS. In 2019, we tallied 469 nests overall, with 185 in the upper stretch, and 284 nests in the lower Chambal. Of these, ~297 nests hatched, and 172 were lost, to predation or egg failure. The relative importance of the Chambal gharial population cannot be overstated. With realistic counts of the other subpopulations, the NCS population comprises 85% of the global total (>550/650). It also represents ~90% (>450/500) of the global yearly nesting. Importantly, the Chambal population is the ONLY self-sustaining population living in an open river, protected habitat. Major threats, in order of importance, are: a) dams and river-linking, b) water extraction, c) sand mining, and d) net fishing.

## Keywords

Gharial, Population, Nesting, Survey.



# Potential distribution of the broad-snouted caiman (*Caiman latirostris* Daudin 1802) in the Espírito Santo State, southeastern Brazil

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## Abstract

The broad snouted caiman (*Caiman latirostris*) is widely distributed in South America, occurring in aquatic ecosystems from northeastern Brazil to Uruguay. However, the advance of human activities has negatively affected its populations. However, the species can colonize altered environments in response to the destruction of its natural habitats, which makes studies in anthropic environments important for guiding species conservation programs. To evaluate the effect of anthropic environmental modifications on the species distribution of *C. latirostris*, occurrence data were used in a distribution modeling in the state of Espírito Santo, Brazil. Two models of Potential Distribution of Species were generated, the PDM 1 that only uses environmental variables and the PDM 2 that includes natural and anthropic variables that more influence in the prediction of the adequacy of the areas for the species. The environmental variables that contributed the most to the potential distribution of the species were isothermal, altitude, mean annual temperature and seasonal precipitation. By introducing, in MDE 2, the variables human density and forest proportion, the performance of the model improved and the variables that contributed the most were isothermal, human density, mean annual temperature and altitude. Isothermal influences significantly and negatively the prediction of habitat suitability, which means, more adequate habitats have greater thermal variation. The variable human density reduced the total area of adequacy, but increased the adequacy in densely populated regions, suggesting a tendency to synanthropy of the species. 61.5% of the protected areas territory in the state was considered





as potentially appropriate habitats to the species in PDM 1, while in PDM 2 the index was 52%. This information will be useful for the evaluation of factors that affect the distribution of the broad snouted caiman in the Atlantic Forest, contributing also to the definition of areas that must be protected in order to maintain the natural populations and to manage the species in anthropized environments.

**Keywords**

Crocodylians, Geographic distribution, Habitat suitability, Synanthropy.



# Progressive aerial survey results of the *C. porosus* and *C. novaeguineae* wild crocodile nesting trends in Papua New Guinea (1981 to 2020)

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## Abstract

The PNG program is underpinned by the aerial survey program that provides the benchmark for the continued wild harvesting which currently existed without restrictions by CSG and CITES. The management of the long term data has been considered relevant since its inception even though there were gaps in between survey years due to funding and administrative restructuring with the lead mandated agency CEPA formerly DEC. Hence, the results derived from the 2019 *Crocodylus novaeguineae* survey indicated the data sets for (N = 20, N = 30 and N = 43) for the respective periods (1981-2019; 1987-2019 and 1996-2019) reflected notable statistical inferences in Figure. 8, (N = 20)  $Y = 1.1592X - 2220$ ,  $r^2 = 0.3027$ ,  $p = 0.010$ . Mean of 93.45%, (SD of 24.32, Range of 71 – 177); (N = 30)  $Y = 2.2303X - 4334.1$ ,  $r^2 = 0.420$ ,  $p = 0.005$ . Mean of 125.5%, (SD of 35.72, Range of 85 – 223). (N = 43)  $Y = 4.6439X - 9125.8$ ,  $r^2 = 0.5828$ ,  $p = 0.001$ , Mean of 167.5%, (SD of 60.7, Range of 99 – 339). All three sets above reflected between 30 to 60% variation even if there is no difference between the means in nest counts from 1981 to 2019. The *Crocodylus porosus* results is not being update at the time of the submission of this abstract as the survey is yet to be undertaken in March of 2020. The annual total skins export trade figures for the years 2018 (15, 3830) and 2019 (15,783) since the last reported figures of 2017 in the proceeding of the 25th CSG Meeting. The figures are observed to be similar however are lower than the 2017 total export figures. Wild eggs harvested annually by Mainland Holdings (MHL) in 2019 from 169 nests (n = 9,393 eggs) 8099 viable eggs. In 2018, 207 nests were harvested (n



= 12,007 eggs) with 10,155 viable eggs, and the hatchability is 74.90%. These are all wild eggs which are predictable due to environmental factors having <80% hatchability rate. This harvest program is considered important for the livelihood of the local land owners because of the direct cash income that support the conservation program. There are no records of captive breed eggs from Mainland Holdings Farm are reported for the corresponding period. Generally it can be assumed that the program even in the absence of a lot of other scientific intervention programs that are happening elsewhere the PNG program is still sustainably stable.

**Keywords**

Aerial surveys, Nesting trends, Wild crocodiles, Papua New Guinea.



# New slender-snouted crocodylians from the Neogene of north and east Africa and resolution of the Gharial debate

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## Abstract

Phylogenetic analyses made using molecular and morphological datasets yield conflicting results for placement of the modern Indian gharial (*Gavialis gangeticus*) and false gharial (*Tomistoma schlegelii*) among other crocodylians. Morphological analyses indicate they are distantly related, last shared a common ancestor more than 80 million years ago, and are similar because of evolutionary convergence. Molecular analyses instead support a close relationship and a divergence within the past 40 million years, with similarities resulting from common ancestry. Both arguments are well supported, with consistent, robust topologies resulting from separate morphology-, molecular-based, and combined analyses. The continued disagreement between methods limits our ability to use Crocodylia as a model clade for the integration of the earth and life sciences. Numerous undescribed Neogene slender snouted crocodylians from Libya and Kenya, along with described specimens from Uganda, reveal a substantial diversity of gharials in the region until the Pliocene. They preserve derived characters unique to both lineages; the basioccipital is anteroposteriorly broad, and there is a long, broad descending ramus of the exoccipital along the basioccipital tuber, and the orbits are broadly upturned in a manner reminiscent of true gharials, but cranial sutural patterns are more similar to those of tomistomines. Present phylogenetic analyses draw some of these close to *Gavialis* and others close to *Tomistoma*, but this may reflect incompleteness in some forms and insufficient character sampling. Ontogeny may also be a confounding factor in assessing modern relationships. Preliminary results indicate similar morphology between juvenile *Tomistoma* and adult *Gavialis*, suggesting heterochrony may be influencing our current results. Further phylogenetic work on these fossils holds great promise in reconciling modern gharial relationships using traditional morphological methods. This in turn will allow us to comment on the biogeographic histories of the lineage and the evolution of novel traits such as salt tolerance more accurately.

## Keywords

Indian gharial, False gharial, Phylogenetics, Biogeography.



# Collaborating with the Zapata Crocodile Farm on the captive management of Cuban crocodiles

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## Abstract

The Association of Zoos and Aquariums (AZA) manages an important genetic reservoir for the critically endangered Cuban crocodile (*Crocodylus rhombifer*) in North America. The Zapata Crocodile Farm (ZCF) in Matanzas, Cuba manages an important genetically pure population of Cuban crocodiles that are propagated in part for repatriation in to the Zapata Swamp. Since 2017, a multi-institutional team has worked with ZCF staff to improve incubation techniques, evaluate diet, perform health assessments and behavioral studies. This poster will highlight this holistic approach to conserve the critically endangered Cuban crocodile and build capacity for all involved.

## Keywords

Collaboration, Captive Management, Capacity Building.



# Impacts of season and reproductive status on fecal reproductive and adrenocortical steroid metabolites in zoo Cuban crocodiles (*Crocodylus rhombifer*)

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## Abstract

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

## Keywords

Fecal hormone metabolites, Zoo management.



# Individual identification patterns as a monitoring strategy for American crocodiles: Tayrona National Natural Park as a study case

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## Abstract

The American crocodile (*Crocodylus acutus*) is one of the four true crocodiles present in the neotropics and the only one inhabiting across all the Americas. In Colombia, *C. acutus* has shown an increasing trend with larger populations documented in the last two decades. However, the lack of long-term monitoring programs has limited the knowledge regarding the population ecology of the species. We assessed the effectiveness and robustness of a monitoring method of American crocodiles remotely in the Tayrona National Natural Park (individual identification pattern recognition (IIPR)), identifying flaws and improvements necessities to use these data in a technical-wise manner. We collected a total of 92 events from 2008 to 2020 of which only 22.83 % of them were useful to do the IIPR analysis and 77.17 % had not the quality to do so mainly because lack of resolution (16.9 %), presence of visual obstacles (4.2 %), animal under the water (12.7 %), or the impossibility to clearly recognize the scutellation patterns per TLS due to the picture angle (66.2 %). From the useful events, we identified seven individuals only requiring  $4.57 \pm 1.51$  TLSs on average to obtain complete individual identification, with the lowest variation in the post occipital (TSL 1) and nuchal (TSL 2 and 4) regions (only one pattern) compared with the dorsal area (average  $4.67 \pm 1.15$  patterns per TSL). The probability of repeating the most and less common patterns found was  $2.28 \times 10^{-6}$  and  $1.03 \times 10^{-11}$ , respectively, and to repeating the same pattern of each individual range between  $4.95 \times 10^{-10}$





to  $1.26 \times 10^{-7}$ . Recommendations of how to use these data to analyze some population parameters (abundance, animal movement, hotspots) as well as how to improve the number of useful events for a more robust monitoring are presented and discussed.

**Keywords**

Crocodylians, Population ecology, Monitoring



# Population trend and perspectives of *Caiman crocodilus chiapasius*, in the La Encrucijada Biosphere Reserve, Chiapas, Mexico

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## Abstract

*Caiman crocodilus chiapasius*, is the third species of crocodilian found in Mexican territory and the least studied, which should be considered a priority since the state of Chiapas and particularly the La Encrucijada Biosphere Reserve (REBIEN by its acronym in Spanish) are the only sites of their distribution in Mexico. The sampling effort of the Reserve and its monitoring over 20 years by different authors through monitoring in four transects within the REBIEN, generated enough data to describe general patterns of abundance, distribution and population trends. In 2016 we had the opportunity to perform monitors in these four transects, which allows us to define and endorse these patterns and determine the changes throughout all these years. This resulted in the abundance of the population of *C. c. chiapasius*, within the REBIEN, presents a downward trend which puts us on alert about its situation. Another factor to consider is that the sex ratio has a tendency towards males, so it is necessary to conduct studies of the temperatures at which the eggs are being incubated naturally to determine what could be the cause of this trend. Currently the problems of change and land use, habitat destruction, illegal hunting, fishing, pollution, climate change, as well as the increase in the incidence of contingencies (negative interactions) between the crocodilians and the human being put at risk the feasibility of coexistence of this species with the human being and the maintenance capacity of healthy alligator populations. Therefore, it is proposed to generate strategies for the protection and conservation of *C. c. chiapasius* in the REBIEN. It is essential to establish nesting management programs as it is the basis for the development of a



conservation program and potential sustainable use, in addition to having updated and systematized information on the population ecology of *C. c. chiapasius*.

**Keywords**

Alligator, Abundance, Conservation, Sustainability.



# Study of metallic elements in eggshell of *Caiman latirostris*: preliminary results

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## Abstract

Deforestation and other changes in land use are the main reasons why man has drastically modified the wildlife habitat, being the agricultural activity the most contributing one due to the use (often indiscriminate) of agrochemicals, fertilizers and external antiparasitic chemicals, which have had multiple impacts. Recently, in Argentina, agricultural activity has increased exponentially, and livestock farming was concentrated in intensive systems due to the global demand for resources, particularly food, as a result of demographic expansion. This leads to the dispersion of various contaminants, such as heavy metals associated with the use of pesticides and fertilizers. The objective of this study was to determine and compare levels of heavy metals (whose origin may be related to anthropogenic activities), present in the eggshells of *Caiman latirostris* in different reproductive seasons, in the province of Santa Fe (Argentina). For this purpose, we collected *C. latirostris* eggs in sites with different degrees of anthropization. Then, they were taken to the laboratory for processing and analysis, to determine the concentration of metallic elements. We detected heavy metals such as copper (Cu), lead (Pb) and zinc (Zn), being Zn the one found in greater proportion followed by Cu and Pb. It should be noted that in 2014 Pb was not found, while it was detected in recent samples (2020), suggesting that the increase in anthropogenic activities has caused the presence of new metallic elements highly toxic to animals. This study provided valuable information related to the presence of heavy metals in



the eggshells of *C. latirostris*, very useful to monitor possible contamination in their habitats due to the presence of metallic elements.

**Keywords**

Broad-snouted caiman, Reptiles, Heavy metals, Toxic waste.



# Distribution and conservation status of crocodiles in Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico: preliminary data

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## Abstract

Biological monitoring allows to know the state of wild populations and generate guidelines for the species conservation. Two species of crocodiles, *Crocodylus acutus* and *C. moreletii*, inhabit the Sian Ka'an Biosphere Reserve (SKBR), during every stage of their life cycle. Some areas occupied by crocodiles in Sian Ka'an often are used by humans, in which several economic/tourist activities take place. This study addresses the distribution and occupation zones of crocodiles in the SKBR, specifically in Ascension Bay and the associated lagoon system. We conducted diurnal surveys and three nocturnal counts of crocodiles, as well as opportunistic records during August-October 2019. Additionally, we conducted 19 interviews to local inhabitants in order to collect information regarding distribution, seasonality and local perception on the crocodile species. We recorded a total of 30 crocodiles (three in August, 19 in September and eight in October). From spotlight surveys, we obtained an encounter rate of 0.36 ind/km in September, and 0.4 ind/km in October. As a result of daytime surveys, 10 individuals were observed, including one dead (adult female *C. acutus*). The interviewees provided information on sighting (n=17) and nesting (n=11) areas, with a highest mention frequency for eight sighting, and three nesting areas. These preliminary results may facilitate the management and conservation of critical areas for crocodiles in SKBR. The waterways areas along the lagoons stand out as important sites for both species; however, this area has the highest boat traffic, this may represent



a danger for individuals who cross from one shore to another. In addition, it seems necessary to deepen whether tourist activities influence crocodile populations in the SKBR.

**Keywords**

*Crocodylus acutus*, *Crocodylus moreletii*, Spatial ecology, Human-crocodile interactions.





# SNPs marker toolbox for molecular identification of nominal and candidate species of the genus *Paleosuchus*

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## Abstract

Recent studies have identified the existence of species complexes in crocodilians, including in the New World Caimaninae. Both species of the genus *Paleosuchus* are species complexes with three or four species subsumed under the *P. palpebrosus* epithet and two under the *P. trigonatus* epithet. From the conservation point of view, it is important to recognize the evolutionary and ecological uniqueness of these lineages, regardless of the taxonomic status they may receive. Candidate species of the genus *Paleosuchus* have not yet been formally described and therefore do not have diagnostic morphological characters that would allow their identification in nature. This problem motivated us to develop a SNP (Single Nucleotide Polymorphisms) toolkit that enables molecular identification of the nominal and candidate species of *Paleosuchus*. For this, a ddRADseq (Double Digest RAD-sequencing) protocol was used to obtain reduced representation genome of 20 *P. palpebrosus* samples, five from each of four lineages ("Amazonia", "Bolivia", "Madeira" and "Pantanal"), and five samples of *P. trigonatus*, three from the "Amazon" and two from the "Guyana" lineage. We selected from between 11 and 15 private SNPs for each lineage that unambiguously assign individuals to one of these lineages. Additionally, we selected 11 mutually exclusive private SNPs that unambiguously assign individuals to one of the two species complexes. The use of the toolkit is affordable and fast-to-apply in comparison to other molecular identification methods, and so it will enable a rapid molecular assignment of individuals to the newly identified lineages of the genus, which may be suffering different degrees of threat. Additional applications of this marker set are: the assignment of zoo specimens, pet trade individuals, museum samples, or degraded samples to source lineages; molecular identification seized animal parts (eg. bush meat); and identification of the origin of illegally traded animals or their by-products.

## Keywords

Dwarf caiman, Species complex, Species identification, Forensic genetics.



# IUCN-CSG social media's role in conservation & science

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## Abstract

Our conservation projects aim to modify community behaviours and attitudes, and we seek funding to help us achieve these goals. Social media can be used to leverage the global community to further extend the reach of our conservation projects and issues. This is a resource and a tool to reach people we would not otherwise be able to physically meet. An obstacle we need to overcome is the stigma that social media is often viewed as a place for pointless conversations, photos of the individual social media user, or a place for those users to say whatever is on their mind without due consideration first. We will discuss some marketing data to provide an insight into what is current and what is performing well. *Awareness* is the term we use when we share our knowledge or perception of a particular issue, with *education* the process of increasing this awareness or to bring about an enlightening experience. Social media platforms are becoming an increasingly important tool for everyone to use: for broader awareness of their research, conservation projects, and for educating the worldwide community on certain issues. Over 3 billion users on Facebook and over 1 billion users on Instagram; the two most popular social media platforms, with TikTok and YouTube growing in popularity. There are a few simple and effective measures to improve our own social media profiles to better utilize the current algorithms and technologies. The objective is to increase the visibility of our conservation projects, issues, and research to reach and engage with the social media community. This can effectively lead to increases in donations or funding of our research, or behavioral changes in the public for the benefit of wildlife and their habitats. We will share the current status of the social media presence of the IUCN-SSC Crocodile Specialist Group on Facebook, Instagram, and Twitter; as well as the goals for each



social media platform. We are encouraging our members to share with us the projects they are involved in. While many of us are biologists, we also need to be marketers for these conservation actions. We want to promote the species we are trying to conserve, and to create value for theye and their habitats within the local communities, as well as to the broader global community.

**Keywords**

Social media community, Conservation, Visibility.



# The perks of being a claw: another possibility for metal exposure studies in crocodylians

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## Abstract

In the past decades, studies of metals in crocodylian keratinized tissues (mostly, caudal scutes) and blood have been conducted. However, these samples present some disadvantages: the amount of tissue and blood required for such analyses is considerably high and the collection of blood requires especial equipments. Few studies have explored the advantages of claws as an indicator of metal exposure. We therefore analyzed two physiological (Cu and Zn) and two xenobiotic (Cd and Hg) metals in keratinized tissues (caudal scutes, skin and claws) of captive Morelet's crocodiles (*Crocodylus moreletii*) and compared them with concentrations of a wild population from Chichankanab Lake, in order to assess the potential of claws for the monitoring of metals. Claws presented the highest concentrations of metals in both captive (Hg =  $0.44 \pm 0.23 \mu\text{g g}^{-1}$ , Cd =  $11.10 \pm 5.89 \mu\text{g g}^{-1}$ , Cu =  $45.98 \pm 23.18 \mu\text{g g}^{-1}$ , Zn =  $124.75 \pm 75.84 \mu\text{g g}^{-1}$ ) and wild individuals (Hg =  $1.31 \pm 0.32 \mu\text{g g}^{-1}$ , Cd =  $26.47 \pm 21.15 \mu\text{g g}^{-1}$ , Cu =  $191.75 \pm 165.91 \mu\text{g g}^{-1}$ , Zn =  $265.81 \pm 90.62 \mu\text{g g}^{-1}$ ). The post-hoc test revealed that Hg and Cd in claws and scutes are not different, although both metals were different from the concentrations in skin. As for Cu and Zn, the concentrations in claws were completely different from scutes and skin. Our results demonstrate claws are an excellent tool for assessing metal exposure, especially in populations in which scutes clipping as a marking technique is not allowed, and their collection and preservation is less complicated than other tissues. We strongly recommend their implementation in studies of metal exposure in crocodylians.

## Keywords

Keratinized tissues, Metal detoxification, Xenobiotic metals, Claws.



# Study on cranial morphological variations of broad-snouted caiman (*Caiman latirostris*) during its ontogeny to establish relationships according to sex and kinship

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## Abstract

The study of morphological features in crocodilians is relevant in the fields of systematic, evolution, ecology and conservation. Therefore, it is very important to detect similarities and differences on the forms of the traits on individuals to be analyzed in a broader context. The aims of this study were to assess and estimate cranial morphological variations on lateral view of broad-snouted caiman (*C. latirostris*) during its ontogeny and establish relationships according to sex and kinship. Forty young individuals from 4 different nests were photographed with digital camera and a homogeneous number of landmarks were digitized for each feature. Generalized procrustes analyses (GPA) were conducted by overlapping of the average configurations to remove unwanted parameters outside of the form. The allometric effect was analyzed in each of the configurations, but the regression residues were used in the case of allometry. The shape of the traits was evaluated by means of a principal component analysis (PCA). Our results evidenced similar forms among the individuals in each nest. When analyzing the forms with respect to sex, in the first instances both sexes presented homogeneous forms, although in advanced ontogenetic stages the females presented more robust forms while the males presented stylized forms. Finally, we can conclude that geometric morphometric is useful analysis tool to identify the relationship between individuals of each nest in terms in lateral view. In addition, this tool allows us to distinguish sex in more advanced ontogenetic stages of *Caiman latirostris*. The identification cranial spots as individual patterns in broad-snouted caiman are under analysis.

## Keywords

*Caiman latirostris*, Geometric morphometric landmarks, Cranial morphology.



# Increased hatching success of cracking eggs of broad-snouted caiman (*Caiman latirostris*) through a new incubation method

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## Abstract

The shell of crocodilian eggs is highly fragile during the firsts days of development making them prone to cracking during the eggs laying or collecting and the embryos usually dead. There are many studies about different techniques for egg artificial incubation and how to increase the hatching success with problems in the eggshell, but as far we know, there are not precedents in crocodilians. For this reason, the objective of this research was to evaluate the hatching and survival success of cracked eggs of *Caiman latirostris*, using “windowing” incubation method (adapted for crocodilians) and the *ex - ovo* incubation of embryos in artificial culture vessels. We used fertile eggs with cracked shell [windowing method (WMT) and *ex - ovo* (EOT) treatments] and non-cracked eggshell (control treatment). All eggs were cleaned with alcohol to avoid contamination during incubation time. In the WMT, a portion of eggshell was removed, whereas for the EOT, the caiman embryos were separated from the eggs. Every treatment was incubated in an artificial culture vessel with an aqueous antimicrobial solution of 0.01% benzalkonium chloride at  $31 \pm 1$  °C. Also, others incubation conditions such as calcium, water supplementation and gas exchange were controlled. After a maximum of 38 days of incubation, the hatching success for WMT was 66.67%, for EOT 0% and controls 100%. The posterior survival of hatchlings of WMT was 50% and control 100%. The results indicated that the incubation in artificial culture vessels increased the viability and hatching success of cracked eggs, working as an apparently antimicrobial barrier and helped to maintain sterile conditions and do not interfere with embryonic development. In addition, provide a unique accessibility of monitoring for developmental studies or other manipulations to the crocodilian embryos. However, the EOT is not recommended, because fails to recreate the conditions into the egg.

## Keywords

Artificial culture vessel, Cracked eggshell, Crocodilians, Egg survival.



# Education for Conservation: “DEMYSTIFYING CROCODILIANS IN AMERICA”

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## Abstract

Being able to touch a crocodile and walk among adult specimens may seem to some people to be a daring action, an extreme adventure, but it is not. Crocodiles are not the gigantic and bloodthirsty man-eaters that some movies have led us to believe, nor are they the hungry and aggressive predators that devour huge herbivores that documentaries show us. Crocodilians in America and many of them throughout the world spend their lives feeding on fish, crustaceans, birds, and small mammals. In the past 40 years it has been possible to demystify the shark, the wolves, the bears, and the felines, it is time to understand and put crocodiles in their true place, as a top predator, yes, it is, but in its ecosystemic function is not to control human overpopulation. It is our task to implement strategies to learn to coexist with crocodiles where possible, prevent conflicts where there is a greater intensity of interaction and have management programs for adult specimens, where and when necessary; but all the strategies to implement will be impossible if the human population considers them little less than man-eating dragons. Let's demystify crocodilians.

## Keywords

Environmental education, Crocodiles, Crocodilians, Demystification, Conservation.





# Research advances in the knowledge on crocodylians of Mexico: analysis from the Web of Science database

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## Abstract

The knowledge on wildlife is fundamental for the implementation of programs for the conservation, management, and sustainable use of species, including crocodylians. Mexico is home to two crocodile species (*Crocodylus acutus* and *C. moreletii*) and one caiman species (*Caiman crocodilus*), all of which are in some risk category at the international (IUCN) and national level (NOM-059-SEMARNAT-2010). Here we present the results of a search for publications of studies carried out in Mexico, including information on the three crocodylian species, published in journals indexed in the Web of Science database up to 2021. Most of the products focused on either or both species of crocodiles (55 included *C. moreletii*, 52 included *C. acutus*), and only 10 articles mentioned *Caiman crocodilus*. Most publications correspond to articles (93%), while the remaining include proceeding papers, letters, meeting abstracts, and scientific notes among others. The publications are mainly concentrated in 11 thematic areas, with Zoology standing out with 32, Biodiversity Conservation with 24, Environmental Sciences Ecology with 20, and Veterinary Sciences with 11. Considering authors' productivity, specialists with the highest number of publications are Pierre Charruau with 22, J. Rogelio Cedeño-Vázquez with 10, Sergio E. Padilla-Paz with 9, Armando H. Escobedo-Galván with 8, Marco A. López-Luna and Mauricio González-Jáuregui with 7 publications each. Future research efforts must be focused on topics less aborred, such as Toxicology, Biochemistry Molecular Biology, Parasitology, Evolutionary Biology, and Physiology.

## Keywords

Knowledge, *Crocodylus acutus*, *Crocodylus moreletii*, *Caiman crocodilus*, Mexico.



# Recent advances and perspectives on South American fossil crocodylians

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## Abstract

The past decade has seen major discoveries and advances on the fossil crocodylian fauna of South America. The diversity of South American gharials has expanded with the description of *Aktiogavialis caribesi* and *Gryposuchus pachakamue*. In addition, several new caimanine species have been described, with some revealing entirely new evolutionary lineages and others shedding light on the evolution of previously known groups. *Globidentosuchus*, *Gnatusuchus*, *Kuttanacaiman*, and *Caiman wannlangstoni* establish the existence of previously unknown lineages of highly specialized durophagous caimanines. Another new caimanine, medium-sized *Agresuchus pachytemporalis*, was argued to be closely related to giant *Purussaurus*, providing important insights on the evolution of gigantism and skeletal novelty among caimanines. Additionally, the taxonomy, anatomy and feeding habits of the strange caimanine *Mourasuchus* have been extensively revised. A comprehensive revision of alligatoroid phylogeny, focused on South American caimanines, shows that the durophagous ecomorphotype may have arisen up to three times in Caimaninae, although most durophagous taxa belong to a single clade. The analysis reinforces that *Purussaurus* evolved from a modest-sized generalist caimanine and a close relationship between *Agresuchus* and *Caiman*. A better understanding on the evolution of *Mourasuchus*, however, requires further assessment. Biogeographically, all South American alligatoroids included were recovered in Caimaninae; non-South American caimanines include North American *Bottosaurus* and *Tsoabichi*, Central American *Centenariosuchus*, and possibly Asian *Protoalligator*. As such, our knowledge on South American fossil caimanines has advanced significantly in the last



decades, but much is yet to be done, especially on the use of most modern techniques on morphological and paleoecological studies.

**Keywords**

Alligatoroidea, Caimaninae, Gavialoidea, South America.



# Cross-border trade in wildlife species, parts, and derivatives

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## Abstract

International trade of wildlife species specimens, parts and derivatives, including *Crocodylus moreletii*, requires regulation by the General Department for Wildlife (DGVS), Administrative Authority of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in Mexico, which is part of the structure of the Ministry of Environment and Natural Resources (SEMARNAT), this regulatory procedure is based on the said Convention and the General Law of Wildlife (LGVS). The LGVS and its Regulations establishes in its articles 53, 54 and 55, as well as 12, 62, 63, 64, 65, 66 and 67, respectively, the regulations to comply to be able to carry out cross-border movements, such as export, re-export and import; complementing other regulatory instruments such as the General Law on Sustainable Fisheries and Aquaculture (LGPAS), the General Law on Sustainable Forestry Development (LGDFS), the General Law on Ecological Balance and Environmental Protection (LGEEPA), among others, the Official Mexican Standard NOM-059-SEMARNAT-2010 and the Agreement that Establishes the Classification and Codification of Goods whose import and export is subject to regulation by SEMARNAT. These instruments aim to establish what is regulated and how it should be done, emphasizing that the use of natural resources has been carried out in a sustainable manner. The LGVS in its article 1, paragraph 2 allows to discern the attribution to regulate timber and non-timber forest species, as well as those whose total livelihood is water, since in this case it only applies to those species or populations in risk. The NOM-059-SEMARNAT-2010 and its Amendment to Normative Annex III, establishes the native Mexican species of wild flora and fauna-Risk categories and specifications for their inclusion, exclusion, or change-List of species at risk. Species at risk are those identified by the Secretariat as probably extinct in the wild (E), endangered (P), threatened (A) or subject to special protection (Pr). CITES was established in 1973 with the signature of 23 countries, entering into force in 1975. On June 24, 1991, the accession of Mexico was approved and on September 30 of the same year it entered into force. The DGVS as the Administrative Authority before the Convention is responsible



for issuing permits, certificates, annual and biennial reports on trade, as well as establishing communication with the countries that are part of CITES; the Scientific Authority rests with the National Commission for the Knowledge and Use of Biodiversity (CONABIO) and the Law Enforcement Authority oversees the Federal Attorney for Environmental Protection (PROFEPA). Finally, it should be noted that the regulatory purposes to carry out international trade were conceived to regulate it and not as a prohibition on exploitation as perceived by many sectors. There are prohibitions for cross-border movements of wildlife, indicated in the LGVS, which were made known through Decrees published in the Official Gazette of the Federation (DOF) and which are indicated below: Article 55 Bis.- Importation is prohibited , export and re-export of specimens of any species of marine mammal and primate, as well as their parts and derivatives, with the exception of those intended for scientific research, prior authorization from the Secretariat. Article 60 Bis 2.- The import, export and re-export of any specimen of bird corresponding to Psittacidae family whose natural distribution is within the national territory is prohibited and Article 27 Bis 1.- The import of invasive exotic species shall not be authorized or wild species that are carriers of said invasive species that represent a threat to biodiversity, the economy or public health, the Secretariat published for this purpose the AGREEMENT by which the List of Invasive Alien Species for Mexico is determined in the DOF on December 7, 2016.

### **Keywords**

Import, Export, Re-export, CITES, DGVS.



# Venom factor-like in crocodilians

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## Abstract

The archosaurs, including crocodilians, dinosaurs, and birds were traditionally considered a completely non-venomous group of animals. However, crocodilians, in particular, have a protein similar to cobra venom factor (CVF), an unusual non-toxic complement-activating protein reported in the venom of many elapid snakes. In this work, bioinformatical and phylogenetic analyses were applied and then conventional PCR with specific primers for *Caiman latirostris* were performed. The bioinformatical analysis of Venom Factor-like (VF-like) in crocodiles was identified in the complete genome of *Caiman latirostris*. The phylogenetic analyses were made with a cross-platform program for Bayesian analysis of molecular sequences (BEAST v1.8.4) with VF-like, CVF and C3 complement component of some crocodilians species, Elapidae snakes, and other relevant sequences, to explain the presence of VF-like in crocodilians. Thus, our results demonstrated the presence of VF-like in *Caiman latirostris* and showed the strong homology that exists with complement system component C3. It supports the presence of venom toxins of snakes in non-venomous reptiles and represent a contribution to know and understand how the immune system of crocodilians works. However, more in-depth research will be necessary to understand about the origin, expression and function of VF-like in crocodilians.

## Keywords

Crocodiles, Snake venom, Venom factor like.



# Detecting the emerging contaminant amphetamine in the apex predator *Alligator mississippiensis*: a novel study

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## Abstract

The Gulf of Mexico is a vast area that includes many different habitats such as mangroves, estuaries, and swamp lands. This area includes both highly urbanized areas and more remote areas. Many studies of environmental contaminants cover substances such as pesticides, pharmaceuticals, and personal care products. However, in more recent years a new class of contaminant is starting to surface: illicit drugs. This study focuses on the detection of such contaminants, specifically amphetamine, MDA, MDEA, MDMA, and methamphetamine, in the keystone species *Alligator mississippiensis* collected from the Houston, TX area and the Rockefeller Wildlife Refuge in Grand Chenier, LA. *A. mississippiensis* are of particular interest as they are not only apex predators, but they are considered environmental indicators as well as trophic regulators. Given that this species is a highly opportunistic predator, it is suggested that there may be a potential of this chemical transferred to this apex predators through environmental exposure and/or trophic transfer through contaminated prey items. This study utilizes tissues adipose, liver, and scutes collected from alligators in the Houston, TX area and the Rockefeller Wildlife Refuge in Grand Chenier, LA. Tissues were homogenized and processed using QuEChERS salt extraction methods. Chemical analysis using liquid chromatography-mass spectrometry (LC-MS) indicate that amphetamine was found in alligator adipose, liver and scute tissue at both locations in the range of 2-17 ppb. This study will highlight the use tissue in determining narcotic concentrations in an apex species.

## Keywords

Toxicology, Contaminants, Apex predators.





# Human animal conflict in Sri Lanka with special reference to Crocodile attacks

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## Abstract

Sri Lankans, especially those in rural areas with farm and domestic animals face conflicts with *Crocodylus palustris*, *Crocodylus porosus*, other megafauna (elephants, leopards, bears, buffaloes), and highly venomous snakes, that can cause minor to grievous injuries. Victims may be left with permanent disability of varying degrees, or in a few cases an attack may be fatal. This communication reviews the pattern of crocodile attacks from surveys conducted from 2009 - 2011. Ancient traditional medical works of the country indicate that Human Crocodile Conflict (HCC) has existed historically, as some medical manuscripts (e.g., *Sārārtha Sangrahaya*, written around 337-365 ACE) record medicaments for crocodile bites. Additionally, the Great Chronicle of Sri Lanka, the *Mahāvamsa*, (6th century ACE) records perhaps one of the first references to the existence of man-eating crocodiles in the country. During our surveys conducted on HCC from south to north Sri Lanka, we observed approximately 177 cases; 148 (84%) were male victims, 27 (15%) were female and 2 cases where sex was not recorded. Fifty (28%) were fatal. We visited houses of 131 victims, discussed the incident and subsequently, visited locations where the attacks took place. Fifty-eight (45%) attacks by *Crocodylus palustris* took place in manmade water bodies, 45 (35%) in small rivers (Oya), and 22 (17%) in large rivers. The highest frequency of attacks 65 (50%) were when people were bathing. Legs were most vulnerable to crocodile attack (n=45 (47%)), followed by arms (n=25 (19%)). In 12 cases the trunk including the chest was attacked, and 4 cases where buttocks were attacked. Ninety-eight (93%) victims had been dragged into the water by the crocodile. It is worth noting that 90% of victims were aware of the presence of crocodiles before the attack, and 64% of the victims interviewed reported routinely visiting these water bodies on a regular basis at similar



times to engage in activities such as fishing, bathing, and washing clothing prior to attacks. We would like to note that many recent attacks since the completion of these surveys are excluded from this communication. We recommend education of the behavior and intelligence of crocodiles, as the best approach to reducing and mitigating conflicts with humans.

**Keywords**

Human Crocodile Conflict, Attacks, Sri Lanka.



# Insights into the ecology and evolutionary success of crocodilians revealed through bite force and tooth pressure experimentation

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## Abstract

Crocodilians have dominated predatory niches at the water-land interface for over 85 million years. Like their ancestors, living species show substantial variation in their jaw proportions, dental form and body size. These differences are assumed to reflect specialization related to feeding and niche occupation, but how they relate to biomechanical performance during feeding and their relevance to evolutionary success are not well understood. During the course of the last two decades we measured adult bite forces and tooth pressures in 23 extant crocodilian species and analyzed the results in ecological and phylogenetic contexts. We demonstrate that these animals generate the highest bite forces and tooth pressures known for any living animals. Body size changes are the dominant mechanism of feeding evolution in this group with jaw shape demonstrating surprisingly little correlation with bite forces and pressures. Once achieved, the relative force capacities of this system went essentially unmodified throughout subsequent diversification. Rampant changes in body size and concurrent changes in bite force served as mechanisms to allow access to differing prey types and sizes. Further access to the diversity of near-shore prey was gained primarily through changes in tooth pressures via the evolution of dental form and distributions of the teeth within the jaws. Bite forces can now be predicted in fossil crocodilians using the regression equations generated in this research and for other fossil archosaurs (e.g. dinosaurs) using models developed during the course of our work.

## Keywords

Feeding, Biomechanics, Evolution.



# Bioaccumulation and trophic transfer of polycyclic aromatic hydrocarbons (PAH) and organochlorine pesticides (OC) in the swamp crocodile (*Crocodylus moreletii*) and its prey in a lagoon system of Emiliano Zapata, Tabasco, Mexico

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## Abstract

The present study evaluated the origin and trophic transfer of polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCs) in two trophic chains of the sites of Nuevo Pochote and Emiliano Zapata, Tabasco. These evaluations were based on the predation relationships of 107 organisms representative of both trophic chains, as well as the normalization of lipids to improve the prediction of bioaccumulation of these pollutants. Our results showed that the OCs with the highest presence at both sites were: methoxychlor (508.7 ng/g) >  $\Sigma$ dienes (306.2 ng/g) >  $\Sigma$ DDTs (292.2 ng/g) >  $\Sigma$ HCHs (215.6 ng/g) >  $\Sigma$ endosulfans (88.8 ng/g). As for PAHs, 2- to 4-ring PAHs had the highest presence at both sites: acenaphthene (1,455 ng/g), naphthalene (649.6 ng/g), fluorene (552.9 ng/g) and benzo[a]anthracene (395.7 ng/g). The results also showed that the size and quantity of lipids present in the organisms of the different trophic levels evaluated significantly influenced the bioaccumulation and trophic transfer of these organic pollutants. PAHs and OCs in both study sites presented higher accumulation in sediments, livers and hepatopancreas, and the concentrations of these compounds increased according to the type of feeding of the species in accordance the following classification order: zoobenthivorous > omnivorous > carnivorous. As for PAHs, the predominance of lower molecular weight congeners demonstrated that petroleum and the combustion products of fuel oil were the most predominant in aquatic species and to a lesser extent the pyrogenic sources, whereas the total OCs concentration may be subject to the ingestion of food and the high persistence due to past or current uses in agricultural and public health activities in the region, despite their prohibition and restriction in recent years.

## Keywords

OCs, PAHs, Bioaccumulation, Trophic levels.



## Introduction

Organochlorine pesticides (OCs), such as DDT, lindane and endosulfan, were used for a long time in agriculture and livestock farming to control pests and ectoparasites, and in public health to eradicate diseases such as malaria, chagas, malaria, dengue fever, among others (Albert and Viveros, 2018). Polycyclic aromatic hydrocarbons (PAHs) are generated by processes such as decomposition, volcanic eruptions, fossil fuels, fires, and burns (Dupree and Ahrens, 2007). These compounds are highly persistent and can remain in environmental substrates for a long time. Upon entering aquatic ecosystems, these compounds bioaccumulate in fatty tissue in organisms through feeding, respiration, or the dermal route; and they biomagnification at trophic levels affecting top predators, such as the swamp crocodile (*Crocodylus moreletii*), and causing adverse effects at the endocrine level of organisms (Covaci et al., 2005; Eqani et al., 2013; Nilsen et al., 2014).

The objectives of the present study were: 1) to analyze sediments and aquatic biota for organic contaminants, 2) to evaluate bioaccumulation and biomagnification at each trophic level sampled, 3) to evaluate the influence of the lipids of the organisms studied with respect to the trophic distribution of contaminants.

## Materials and methods

Two study sites were selected: the municipality of Emiliano Zapata and the community of Nuevo Pochote in Tabasco. Both sites have anthropogenic influences, such as river fishing; agricultural activity with slash and burn (RTQ) applications, crude oil and natural gas extraction, and sewage discharges. Sediment samples were collected near ditches, drains and cultivation areas. Plants and mollusks were collected directly. Crustaceans were collected using nets. Fish were captured using trawls and traditional techniques (chinchorro). Waterfowl were collected opportunistically. Amphibians were collected using wooden line nets. Turtles were captured directly. Crocodiles were captured using a pole.

In the laboratory, extraction of PAHs and OCs in sediments and leaves was performed by microwave digestion (Wang et al. 2007). In biological samples, extraction was performed by sonication in ultrasonic equipment (Zhao et al. 2005). The concentrated extracts were passed through a chromatographic column. Contaminant analysis was carried out using a gas/mass spectrometer (GC-MS/MS). Hydrocarbons with 2 to 3 rings indicated that the compounds



came from petrogenic sources and with 4 to 6 rings from burning and fires (Neff et al., 2005; Ortiz-Salinas et al., 2012). OCs were grouped according to the summations of the concentrations of each contaminant and its chemical family:  $\Sigma$ HCHs ( $\alpha + \beta + \gamma + \gamma + \gamma + \delta$  HCH),  $\Sigma$ dienes (aldrin + dieldrin + endrin aldehyde + endrin ketone),  $\Sigma$ endosulfans (endosulfan I + II + endosulfan sulfate),  $\Sigma$ DDDTs (p,p' DDE + p,p' DDD + p,p' DDT),  $\Sigma$ heptachlor (heptachlor + heptachlor epoxide) and methoxychlor.

For lipid standardization, an extract of the biological subsample was used for gravimetric determination of lipid content.

## Results and discussion

### PAHs by Trophic Level

The highest concentrations of  $\Sigma$  PAHs occurred in Nuevo Pochote mainly in zoobenthivorous, omnivorous, and carnivorous species, such as *T. pasionis*, *T. venusta* and *C. moreletii* (Table 1).

**Table 1**  
**Mean concentrations ( $\pm$ SD) of  $\Sigma$ PAHs and OCs (ng/g d.w.), in aquatic species from Nuevo Pochote and Emiliano Zapata, Tabasco, categorized according to Trophic Level (TL).**

Trophic level		$\Sigma$ HCHs	$\Sigma$ endosulfans	$\Sigma$ DDTs	$\Sigma$ dienes	$\Sigma$ heptachlor	methoxychlor
<b>Nuevo Pochote</b>							
Detritus	3.5 $\pm$ 1.5	0.5 $\pm$ 0.3	0.06 $\pm$ 0.01	0.6 $\pm$ 0.4	0.4 $\pm$ 0.2	0.04 $\pm$ 0.03	1.7 $\pm$ 0.7
Producers	5.1 $\pm$ 1.1	0.01 $\pm$ 0.007	0.01 $\pm$ 0.007	0.35 $\pm$ 0.15	0.13 $\pm$ 0.06	0.007 $\pm$ 0.005	0.04 $\pm$ 0.03
Herbivorous	13.8 $\pm$ 8.3	1.2 $\pm$ 2.2	0.1 $\pm$ 0.09	2.0 $\pm$ 1.1	1.6 $\pm$ 0.3	0.1 $\pm$ 0.08	0.6 $\pm$ 0.7
Detritivorous	118.7 $\pm$ 161.7	10.8 $\pm$ 8.3	2.3 $\pm$ 1.2	13.4 $\pm$ 13.3	13.6 $\pm$ 7.1	1.7 $\pm$ 1.2	27.0 $\pm$ 22.7
Omnivorous	216.3 $\pm$ 66.2	13.3 $\pm$ 6.4	4 $\pm$ 4.4	69.6 $\pm$ 76.33	37.7 $\pm$ 13.6	1.9 $\pm$ 1.2	33.6 $\pm$ 63.7
Zoobenthivorous	574 $\pm$ 886	171 $\pm$ 195.5	74.5 $\pm$ 120.8	143.5 $\pm$ 161.5	181 $\pm$ 258	21.1 $\pm$ 28.2	393 $\pm$ 520.5
Piscivorous	34.8 $\pm$ 51.7	0.6 $\pm$ 0.8	0.1 $\pm$ 0.1	2.6 $\pm$ 2.9	0.9 $\pm$ 1.2	0.01 $\pm$ 0.01	0.6 $\pm$ 0.8
Carnivorous	405 $\pm$ 667	3.5 $\pm$ 4.4	6 $\pm$ 11	7.7 $\pm$ 12	56 $\pm$ 97.5	3.2 $\pm$ 5.5	6 $\pm$ 8.8
Total mean	469.1 $\pm$ 230.4	25.1 $\pm$ 27.2	10.8 $\pm$ 17.2	29.9 $\pm$ 33.46	36.4 $\pm$ 47.2	3.5 $\pm$ 4.5	57.8 $\pm$ 77.2



Emiliano Zapata							
Detritus	4.3±1.8	0.5±0.3	0.04±0.02	0.4±0.3	0.4±0.3	0.04±0.03	1.6±0.9
Producers	4.5 ± 1.7	0.02±0.01	0.01±0.005	0.4±0.25	0.15±0.05	0.005±0.002	0.02±0.01
Herbivorous	24.7 ±25.3	0.6 ±0.5	0.025 ±0.02	4.5± 4.4	2.8 ± 2.0	0.1 ±0.1	5.0± 3.4
Detritivorous	44.4±22.8	5±7	4.2±8.0	8.5±9	29.6±24.2	1.4±1.3	18.8±19.3
Omnivorous	22.1±11.7	0.2±0.2	0.20±0.20	5.4 ± 4.5	2.0± 1.2	0.05 ±0.1	0.9 ± 1.4
Zoobenthivorous	80.7 ± 24	12.6 ± 12	1.2 ± 1.5	15.1 ± 10.8	12± 13	0.35 ± 0.5	31 ± 52.5
Piscivorous	3.5 ± 2.5	0.03 ±0.02	0.04±0.04	0.4±0.4	0.18± 0.16	0.01±0.005	0.05 ± 0.05
Total mean	26.3 ±12.8	2.7 ± 2.8	0.8±11.6	4.9±4.2	6.7±5.8	0.27±0.29	94.5 8.19 ±11

The trophic levels studied showed a predominance of petrogenic and pyrogenic  $\Sigma$ HAPs. In Emiliano Zapata, zoobenthivorous species showed the highest concentrations of  $\Sigma$ HAPs highlighting the species *G. dormitor*. The concentrations of  $\Sigma$ HAPs did not show significant differences between the trophic levels of Nuevo Pochote and Emiliano Zapata ( $p > 0.05$ ), (Fig. 1). A study by Ponce-Vélez (2012) in Laguna el Yucateco (Tabasco) observed an accumulation of petrogenic  $\Sigma$ PAHs in the aquatic trophic levels, where detritivorous fish presented a higher load of contaminants (47.75 ng/g). Another report by Froehner et al. (2011) suggested a biomagnification process of petrogenic  $\Sigma$ PAHs in sediment-feeding detritivorous fish, with  $\Sigma$ PAHs concentrations between 40.8 and 406.8 ng/g.

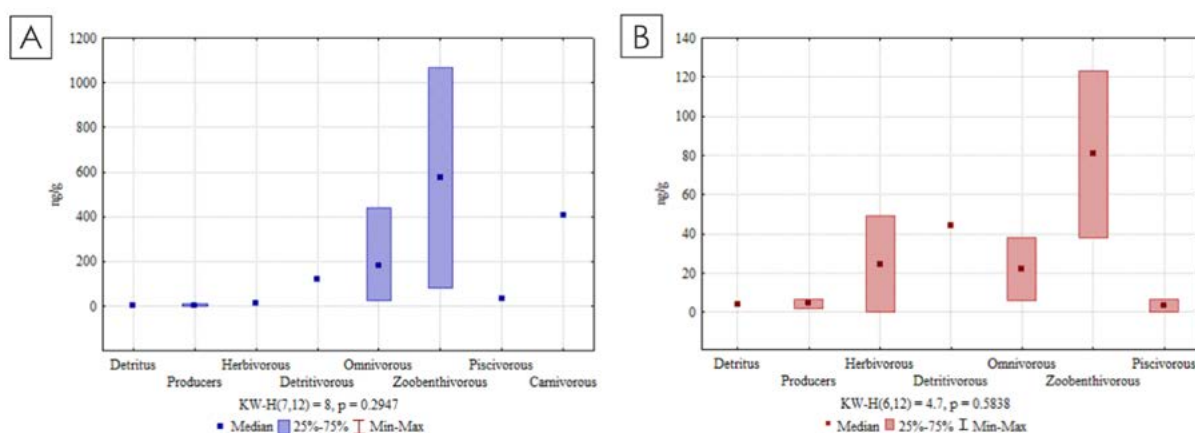


Figure 1. Boxplots of  $\Sigma$ PAHs for different trophic levels (ng/g d.w.) per study site: (A) Nuevo Pochote and (B) Emiliano Zapata. Boxplot: 25-75 percentiles, line: median, whiskers: Min-Max, each individual value was plotted.

### OCs by Trophic Level

The mean concentrations of OCs in the trophic levels of Nuevo Pochote showed a predominance of the six groups of OCs, mainly for zoobenthivorous





and omnivorous species, highlighting *T. pasionis* and *T. venusta*. In Emiliano Zapata, the group of zoobenthivores and detritivores presented the highest concentration for the six groups of organochlorines, highlighting the species *G. dormitor* and *P. pardalis* (Table 1). There was no significant difference between the concentrations of OCs of the trophic groups of Nuevo Pochote and Emiliano Zapata ( $p > 0.05$ ). (Fig. 2)

It is possible to evidence a continuous and current use of some OCs in Tabasco, such as endosulfan and lindane, especially in agricultural crops, forest plantations, in the control of ectoparasites in livestock, for the treatment of scabies and lice, during periods of insect control (spring and summer) and diseases (Benítez and Barcenás, 1996; WHO, 2002; Torres-Dosal et al., 2012).

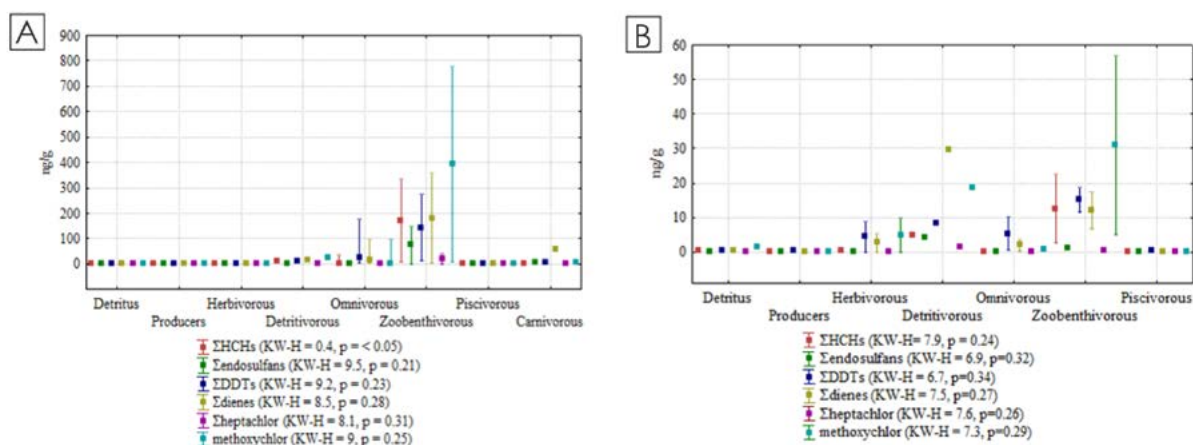


Figure 2. Concentrations of OCs by chemical family (ng/g d.w.) for different trophic levels per study site: (A) Nuevo Pochote and (B) Emiliano Zapata.

### Lipid content

With respect to the results, previously mentioned, correlations were found between the percentage of lipids present in the analyzed organisms and the concentration of ΣPAHs and OCs from Nuevo Pochote and Emiliano Zapata. The organisms from Emiliano Zapata presented less lipids in percentage (7%) than the species from Nuevo Pochote (50%). It is inferred that the concentrations of contaminants bioaccumulate according to the size of the organisms and the lipid content in them, which in turn suggests a biomagnification process in the higher trophic levels depending on the type of feeding, especially the zoobenthivorous, omnivorous and carnivorous groups (Fig. 3).



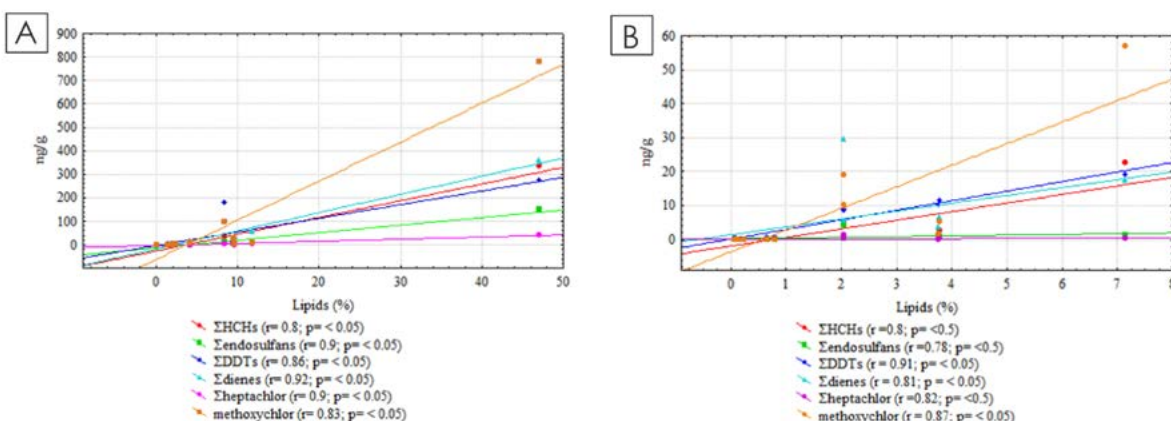


Figure 3. Relation of OCs concentrations (ng/g d.w.) and percentage of lipids (%) present in species by Trophic Level (TL) by locality: (A) Nuevo Pochote and (B) Emiliano Zapata.

## Conclusion

The presence of petrogenic and pyrogenic PAHs, and six dominant groups of pesticides (methoxychlor, ΣDDTs, ΣHCHs, Σdrines, Σendosulfans and Σheptachlor) was confirmed at the trophic levels evaluated. A process of bioaccumulation and biomagnification as one moves up the trophic levels are suggested, as there was a direct significant relationship between feeding habits and lipid content of the evaluated species. The zoobenthivore, omnivore and carnivore groups presented the highest amounts of contaminants for both sites studied, as they have a varied diet and therefore higher exposure pathways. The presence of PAHs may be influenced by oil activities, forestry and RTQ practices, while the presence of OCs derives from agricultural and public health activities in the region despite their restriction.

Through this study we provide current information about the region and learn about the importance of the possible repercussions of contaminants in the aquatic trophic levels, starting from the top predator, the *Crocodylus moreletii*, to its prey, affecting entire populations. In addition to the ecological impacts and risks to human health, which will serve as a basis for future studies.

## Acknowledgments

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# Effect of dietary enrichment with wild food items on the proximal composition of muscle and fat of *Caiman latirostris* in captivity

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## Abstract

Animals' diets, such a crocodilian, are reflected in their tissue's chemical composition. Therefore, the incorporation of items belonging to the wild diet into the farm diet would be evidenced in the tissues of individuals, where each item could induce a change as a source of nutrients. Our objective was to evaluate the effect of enrichment diet with wild food items of *Caiman latirostris* on the proximal composition (ash, moisture, protein, and total lipids) of caiman muscle and fat. Four dietary treatments were offered: diet with insects (DI), with snails (DM), and with red meat (DCR) and captivity diet (control, DC); the diets were offered *ad libitum* for 30 days. The proximal composition of the diets, muscle and fat of caimans under study were analyzed. Our work showed increases in total protein concentrations in the DCR and DI diets, and an increase in total lipids in the DCR diet, with respect to the DC. The PCA of muscle tissue showed that the data from caiman fed the DI diet were associated with changes in lipids and ash, and those fed the DCR diet were associated with few changes in all parameters of proximal composition. In the fat, it was evidenced that DI and DCR reduced moisture content, while DI reduced protein content with respect to DC. Data indicate that DI and DCR diets are recommended for the feeding of *C. latirostris* in captivity, since their incorporation would be a source of proteins and lipids that would favor the correct development of caimans.

## Keywords

Broad-snouted caiman, Insects, Snails, Red meat, Wild diet.



# Stable isotope measurements can assist in the traceability of products derived from crocodiles

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## Abstract

One fifth of reptile species are currently threatened with extinction due to poaching, trafficking, and habitat loss. Crocodilian species are predators playing crucial ecological roles in their respective niches and are also endangered since several products derived from these reptiles have important commercial value. The present study examined the application of dual stable isotope analysis as a tool to identify the origin of skin and meat derived from wild and farmed crocodiles. Scutes and muscle samples were obtained from wild and farmed crocodiles *Crocodylus acutus* (n=14) and *C. moreletii* (n=9). The isotopic values in sampled scutes were significantly different between wild and farmed organisms, and  $\delta^{15}\text{N}$  values showed higher differences than  $\delta^{13}\text{C}$  values between both groups of animals. When both values were integrated under a discriminant analysis, a significant difference was observed, hence indicating the dual isotopic values can be effectively used as a tool to support traceability protocols designed to identify the origin of crocodile skins. Two specimens of *C. acutus* were maintained under controlled dietary conditions to obtain an indicator of the turnover rate of carbon and nitrogen in scutes. Different tissues were also sampled as a mean to obtain reference isotopic values, in particular for skin and muscle. The tissues and organs analyzed from these two individuals showed decreasing  $\delta^{13}\text{C}$  values as follows: liver > dermis > scutes > heart > intestine > blood > muscle. For  $\delta^{15}\text{N}$  values, the corresponding order was dermis > liver > muscle > blood > heart > scutes > intestine.

## Keywords

Vulnerable reptiles, Crocodiles, Stable isotopes, Biomarkers, Traceability, Wildlife.



# Captive management of wildlife in Mexico

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## Abstract

In Mexico there are two types of management: wildlife or free-living, which is carried out with specimens or populations of species that develop in natural conditions, without imposing restrictions on their movements; and intensive or captive management, which is carried out on specimens or populations of wild species in captivity or confinement. To carry out the management and sustainable use of wildlife in Mexico, it is necessary to have a registered Wildlife Conservation Management Unit (UMA) or Property or Facility that Manages Wildlife in Confined Form, Outside its Natural Habitat (PIMVS). UMA are registered properties and facilities that operate in accordance with an approved management plan and their general objective is the conservation of the natural habitat, populations, and specimens of wild species. PIMVS are properties that manage wildlife in a confined manner for the controlled reproduction of species or populations for commercial use. There are 109 intensively managed UMA registered in the country and 73 PIMVS that manage specimens, parts, or derivatives of Morelet's crocodile (*Crocodylus moreletii*), American crocodile (*Crocodylus acutus*) and Common caiman (*Caiman crocodilus*) and are located mainly in Veracruz, Campeche, Tabasco, Yucatán and Quintana Roo. The commercialization of wildlife is a legal activity if the legal origin of the specimens, parts and derivatives is demonstrated with the mark and the authorization for commercial use, whose information includes the "official number, breeding farm data (UMA or PIMVS), owner's data, species, use rate, proportion of the rate, must be replicated in sales invoices, which is verifiable at any moment by the competent authorities.

## Keywords

Captive management, Wildlife, UMA and PIMVS.





# Oil extraction from caiman fat

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## Abstract

Caiman are farmed because their skin and meat, although there are other sub-products, such as fat (at this moment discarded) that could be used as source of natural oils. In recent years, demands of natural oils from the industry have increased, looking for natural options, with good lipid profile, that produce positive effects on human health. Our objective was to obtain oil from *Caiman latirostris* fat deposits, to be used in cosmetology and food industries. Extracted oil was evaluated based on oxidative stability, fatty acid profile, and microbiological analysis. Fat fatty acid profile was correlated to oil profile, with a high content of oleic acid (34%) and linoleic acid (29%), and 2% of  $\alpha$ -linolenic acid (essential of the  $\omega$ -3 family). The oil obtained showed good performance, high oxidative and hydrolytic stability, no microbial load and excellent nutritional quality, aroma and appearance. It has a low cost and high stability over time and could be an excellent source of good fatty acids for the prevention of chronic non-communicable diseases one of the most important causes of death in the world in recent years.

## Keywords

Broad snouted caiman, Fat deposits, Fatty acids.



# Effect of incubation temperature on the learning ability of hatchlings Morelet's crocodile (*Crocodylus moreletii*)

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## Abstract

Learning is the process that modifies and causes lasting changes in the behavior of organisms to adapt and make front to the conditions of the environment that surrounds them. In oviparous species, the incubation temperature during embryogenesis may influence the learning ability of individuals and eventually impact their fitness. This study aimed to evaluate the effect of different incubation temperatures on post-hatch learning ability in hatchlings Morelet's crocodile (*Crocodylus moreletii*). We conducted the study at the crocodile farm "El Colibrí" located in La Antigua, Veracruz, Mexico. We artificially incubated 64 fresh eggs randomly at two mean temperatures: 32.3°C and 32.8°C; after hatching, discrimination learning test were performed every three months. We used a three-arm Y-maze with a central decision point with visual cues for reward association placed in two of the arms (only one arm with reward). Each trial consisted of three tasks with three repetitions, switching the visual cue site with the reward. If necessary, hatchlings were stimulated every 30 seconds with a brush to reach the decision point. We evaluated the successful execution rate, the decision latency, and the number of stimuli performed in each group. We found differences in the decision latency and the number of stimuli between treatments. We discussed the effect of different incubation temperatures on post-hatch learning ability in hatchlings Morelet's crocodile from hatch to six months age.

## Keywords

Cognition, Neonates, Sensory perception.



# Revitalizing conservation and management of the American crocodile (*Crocodylus acutus*) in Dominican Republic

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## Abstract

Crocodilian populations declined globally during most of the 20th century because of overhunting and habitat loss. Some crocodilian populations have recovered over the past 50 years through legal protections and habitat restoration, but the statuses of many crocodilian populations are still unknown because of a lack of recent data. The American crocodile (*Crocodylus acutus*) population in the Dominican Republic (DR) is one of these data-deficient populations, with country-wide surveys not carried out since the 1980s. To fill this knowledge gap we surveyed areas within DR where *C. acutus* is likely to still reside from May to July 2021. Our surveys yielded no crocodile sightings in Monte Cristi, suggesting that crocodiles have been extirpated or near-extirpated from this area. Our surveys of Lago Enriquillo, the largest lake in the Caribbean, produced 120 crocodile sightings over 72.6 km of shoreline, for an encounter rate of 1.2 crocodiles/km. Encounter rates were very high in the main nursery area of the lake (La Azufrada; 60.0 crocodiles/km) and low to moderate elsewhere. The *C. acutus* population was composed of 18 (15%) hatchlings, 45 (37.5%) juveniles, 12 (10%) subadults, and 32 (26.7%) adults, while we were unable to estimate size for 13 (10.8%) individuals. During 2021 nest surveys, we only located 42 nests in Lago Enriquillo. Our data suggest that the DR population of *C. acutus* is critically endangered and is continuing to decline due to the pressures of hunting, fishing, and habitat destruction (both anthropogenic and natural lake level fluctuations). Implementing a long-term conservation management plan is critical to the survival and recovery of this population.

## Keywords

American crocodile, Population survey, Conservation, Management.



# Evaluation of a traslocation of *Crocodylus moreletii* individuals to Área de Protección de Flora y Fauna Yum Balam, Quintana Roo, Mexico

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## Abstract

Currently there are several translocations in Mexico without any control, that is, with a lack of knowledge of the biology and ecology of the species, their movements, spatial distribution and the local population, this without considering that most do not meet procedures to move and release animals in wilderness, thereby harming wild populations and their habitats. The translocation is a tool for the management and conservation of wildlife, however, in order to be effective, the local population must be known prior to the relocation of foreign individuals. A total of 22 individuals of *C. moreletii* rescued from a construction of a theme park in the Riviera Maya tourist corridor in the Mexican Caribbean was transferred to Yalikin River at Área de Protección de Flora y Fauna Yum Balam protected area, with the aim to evaluate the survival and dispersion of the translocated specimens, as well as to know their possible impact on the local crocodile population, where two species are present (*C. moreletii*, *C. acutus* and possible hybrids). Our results revealed that the spatial distribution of all crocodiles is aggregated with possible segregations as they move away from the water body entrance. Estimated total abundance was 49 crocodiles with an encounter rate of 6.50 ind/km. The population structure by size classes consists of yearlings (1.14%), juveniles (9.66%), sub-adults (11.36%), adults (13.64%) and large adults (5.68%). An important fraction of sightings (58.52%) was assigned to the “Eyes Only” category. The sex ratio for both species was 1:1. Population studies prior to a translocation show whether it is appropriate to perform a management in



any specific age category or sex. In addition to the spatial distribution, the dynamics of the local population and the possible impacts of the introduced specimens provides us with information relevant to the best decision-making by natural resource managers regarding sustainable management and conservation.

**Keywords**

Impact assessment in local populations, Management and conservation strategies, Population dynamics, Translocation.



# Deep genomic divergence between *Osteolaemus osborni* and *O. tetraspis* from the locality of their syntopic occurrence

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## Abstract

The Congo Dwarf Crocodile (*Osteolaemus osborni*) was described more than 100 years ago, but until recently it was considered a subspecies of *O. tetraspis*. *Osteolaemus osborni*, occurring in the Congo Basin, represents one of the least known crocodilian species. Field surveys were conducted on the edge of the Congo Basin in the northwestern Republic of the Congo to more accurately identify the distribution limits of *O. osborni* and *O. tetraspis*. A site was discovered where both species occur in syntopy in the same forest swamp. One individual of each species from the syntopic site was examined together with an allopatric individual of *O. osborni* using a genomic approach, yielding more than 400 nuclear DNA loci and 650,000 bp. Phylogenetic divergence was compared with a crocodilian genus ecologically parallel to *Osteolaemus*, caimans of the genus *Paleosuchus*. The genomic divergence between *O. osborni* and *O. tetraspis* was found to be similar to the divergence between *P. palpebrosus* and *P. trigonatus*, dated to the Late Miocene. Intraspecific divergence within *O. osborni* was shallow, indicating that gene flow from *O. tetraspis* (hybridization) probably did not occur in the individual from the syntopic site. The available distribution data suggest that the two *Osteolaemus* species probably live in parapatry, with only limited sympatry. This indicates that the ecological niches and/or behaviors of the two *Osteolaemus* species are likely to be more similar, resulting in higher interspecific competition than in the two largely sympatric *Paleosuchus* species.

## Keywords

Congolian rainforests, *Osteolaemus*, Phylogenomics, Syntopy.



# Feeding of *Crocodylus acutus* hatchlings in captivity as a strategy for the conservation of the species

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## Abstract

The study was conducted in the Cipactli Reptile with code: INE/CITES/DGVS-CR-IN-0610-JAL/00, located in the Centro Universitario de la Costa de la Universidad Guadalajara in Puerto Vallarta, Jalisco, Mexico. Four different diets were supplied for one year, recording the growth and survival of artificially incubated *Crocodylus acutus* hatchlings ( $n = 25$  pups). The biometries of the hatchlings at birth were  $61.90 \pm 0.42$ g in weight and  $28.19 \pm 3.47$ cm in total length (Lt). The hatchlings were kept in an aquarium for 112 days, fed twice a week with 90% marine fish and 10% beef liver (diet I), then biometrics were performed and randomized in three aquariums. Three diets were supplied for 253 days, in two, marine fish was replaced by beef liver in 40% (diet II) and 20% (diet III), and one consisting only of fillet of marine fish (diet IV). Diets containing beef liver had the highest somatic growth; diet I presented 21.28 g/month and 2.26 cm/month; while with diet II, 38.53 g/month and 1.62 cm/month were obtained; and with diet III, 43.54 g/month and 1.91 cm/month grew; Finally, with diet IV (100% fish), the lowest growth was obtained, 18.2 g/month and 0.81 cm/month. However, in the diets with beef liver the survival varied, since with diets I and II 100% was obtained; while with diet III only 50%; and finally with diet IV, 66% was obtained. It is concluded that in order to carry out conservation programs of *C. acutus*, the aspects of integral management of organisms that consist of: care of breeders, eggs incubation, revival of hatchlings and establishment of diets according to the life stage should be taken into account.

## Keywords

*Crocodylus acutus*, Feeding, Conservation.





# Digestibility of soybean meal by farmed *Caiman latirostris* in Argentina

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## Abstract

The objective of this study was to determinate digestibility of diets with protein derived plant sources as a supplement of broad-snouted caiman (*Caiman latirostris*) food. Caimans were laxed with 1.5 mL of lactulose (65 % w/v) per Kg of body weight (BW) once per day and for 48 hours. After that, they were force-feeding with 1% BW of their corresponding treatment (control group: ovalbumin (OVO); and three treatment groups: soybean meal (SOY) mixed with ovalbumin in different percentages A: 20/79.9% SOY/OVO; B: 40/59.9% SOY/OVO; C: 60/39.9% SOY/OVO) once per day during 7 days. Then, every digestives tract was extracted, and feces collected. Digestibility was established through a dietary marker chromic oxide (0,01%) in feed and feces by method of Brisson (1956), and acid digestion of Furukawa and Tsukahara (1966). Digestibility indexes were determined with a standard equation (NRC, 1983). Digestibility of treatment diets were differences among 97-99% (SOY/OVO) between control diet and treatments ( $P = 0.0006$ ), being control diet lower ( $P = 0.0050$ ), while digestibility of soybean meal only was 90-95%. There were differences according to the treatment diet ( $P = 0.018$ ). Digestibility of soybean meal in diet A was lower than B ( $P = 0.0202$ ), and C ( $P = 0.0202$ ). Results indicated that inclusion of soybean meal increased digestibility of the diet in 2.45% and that broad-snouted caiman efficiently digested nutrients of plant products when these ingredients were provided at levels of 20–60% without signs of malnutrition. Based on the results obtained we could think that reports is deliberate to better digestion and absorption of their diet nutrients, and do not only as gastrolith. This information could be used to developing crocodilian diets and will assist future research to determine optimum nutrient levels and ingredient combinations for farm-raised crocodilian fed compounded diets.

## Keywords

Broad-snouted caiman, Nutrition, Plant diets, Digestibility.



# Relationship between skin color, ophthalmological and skin diseases in captive *Caiman latirostris* in Argentina

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## Abstract

The valuation of a species and the environment is essential for sustainable use to serve as a conservation tool being that the commercial use of crocodilians for the production of skin and meat has been considered one of the most successful models, having the skin as its most valuable product. However, diseases can negatively affect this industry, causing great losses. In this context, this study attempts to examine the relationship between color and skin diseases in captive *Caiman latirostris* in Argentina. A total of 151 individuals were measured, weighed, physically examined and classified according to the skin color (dark/light) and the type of disease found (dermatitis and “red eyes”), with 51.66% of the individuals observed had dark color and 49.34% light color. The prevalence of “red eyes” in these individuals was 41% and dermatitis was 23%. The statistical test indicated that there is a direct relationship between skin color and health condition ( $\chi^2 = 19,956$ ,  $Df = 1$ ,  $n = 151$ ,  $\alpha = 0.001$ ), where light-skinned alligators (84.1%) are more affected than those with dark skin (64.3%); however, some dark-skinned individuals seemed more vulnerable, presenting eye diseases and dermatitis at the same time (14.57%). In addition, the weight and length of healthy animals, of both colors, were higher than caimans with eye disease or with both associated diseases. These results may help, in the future, crocodilians farms to isolate susceptible animals, establishing stricter criteria for health status. This may imply a decrease in diseases that affect the quality of the skin and the loss of individuals, with a consequent increase in profits obtained by the industry.

## Keywords

Dermatitis, Red eyes, Broad-snouted caiman, Industry.



# **An investigation into human-crocodile co-existence in the Limpopo-, Luvuvhu-, and Olifants Rivers within Limpopo Province, South Africa**

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## **Abstract**

Human-crocodile conflict (HCC) is a growing problem in Africa which mainly involves the Nile crocodile (*Crocodylus niloticus*). Compared to some other African countries, HCC research is limited in South Africa, while perceptions towards crocodiles remain unstudied. The aim of this study was to investigate the nature and extent of HCC and the perceptions towards crocodiles of people living adjacent to three large river systems in the Limpopo Province. A total of 275 questionnaire surveys were conducted at Limpopo River (50), Luvuvhu River (106), and Olifants River (119). One-hundred-and-twenty HCC incidents were recorded, mostly at Luvuvhu River (52.5%), followed by Olifants River (30%) and Limpopo River (17.5%). These incidents included attacks on humans (52.5%), attacks on domestic animals (34.17%) and damaged fishing equipment (13.33%). Potentially dangerous activities identified were fishing, fetching water, washing laundry, swimming, and crossing rivers. People most vulnerable to crocodile attacks were African men and women, children, people with a low level of education as well as the unemployed. Respondents who liked crocodiles (41.61%) mostly accepted them as part of the environment (46.49%) or God's creation (20.18%), while respondents disliking crocodiles (55.47%) gave depredation on humans (57.89%) and domestic animals (15.47%) as motivations. Their dislike was mainly influenced by HCC experiences of friends and/or family as well as the proximity of crocodiles to human habitations. Education campaigns should be the main HCC focus with children and other highly susceptible groups of HCC as the primary target audiences. Future HCC



research in South Africa should not be limited to attacks on humans, but also include other types of HCC such as persecution and poaching.

**Keywords**

Crocodile attacks, Domestic animal losses, Nile crocodile, DCAs.



# Investigating relationships between contaminant bioaccumulation and movement behavior in the American alligator (*Alligator mississippiensis*)

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## Abstract

Animal movement behavior provides insight into their ecological roles and organismal function. Anthropogenic disturbances, such as urbanization and habitat fragmentation are key drivers of variation in animal movement. The long lifespans and predatory diets of crocodilians often lead to the bioaccumulation of persistent contaminants and confers a marked vulnerability to the attendant physiological effects resulting from elevated body burdens. In this study, we investigate the relationships between blood concentrations of mercury (Hg), a widespread contaminant with well characterized neurotoxicity, and movement patterns in free living, naturally exposed American alligators. We sampled alligators from two former nuclear cooling reservoirs that vary with respect to historical Hg contamination and placed GPS and accelerometer transmitters on male alligators from each reservoir (13 total). Data from July 2020 – March 2022 was analyzed using a generalized linear mixed model framework combined with AIC model selection to resolve the relationships linking alligator activity to meteorological conditions, reservoir, individual traits, blood Hg levels (mg/kg; wet weight), and season. The most parsimonious model included snout-vent-length, average daily temperature, humidity, wind speed, season, and blood Hg levels (AICc weight = 0.68, conditional R<sup>2</sup> = 0.90). Additionally, we found that when comparing activity between reservoirs, alligators from Par Pond ( $x = 1.72$  mg/kg, ww) had significantly higher Hg levels than those on L Lake ( $x = 0.63$  mg/kg, ww;  $p < 0.001$ ), and the alligators on Par Pond were less active despite our tagged animals having the same size range, and same daily meteorological conditions, as those on L Lake. The findings presented here provide insight into the contributions of climatic factors and how the exposure of contaminants interact with individual traits to influence behavior.

## Keywords

Movement behavior, GPS, Mercury, Ecotoxicology.



# Population status of the West African crocodile in the complex W-Pendjari Biosphere Reserves of Benin in West Africa

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## Abstract

The current taxonomic resurrection of the West African crocodile (*Crocodylus suchus*) calls for new assessment of their population in their potential habitat. We aimed to map the current distribution of *C. suchus* in the complex W - Pendjari Biosphere Reserve and to assess their abundance. Data were collected from November 2018 to November 2019. The distribution area of *C. suchus* was mapped with ArcGis 10.5 software using geographical coordinates of presence/absence points. And, we determined population size and structure during day and night counts on foot. *C. suchus* occurred in 54.2 % of water points of the complex (N = 83). A total of 389 crocodiles were recorded across the complex (77.6 % in the Pendjari Reserve and 22.4 % in the W), giving a relative abundance of  $10.3 \pm 1.13$  crocodiles/km in the Pendjari Reserve and  $11.4 \pm 3.82$  crocodiles/km in the W reserve. We used a Getis-Ord Gi\* Hot Spot Analysis to show that the two main hot spots of occurrence were located in the most secure parts of the Pendjari Reserve (Getis-Ord Gi\* Z score = 8.08; Confidence = 99 %) and W National Park (Getis-Ord Gi\* Z score = 2.41; Confidence = 95 %). Based on comparison with previous efforts, the crocodile population in the Pendjari reserve is likely to be growing, while the crocodile population in the W reserve is threatened by siltation, illegal fishing and hunting, pollution by pesticides carried from outside the reserve, and illegal access of cattle which call for better management.

## Keywords

*Crocodylus suchus*, Distribution, Illegal fishing and hunting, Conservation.



# Are the head of hatchling females and males similar? a Geometric morphometry approach

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## Abstract

Studies of crocodilians cephalic region are relevant in fields of ecology, systematics, evolution, and conservation. In addition, these studies have the potential to be applied to sexing of individuals, which would allow sexual discrimination of hatching to be as effective as they are for adult crocodiles and could replace current sexing techniques (surgical examination of gonads and histological cuts). In this study we analyzed the cephalic region of *Caiman latirostris* neonates using geometric morphometry tools, with the aim of determining if there are morphological differences associated with hatchling sex. We collected 11 clutch and incubated at a constant 32°C (males and females producing temperature), which would allow us to evaluate if there is sexual dimorphism in the cephalic region in dorsal view of hatchlings. We used canonical variate analysis and a principal component analysis for data analysis. When analyzing the data from all the clutches together, we found no differences between males and females. However, when we analyzed clutches including the sites as grouping variable, we registered sexual dimorphism in hatchlings, and also, we observed differences on hatchling morphology from different sites. Our results suggest that geometric morphometry technique allows, through analysis of dorsal images of cephalic region, a reliable sexing of the hatchlings, without having to sacrifice the animals for the internal gonads inspection or waiting for the growth of the individuals.

## Keywords

Broad snouted caiman, Cranial morphology, Sexual dimorphism.





# Parasite induced metabolic bone disease in a yearling Morelet's crocodile (*Crocodylus moreletii*)

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## Abstract

Crocodylians have a rich diversity of host-specific parasites relative to other archosaurian descendants. While most of these relationships exhibit commensalism or mutualism, the pentastomids appear to be the only true parasite of crocodylians. Parasites like pentastomids can cause a variety of health complications in host organisms, such as vitamin and mineral deficiency in the host given the parasite absorbs these nutrients for itself. Herein, we describe the death of a wild-caught yearling Morelet's crocodile (*Crocodylus moreletii*) caused by pentastomid parasites. This crocodile illustrated symptoms of metabolic bone disease (MBD), i.e., severe scoliosis, malformed digits, and stunted growth, and it was presumed death was caused by MBD. Postmortem examination revealed 7 large pentastomids (*Sebekia* sp.) in the lungs and trachea of the yearling crocodile, and 5 small nematodes (*Dujardinascaris helicina*) in the stomach. The abundance of parasites found was atypical for a yearling crocodile, likely increasing its susceptibility to complications such as MBD relative to an adult. Examining size, life cycle stage, and quantity of parasites compared to host, we hypothesized that the crocodile's MBD could have been caused by the pentastomids absorbing nutrients that are essential for growth in a young crocodile. MBD is typically associated with poor diet in animals under human care, however our findings suggest a novel uncommon route or cause with implications on veterinary medicine for both captive and wild crocodylians. Additionally, these findings further illustrate the negative parasitic relationship pentastomids share with crocodylians and could provide insight into the symbiotic relationship between crocodylians and endoparasites.

## Keywords

Parasite, *Crocodylus moreletii*, Belize, Metabolic bone disease.



# **New population record of Philippine crocodile (*Crocodylus mindorensis*, Schmidt, 1935) in Southern Philippines**

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## **Abstract**

The extant wild populations of the Critically Endangered Philippine Crocodile (*Crocodylus mindorensis*) remained barely understood. Its elusive nature, added with security concerns in some areas, stalled the exploration of *C. mindorensis* populations in the southern Philippines. In December 2019, a new population has been confirmed and recorded in three major river systems in the Municipality of Malabang, Lanao del Sur. Molecular phylogenetic analysis was performed to show the relationship of the sampled individuals. Maximum Likelihood tree showed identical COI sequences. The discovery of this healthy viable population signifies that Mindanao remains the stronghold population of this species. We perceive that its existence will continue into the next decades through the ecologically harmonious cultural practices of the indigenous Muslim communities protecting the shared habitat.

## **Keywords**

Mindanao, Exploration, Discovery.



# Some biological aspects of the *Caiman crocodilus chiapasius* in La Encrucijada Biosphere Reserve, Mexico

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## Abstract

The information about the Spectacled caiman (*Caiman crocodilus chiapasius*) within the Mexican territory is still scarce. Thus, in the present study we have decided to evaluate three important ecological and biological aspects of this species in La Encrucijada Biosphere Reserve, in the Mexican state of Chiapas: 1- its relative abundance through the night visual detection method in 28 km of El Hueyate estuary, from 2015 to 2022, 2- its diet, through the stomach wash of sexually mature specimens (snout-vent length > 89cm), using a modified method of Taylor et al. (1978), analysing through habitat use (II-Jacop index, D = values from -1 to 1) with existing information on other sizes, and 3- its nuchal scutellation patterns, through the analysis of photographic records of captured specimens during the 2014-2022 period. Relative abundances ranged from 1.53 to 2.17 ind/km, with the highest abundance in 2022. Regarding the stomach contents, we found nine categories in processed caimans (parasites, leaves, roots and stems, reptiles, fishes, spiders and insects, crustaceans, stones/sand and plastic residues), hatchlings and juveniles did not habitat selection ( $D < 0.2$ ), sub-adults presented moderate selection to crustaceans and fish ( $D = 0.3 - 0.4$ ), and adults presented strong selection to fish ( $D = 0.6$ ). Then, we determined 15 nuchal scutellation patterns from 72 individuals. Three patterns coincide with previous reports in scientific literature and the other 12 patterns were atypical. Pattern 2-4-2-2-0 was the most frequent.

## Keywords

Abundance, Diet, Scutellation pattern, Spectacled caiman.



# Identification of crocodilian species through barcodes

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## Abstract

Systematics studies have become an important aspect for management and conservation of species from the order Crocodylia. All of them are listed in CITES appendixes, and in order to control illegal traffic of animals and sub products, we must be able to correctly assess the specific identity of the samples. Genetic barcoding is a very efficient tool for species identification in the animal kingdom. This technique is based on the sequencing of a region of a mitochondrial gene, the Cytochrome oxidase I subunit b (COI). Our principal aims were to design a single primers pair that allows obtaining this sequence from the genetic material of any crocodile species and, test the potential utility of barcoding in forensic studies as well as verify the correct identification of museum's collections. We obtained successfully barcodes, using our designed primers, from blood and tissue samples of 10 specimens of each native species (n= 20) and from 12 museum preserved caiman specimens. The studied fragment's length was 610 bp, and each species had one single haplotype. We also compared sequences from public databases of all the species included in the order Crocodylia (N=346). We performed a phylogenetic analysis and we obtained a tree which resulted similar to the current crocodilian phylogeny. Barcodes are very useful tools to identify specific crocodilian haplotypes and, in our study, they have allowed identify certain taxonomic classification problems in sympatry regions among species, and potential hybridization zones, where further studies are necessary. The primers recently designed by our working group can be applied to obtain barcodes from the other crocodilian species samples, and this information can contribute significantly to systematic studies.

## Keywords

Caiman, barcoding, systematics.



# Communitarian monitoring of nesting and egg ranching for the rehabilitation of American crocodile (*Crocodylus acutus*) wild population in La Manzanilla estuary, Jalisco, Mexico

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## Abstract

Since 2015, the community in charge of the Environment Conservation and Management Unit “UMA Ejido La Manzanilla” (SEMARNAT-UMA-EX-226-JAL) has implemented annual campaigns for the Location and Monitoring of Nests of the American crocodile (*Crocodylus acutus*) in the La Manzanilla estuary, on the pacific coast of the state of Jalisco, Mexico. Until 2019, 27 nests were registered in two distinct geographic areas: 7 in the sand bar that separate the wetland from the ocean and 20 in the hills skirting the mangrove, inland. The nests are clearly different in each area: greater depth in the sand bar, less depth, greater height and distance to the water in the hills. In both cases, the threats are different: predation by *Nasua narica* on the hills and urban tourism impact on the sand bar. One of the UMA's objectives being the rehabilitation of the *Crocodylus acutus* population in the estuary, a strategy of ranching has been implemented in order to protect and rescue as many eggs as possible. They are incubated in a bed of sand, under surveillance, within the unit facilities. This “nesting bed” replicates the conditions and natural characteristics of the sand bar's nesting sites; in such a way that in 2019 two females made their nests there. The neonates resulting of this ranching are marked and raised in the unit facilities' ponds until their release in the estuary, generally at six months old.

## Keywords

Egg ranching, Nesting.



# Twenty-five years of communitarian conservation of the American crocodile (*Crocodylus acutus*) in La Manzanilla estuary, Jalisco, Mexico

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## Abstract

Since 1995, the Ejido La Manzanilla's community, on the pacific coast of Jalisco, Mexico, has actively participated in the conservation of *Crocodylus acutus* and the La Manzanilla mangrove and estuary. The timeline of this American crocodile communitarian conservation experience is presented. The main dates that shaped this history and explain community organization strength are highlighted. Natural disasters, such the tsunami of 1995 and two droughts drove the community to protect the mangrove and start ecotourism. In 2008 starts the formalization of the Environment Conservation and Management Unit "UMA Ejido La Manzanilla" (SEMARNAT-UMA-EX-226-JAL), for the protection and rehabilitation of the *Crocodylus acutus* population and its habitat, in 190 ha of mangrove. The UMA strengthens the communitarian conservation project since it considers both crocodiles protection and their ecotourism exploitation, through sightings and interpretive tours, on foot and by boat. The ecotourism income supports most of the UMA's ecoturistic operation nowadays, which generates up to 20 sources of employment during the tourist season. In 2017, the crocodile's communitarian museum opens, where are exhibited some whole *Crocodylus acutus* skeletons of over 4 meters, rescued in the UMA. In 2019, the environment ministry (SEMARNAT) recognizes this scientific and educational effort with the registration of the "UMA Ejido La Manzanilla's Museographic Collection" (DGVC-CC-318-19). In 2020 begins the museum's extension, with support from the Dedicated Grant Mechanism for Indigenous Peoples and local communities (DGM), funded by the World Bank's Forest Investment Program (FIP) and operated by the Rainforest Alliance NGO.

## Keywords

Communitarian conservation, Ecotourism.



# Influence of enrichment diet on Immune System of *Caiman latirostris*

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## Abstract

Diet enrichment with omega-3 and antioxidant sources have become frequent in farming of animals. These diets beyond improving meat quality, could benefit animals' health during captivity. Reptile immunology involves cell-mediated and humoral components and their study can be a good indicator of health condition of this animals. Our objective was to evaluate the effects of diet enrichment with flaxseeds and thymol fed during 30 days, on total (TWBC) and differential (DWBC) white blood cell count as well as Heterophils/Lymphocytes (H/L) index and Natural Antibodies (NABs Titres) in *Caiman latirostris* blood. Animals were raised in plastic trays and fed 3 times a week with experimental diets: Control Diet (C), C+Flaxseed (F), and C+T+F (TF). Although the higher values for TWBCC were found in treated animals (F and TF), we did not find statistical differences respect to C. However, when we evaluated the DWBCC, were found a decline of monocytes/mm<sup>3</sup> ( $p=0.043$ ), of eosinophils/mm<sup>3</sup> ( $p=0.002$ ) and of lymphocytes/mm<sup>3</sup> ( $p=0.05$ ) in TF respect to C animals, with an increase of heterophils/mm<sup>3</sup> in these treatments. Furthermore, F treatment showed low values for those leucocytes populations respect to C, being different for monocytes/mm<sup>3</sup> ( $p=0.043$ ). Moreover, H/L index, as well as the others leucocytes types analyzed values, showed no differences among treatments. NABs showed higher titres in animals feed with diet enrichment related to C, being statically significant for F treatment ( $p=0.035$ ). The decreases in some types of white blood cells such as eosinophils and monocytes in peripheral blood of F and TF caimans, which





especially have allergic functions, show lack of reactivity towards enriched diet components. In addition, both the decrease in lymphocyte populations with increases in heterophils, as well as the increase in antibody titers in the animals fed with enriched diet, could suggest an improvement in the immune system of these animals.

**Keywords**

Antioxidants, Fatty acids, Immunology.



# Influence of the combination of stress factors on immune functions in *Caiman latirostris* (Preliminary Results)

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## Abstract

Exposure to factors like pathogens, toxic substances, food restriction, climatic events factors such as extreme temperatures, drought, etc. are some of the stressful situations that *Caiman latirostris* populations could face. In this context, the ability to mount an effective immune response, as well as its regulation after exposure to any of these stressful situations, are very important in the life history of these organisms. Previous studies have indicated that artificial constant high temperatures appeared to be beneficial, individuals exposed to heat treatment ( $37 \pm 1^\circ\text{C}$ ) grew more, showed better body condition, and higher levels of natural antibodies. However, stress factors in the wild are not found alone. In the present study, we evaluated the effect of 8-weeks exposure to treatments of combinations of potentials environmental factors (food restriction + high temperature: FT, glyphosate + high temperature: GT, and control) and then they were challenged with bacterial (B) or saline solution (SF). Growth (weight, TL and SVL), immunological investment (white blood cells counts, natural antibody levels, complement system activity) and corticosterone levels of juveniles *C. latirostris* (10-month-old) were measured. FT treatment showed the lower growth and corticosterone levels related to caimans of GT+B and control groups, whereas those caimans exposed to GT+B had higher lymphocyte and eosinophil counts than control. Additionally, animals exposed to GT+B had higher activity of the complement system than control. In this study, we also identified and calculated certain broad-



snouted caiman immune-related genes expression (TNF- and IL-6) and they have depicted different patterns during B infection in both treatments. Our results suggest that *C. latirostris* juveniles are able to tolerate combined environmental factors without compromise immune system activity.

**Keywords**

Broad-snouted caiman, Ecoimmunology, Molecular biomarker.



# Population genetic structure in *Paleosuchus palpebrosus*: a novel Management Unit from the Brazilian Cerrado biome

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## Abstract

To investigate the spatial distribution of the genetic diversity of widely distributed species is important to prevent that genetically structured groups are neglected from the conservation point of view. In a previous study, we identified four conservation units of *Paleosuchus palpebrosus*, three Evolutionarily Significant Units (ESUs): “Amazon” (A), “Madeira-Bolivia” (MB) and “Pantanal” (P), and two Management Units (MU) within MB: “Madeira” (M) and “Bolivia” (B). In this study, we expanded sampling geographically and sequenced the mitochondrial cytochrome b gene from 151 additional individuals, totaling 357 sequences, aiming the investigation of additional genetically structured lineages of the *P. palpebrosus* species complex and their genealogical relationships to the other previously-identified lineages. Cluster analysis in BAPS allowed us to detect a genetically structured population apart from those previously found, whose geographical distribution comprises mainly the Brazilian Cerrado biome, so we will name it “Cerrado” (C). Haplotype network revealed that C is most closely related to P lineage and phylogenetic reconstruction showed that this group is not monophyletic. When we plotted the BAPS result on the map, all individuals from the Paraná River basin and upper Tapajós River basin pertained to cluster P, along with the population from upper Paraguai. When we plotted the BAPS result on the map, all individuals from the Paraná River basin and upper Tapajós River basin pertained to cluster P, along with the population from upper Paraguai. We observed sympatry in only four localities of the 45 localities where individuals of either the C or P clusters occur, suggesting either retention of ancestral polymorphism or gene flow between populations. The genetic divergence of the C and P clusters, with the exception of few localities a non-overlapping



distribution and non-monophyly in mtDNA indicate that this population should be treated as an MU and together with the “Pantanal” MU it makes up one ESU. The uniqueness of “Cerrado” MU must be taken into account in future studies, to guide conservation and management decisions and risk assessment of the *P. palpebrosus* species complex.

**Keywords**

Dwarf caiman, Management Unit, Population structure, mtDNA.



# Quintana Roo's Crocodile Specialist Group

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## Abstract

Mexico has a great diversity of ecosystems and Quintana Roo is habitat of two species of crocodiles: *Crocodylus moreletii* and *C. acutus*. Due to the characteristics of the Mexican Caribbean, crocodile populations behave differently than in the rest of the country, so a group of experts was created at the state level with the aim of giving attention to issues such as in situ conservation, monitoring the status of populations, human-crocodile conflict, training, and environmental education. This specialized group named GETQROO is made up of government institutions such as the Comisión Nacional de Áreas Naturales Protegidas (CONANP), the Instituto de Biodiversidad y Áreas Naturales Protegidas de Quintana Roo (IBANQROO), the Secretaría de Ecología y Medio Ambiente (SEMA), Fondo Nacional de Fomento al Turismo (FONATUR infrastructure), Procuraduría Federal de Protección al Ambiente (PROFEPA), Benito Juárez City Council; non-governmental organizations such as Onca Maya, Tsukan, Reserva Ecológica El Edén, Amigos de Sian Ka'an, Centro del Cambio Global y la Sustentabilidad, and research institutions such as the Universidad Nacional Autónoma de México and El Colegio de la Frontera Sur. One of the group's short-term actions is the implementation of the S.O.S. attention strategy that will allow timely attention to the different aspects in the conservation of this saurian.

## Keywords

*Crocodylus moreletii*, *C. acutus*, Human activities, Human-crocodile conflict, Population recovery.



# Allodaposuchidae, a recently described clade of basal eusuchians from the Late Cretaceous of Europe

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## Abstract

Allodaposuchidae is a clade of basal eusuchians comprised of Campanian-Maastrichtian (Late Cretaceous) European crocodyliforms. The type species, *Allodaposuchus precedens*, was initially described based on fragmentary remains from Romania by Nopcsa in 1928, but it was not until the first years of the 21st century that studies of this material were resumed. Several authors discussed the taxonomical position of the species and finally an emended diagnosis was proposed based on information from other referred specimens from the Late Cretaceous of Romania, Iberian Peninsula and southern France. The first phylogenetic hypotheses including *Al. precedens* placed this species as a basal member of Eusuchia. Knowledge on taxa phylogenetically close to *Al. precedens* has increased significantly in recent years through the description of new forms from the Late Cretaceous of western Europe. Several new genus and species have been defined, allowing the definition of the new clade. Thus, many characters previously considered as autapomorphic for *Allodaposuchus* or *Al. precedens* are now recognized as having a broader distribution within Allodaposuchidae. Some recent hypotheses considered these forms now included in the new clade as closely related to Hylaeochampsidae, constituting basal forms within Eusuchia. However, other analyses has reinterpreted Allodaposuchidae as the sister group of Crocodylia. On the other hand, the abundant material included in Allodaposuchidae, as well as its optimal preservation, have allowed both cranial and postcranial morphological studies, ontogenetic analyses and paleoneuroanatomical reconstructions, opening new ways for understanding the origin of modern crocodyliforms.

## Keywords

Europe, Cretaceous, Eusuchia, Systematics.





# Tracking ontogenetic shifts in cranial proportions of *Crocodylus moreletii*

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## Abstract

The Morelet's crocodile (*Crocodylus moreletii*) is a medium sized crocodylian found throughout areas near Mexico's coast with the Gulf of Mexico and the Caribbean Sea, as well as into the Yucatan Peninsula and into Belize and Guatemala. Like all species of crocodylian, offspring hatch out measuring just a small fraction of what their maximum potential size can be. This, however, does not mean that they are perfect miniatures of their fully-grown counterparts. Though at first glance most bodily proportions seem similar, it is obvious upon closer inspection that they may be very different from those of an adult. When comparing a newly-hatched individual with an adult specimen, it is clear that the cranium, in particular, has undergone radical changes. Even comparing a neonate to a yearling shows significant ontogenetic shifts in cranial proportions. It is known that growth rates are highest during the first year of life for crocodylians and this is reflected through changes in proportions to the cranium (as well as other parts of the body) and later affects changes to other aspects of their biology as new prey items may be taken with increasing head size, dominance over other individuals may be more easily asserted, etc. Our study consisted of 13 captive-bred *C. moreletii* over the course of one year beginning at two weeks of age until 12 months. Each month, standard body length and weight measurements were taken for each individual, along with six basic measurements of the cranium: cranial length, snout length, cranial width, snout width, width at nares, and cranial height. These measurements served as the basis for our analysis of cranial proportions over the course of the first year which we hope may begin to identify periods where growth is accelerated, reduced, or maintained, as well as track growth on a bi-axial plane.

## Keywords

Cranium, Ontogeny, Neonates, *Crocodylus moreletii*.



# Chromosomal microdissection for the synthesis of a specific probe in *Caiman latirostris* for future evaluation of target DNA sequences

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## Abstract

The biological impact of pesticides is the result of a cascade of events that can be evident at different levels of biological organization, exerting a marked long-term effect on natural populations. For several years, our research group has been studying the possible effects of massive pesticides in *Caiman latirostris*, using biomarkers of different endpoints. The identification of sensitive early warning markers to be applied in natural biota is indispensable to prevent damage that may affect animal physiology in the long term, leading to possible imbalances in population dynamics. To deepen the characterization of the biological effects of pesticides, we proposed to develop a specific pericentromeric probe to use it later in the micronucleus- and Comet-FISH (fluorescence *in situ* hybridization) techniques, as new markers of specific genotoxic damage. Microdissection was performed in caiman metaphases using a micromanipulator coupled to an inverted microscope. Two probes have been developed: 1) includes 6 microdissections of the central-pericentromeric region from different chromosomes and 2) includes 12 microdissections of the central-pericentromeric region from chromosome pair 1. Then, were



transferred them to different microtubes, and the DNA was amplified using the kit GenomePlex® Single Cell Whole Genome Amplification (WGA4 – Sigma). Following the reactions, the products were verified by agarose gel electrophoresis, and probes were labeled with digoxigenin-11-dUTP using the GenomePlex® WGA Reamplification Kit (WGA3 – Sigma). Positive results were observed for both probes, but they were not consistent in all chromosomes and metaphases. It is necessary to continue improving the probe quality to have more specific results in this type of technique. The micronucleus- and Comet assay-FISH techniques have not been applied in any crocodilian species worldwide and will be integrated to the battery of markers actually used in this species for genotoxic evaluation.

**Keywords**

Fluorescence in situ hybridization, Pericentromeric probe, Molecular marker, Broad-snouted caiman.



# Retrospective analysis of the advance of the agricultural frontier and its effects on the reproduction of *Caiman latirostris*

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## Abstract

In 1990, a monitoring and conservation program of broad-snout caiman (*Caiman latirostris*) was implemented in Argentina known as Proyecto Yacaré (PY) based on the ranching technique that consists of harvesting eggs in nature, their artificial incubation and breeding under controlled conditions. The successful work joint to the local inhabitants has generated that the populations of this are abundant and have recovered their historical geographical distributions. In the work areas of the PY, it is no stranger to the agricultural frontier expansion accompanied by the increase in the use of pesticides, which has generated that the distribution of this species is immersed in these environments. The degradation of the habitat added to the exposure to these substances could reflect certain reproductive alterations in *C. latirostris*. Due to the extensive information collected throughout all these years, the objective in the present work is to assess certain reproductive parameters of *C. latirostris* according to the harvested nests conforming to the proximity to agricultural areas. The distance from the nest to the harvested environments has been considered as a criteria for classification in disturbed or undisturbed. Where the variables number of infertile, percentage of non-viable and days of incubation through the different seasons were considered. In both types of environments (disturbed and undisturbed) there is an increase in the average percentage of non-viable for the last years of collection. In turn, there is little difference when comparing both types of environment. In the other hand the average number of infertiles, there is also an increase in this parameter for the last years of collection in both types of environments, however when comparing



them to each other, there are no notable differences. Finally, there is a significant delay in incubation time in disturbed environments, it takes longer to hatch than those eggs collected in undisturbed environments.

**Keywords**

Agrochemicals, Agroecosystem, Broad-snout caiman, Sustainable use.



# Population abundance of *Crocodylus acutus* and zoning of risk areas in Osumacinta, Chiapas, Mexico

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## Abstract

This study was funded by the CSG SRAS grant, and his goal was to identify and establish zones with any kind of human-crocodile encounter risk in the nearby areas of the Osumacinta municipality in Chiapas, Mexico, based on the estimation of the population abundance, the encounter rate (TE) and the geographic location of American crocodiles (*Crocodylus acutus*) in the east bank of the Manuel Moreno Torres Hydroelectric Dam especially in those areas which are carried out anthropogenic activities such as fishing and production of fish in a floating cage (PFFC). From April to August in 2018 were carried out three-night crocodile counts on April-June-August (one for each month). We registered an average abundance of 45.6 American crocodiles (16, 64 and 57 respectively), additionally the crocodiles were categorized in six different groups or classes according to their estimated size or total length (LT). The class I that includes hatchlings was the most representative (31 individuals), followed by II, III (juveniles-sub adults)) and V (adults) with 2.66 individuals each, while classes IV and VI recorded the lowest averages (1.66 ind. each). The average total TE obtained was 1.3 ind./ km, the highest value of average TE per class was 0.8 corresponding to class I, in the case of class V, III and II the values were 0.07 ind./km, while VI and IV obtained the lowest values 0.04 ind./km. These results were used for the elaboration of buffer areas, which allowed us to establish nine subzones with different levels of human-crocodile encounter risk. We conclude that the study area has in its entirety a medium-low human-crocodile encounter risk level. Nevertheless, it is necessary to continue with the follow-up of the present study, to detect any fluctuations in the population abundance and structure of crocodiles in the area, that can provide us more information and, in this way, establish better conservation strategies towards crocodilians and their habitat, as well as better prevention and action measures for human-crocodile encounters.

## Keywords

American crocodile, Population abundance, Encounter rate, Risk areas.



# Identification, molecular analysis and bioinformatics characterization of *Caiman latirostris* copper, zinc Superoxide dismutase (Cu, Zn-SOD) gene

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## Abstract

Superoxide dismutase (SOD, EC 1.15.1.1) is a vital antioxidant enzyme, it is the first enzyme to regulate oxidative stress by the dismutation of superoxide radicals to oxygen and hydrogen peroxide. SODs are classified in to four groups according to their metallic cofactor: copper, zinc SOD (Cu, Zn-SOD), manganese SOD, iron SOD, and nickel SOD. Cu, Zn-SOD is found in intracellular and extracellular compartments of eukaryotes and represents more than 90% of the total SODs in tissues. Although crocodiles are known to produce high levels of reactive oxygen species, no information has been found on the molecular and biochemical characteristics of the Cu, Zn-SOD gene for *Caiman latirostris*, one of the two crocodilian species living in Argentina. In this work, we reported the presence of the enzyme in *C. latirostris*, the nucleotide and amino acid sequences, the modelled protein structure, and tissue specific expression patterns. Cu, Zn-SOD identified gene sequence was 620 bp open reading frame in length and encoded 178 amino acids. The nucleotide sequences of *C. latirostris* shared high similarity with the Cu, Zn-SOD genes of other vertebrates and, among crocodilian species, it showed to be highly conserved. PCR analysis showed that Cu, Zn-SOD mRNA was expressed in all the tissues examined (liver, gonads, spleen, heart, and whole blood), which suggests a constitutively expressed gene in these tissues. The liver was the tissue with the highest level of expression,





followed by blood, while the heart was the lowest, being this significantly different respect to the others. This study allows further investigation into the structure-activity relationship and the mechanism of action of Cu, Zn-SOD, in addition to exploring the functional breadth and possible alteration factors, including xenobiotics.

**Keywords**

Reactive oxygen species, Antioxidant enzyme, mRNA expression, Xenobiotics.



# Ontogenetic shifts in dietary composition of the American alligator in Southern Louisiana

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## Abstract

American alligators (*Alligator mississippiensis*) play a significant role as apex predators in the aquatic ecosystems of the American Southeast. They have been shown to affect community composition, impact the populations of other species, and induce trophic cascades. The diet of the American alligator varies across its range, and intraspecific niche specialization is known to occur within populations due to prey availability and habitat heterogeneity. Many studies have examined the diet of this species throughout its range using gastric lavage techniques, but here we use the more reliable method of obtaining data on dietary composition from necropsied individuals to resolve variability across all age groups. We evaluate the extent of resource partitioning and dietary overlap in a local population of *A. mississippiensis* based on age group and sex in southern Louisiana, and whether these animals undergo an ontogenetic shift from invertebrate prey to vertebrate prey. We collected stomach contents from 97 animals at Rockefeller Wildlife Refuge during the summers of 2017 and 2018, and classified ingested food items based on taxonomic groups (insect, arachnid, crustacean, fish, reptile, bird, and mammal). We used a non-metric multidimensional scaling (NMDS) ordination plot to define the significance in dietary variation and overlap between different age groups and sex. Overall, we found that juveniles specialized on ingesting insects and crustaceans, and we found no partitioning between sexes. Our results underline the importance of closely examining local dietary differences between age groups of an apex predator to better understand its impacts on the greater ecosystem.

## Keywords

Diet, Alligator, Niche, NMDS.



# Pathogenic *Leptospira* infecting wild and captive crocodiles from the Yucatan Peninsula

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## Abstract

*Leptospira* is a worldwide zoonosis that affects a large number of mammals, amphibians, and reptiles such as crocodilians. In this work, samples were collected from American crocodiles (*Crocodylus acutus*; n = 4) captured in Banco Chinchorro Biosphere Reserve, and from captive Morelet's crocodiles (*Crocodylus moreletii*; n = 14) on a farm in southern Quintana Roo, Mexico. Blood samples were obtained by venipuncture of the post-occipital sinus and serum was separated for subsequent analyses. Each sample was seeded in EMJH medium and observed in darkfield at 250X, and subsequently, DNA extraction was performed. For detection of the genus *Leptospira*, endpoint PCRs based on the 23S subunit and on the LipL32 lipoprotein were applied. For the detection of pathogenic species, PCR based on IS1500 insertion sequence was applied. Additionally, PCR based on the 16S subunit was used to identify if saprophytic *Leptospira* species were carried by the crocodiles. Cultures for isolation were subcultured in EMJH medium and followed up weekly for *Leptospira* isolation. Five crocodiles (5/18= 27.77%) were identified as positive by darkfield observation, and four of them were confirmed to carry DNA from the genus *Leptospira* by PCR, and that they belonged to pathogenic species. No Saprophytic species were identified to be carried by the crocodiles by the 16S PCR. In conclusion, since The DNA of pathogenic species was identified in the peripheral blood of the



crocodiles sampled, it is recommended to avoid contact with peridomestic animals that may function as carriers of *Leptospira* capable of infecting the water bodies and soil where the crocodiles remain.

**Keywords**

*Crocodylus acutus*, *Crocodylus moreletii*, Leptospirosis, Yucatan Peninsula.



# **“Intracascara space” an eggshell structure of *Caiman latirostris* eggs**

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## **Abstract**

In the last decades, eggshells of egg from big reptiles have been studied by many researchers, not just to describe the eggshell (and be able to compare they to old lineages that have once inhabit our planet), but also to understand how the egg provides to the embryo a specific condition during incubation. Previous studies have described and characterized normal and pathologic *Caiman latirostris* eggshells, we also have evaluated how the eggshell changes during incubation. In a study relating temperature variation and eggshell structures of successful eggs, we observed empty structures not previously described that we called “intracascara space”. Those structures were found nearby the superior part of the pore channel (or vertex), and the external surface of the continuous calcium layer, sometimes in contact (though its superior part) with the crater and pore. Intracascara space were found in eggs from five clutches (of two regions -pole and equator- of two eggs from each nest), in both equator and poles region, and were simple or double (one space over the other). We hypothesized that these space could be weak points, to facilitate pore opening. These spaces are formed from calcium deposition of female in the egg.

## **Keywords**

Broad snouted caiman, Crocodilians eggs, Eggshells.



# Timing of nest predation events during incubation of the Broad-snouted Caiman (*Caiman latirostris*)

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## Abstract

In the wild, nest predation is the primary cause of nest failure in Broad-snouted Caiman (*Caiman latirostris*). We analyzed the temporal occurrence -daily and monthly activity patterns- of nest predators during egg incubation of *C. latirostris*. From December to March 2018-2019 and 2019-2020 we recorded activity patterns of nest predators and nesting caiman females using camera-traps in 33 nests. Our sampling effort resulted in 4,531 camera-trap-nights and 3,164 independent records, 1,403 of these were from *C. latirostris* and 589 of animals representing risks to the nests. Most of these records corresponded to four species: 49% to the Black-and-white Tegu (active between 6:46 and 19:20 h); 14.4% to the Capybara (not preying eggs, but destroying nests when settling, active between 09:58 - 19:21 h); 12.3% to the Crab-eating Fox (active between 06:00 - 11:14 h) and 7.2% to the Southern Long-nosed Armadillo (active between 09:58 - 19:21 h). The Black-and-white Tegu was the most frequent predator, explaining by the lower activity overlap with Broad-snouted Caiman. Rarely, females defended nests and this occurred when Capybara and Black-and-white Tegu approached. Considering monthly activity, Tegu and Capybara predated and destroyed nests mainly in January, while Armadillo frequented nests mainly in February. Since caiman females attend nests mostly at the beginning and end stages of the nesting season, visitors commonly appear when nest attendance is reduced. Finally, Foxes predated nests in February and early March, when embryos are in advanced development stages. Results suggest that predators or nest destroyers would be opportunistic in visiting nests at specific times of caiman nesting season.

## Keywords

Antagonism, Nest defense, Camera traps, Activity patterns.



# Body temperature variation during the breeding cycle of the American crocodile (*Crocodylus acutus*) in Western Mexico: mating behavior compromises thermoregulatory behavior

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## Abstract

A comparison of body temperature variation during the breeding season, January to June, between adult wild and captive male and female *Crocodylus acutus* in Jalisco (wild crocodiles) and San Blas, Nayarit (captive crocodiles) was carried out in 2002. Body temperature records showed that reproductive behavior in the wild population resulted in a significant decrease in body temperature during March when reproductive displays and copulation occur. The decrease in body temperature in both sexes was attributed to the fact that the crocodiles spent more time in the water and less time basking during the copulatory phase of the breeding cycle. In the captive population however, no such decrease was observed, because the water in the pens in which the crocodiles were held was much warmer than the water where the wild crocodiles were observed. These results reveal a previously unknown aspect of crocodilian thermoregulatory behavior.

## Keywords

Body-temperature, Mating, Western Mexico.





# Population structure and abundance of *Crocodylus acutus* (Crocodylia: Crocodylidae) in the coast of Sinaloa, Mexico

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## Abstract

The American crocodile (*Crocodylus acutus*) is widely distributed in the New World and occurs in wide variety of habitats. However, the conservation status of the species locally is unknown in different regions of its distribution. Population abundance and structure are important parameters to evaluate and know the conservation status of a population. This study describes the population abundance and structure of *C. acutus* in six sites (El Verde Camacho-BV estuary, El Verde Camacho-BRQ estuary, Chiricahueto Lagoon, El Brinco estuary, Capomitos Stream and El Tular Stream) in Sinaloa, México. The field works were conducted during the period from January to October 2013 for five sites and 2016 for one, the number of individuals in these sites were counted to obtain population estimates. During nocturnal visual detection we recorded a total of 3434 crocodiles. Approximately 30.4 km were surveyed with a recorded general encounter rate of 14.2 crocodiles/km and in specific sites the encounter rate ranged from 8.4 to 42.7 crocodiles/km. The estimated population size using Messel's model ranged from 43 to 187 crocodiles. The distribution of class sizes observed was the following: 11% neonates, 45% juvenile, subadults 26%, adults 20% and 9% were recorded as EO (eyes only). The results of size-class distribution and abundance of crocodiles suggest that Chiricahueto lagoon and estuary El Brinco are two important sites for the conservation of *C. acutus*. The population structure observed shows a dominance of subadult and adult individual in the studied localities, indicates that the long-term recruitment is occurring, which is necessary to implement conservation strategies on these sites.

## Keywords

Abundance population, Population structure, *Crocodylus acutus*.



# How are metals associated with stress responses in captive crocodilians? The case of *Crocodylus moreletii*

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## Abstract

Several studies on metal exposure in crocodilians has been performed worldwide. Nonetheless, few studies have investigated the effects of metals in the health and physiology of these reptiles. Hence, we evaluated the association of five metals of ecotoxicological importance (Hg, Cd, Pb, Cu and Zn) with the neuroendocrine response to stress and oxidative stress in 42 captive female Morelet's crocodiles (*Crocodylus moreletii*). We measured glutathione (GSH) and glutathione disulfide (GSSG) as markers for antioxidant system and thiobarbituric acid reactive substances (TBARS) for oxidative damage in the liver, and corticosterone (B) as biomarker of the neuroendocrine response to stress in blood plasma. The mean  $\pm$  SD concentrations of metals in the liver expressed in  $\mu\text{g/g}$  (dw) were: Cd:  $0.004 \pm 0.003$ , Hg:  $0.014 \pm 0.019$ , Cu:  $0.017 \pm 0.013$ , Zn:  $0.043 \pm 0.035$ , Pb:  $0.16 \pm 0.256$ . The mean  $\pm$  SD levels expressed in nmol/mg protein for the oxidative stress biomarkers were: GSH:  $0.42 \pm 0.35$ , GSSG:  $0.24 \pm 0.20$  and TBARS:  $0.36 \pm 0.21$ . The mean  $\pm$  SD concentration of B was:  $393.57 \pm 405.14$  pg/mL. We observed a significant negative relationship between Hg and B. Cd had a negative relationship with both GSH and GSSG; meanwhile, Zinc showed a negative relationship with TBARS levels. For the first time we observed that B had a negative relationship with oxidative damage in crocodilians. The connections found between Hg and the neuroendocrine response to stress



as well as Cd with antioxidant activity, and on the other hand Zn and B with oxidative damage should be studied further, due to their toxicological importance and implications for the conservation of *C. moreletii* and other crocodilian species.

**Keywords**

Biomarkers, Corticosterone, Oxidative stress, Pollutants.



# The caves: refuge of crocodiles and caimans (*Crocodylus acutus* and *Caiman crocodylus*) before adverse conditions in an area of the coast of Chiapas, Mexico

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## Abstract

Crocodiles and alligators are considered key species because they maintain the structure and function of the ecosystems where they live. Among their activities, they avoid dusting by opening roads and channels for water flow, which at the same time serve as microhabitats for other species. The objective was to describe the habitat of crocodiles and alligators (*Crocodylus acutus* and *Caiman crocodylus*) in the eastern portion of the Puerto Arista Estuarine System, Chiapas, Mexico. Day tours were conducted in 5 transects established in the study area, by canoe with outboard motor, canoe rowing and walking tours. In each of the transects the coordinates, the type of vegetation and the conditions of the site were recorded. In the 5 transects, the mangrove was registered as the main type of vegetation (between 2.5 and 7 meters high) consisting mainly of four tree species: *Rhizophora mangle* (red mangrove), *Avicennia germinans* (black mangrove or mother salt), *Laguncularia racemosa* (white mangrove) and *Conocarpus erectus* (buttonwood mangrove). 11 caves were located in three of the transects. In the Estero Prieto transect, 6 cavities with the presence of crocodiles and alligators were counted. For the Las Manzanas transect, 4 caves and a *Crocodylus acutus* nest near them were counted, but there were no specimens present. In the Laguna transect, 1 cave was counted, with the presence of an alligator. Despite the drought presented this year, several interconnected channels and caves were observed that maintained the flow of water in the Estero Prieto and Laguna transect, effective strategies for the survival of these species when used as refuge and thermoregulation areas. The above shows that these shelters satisfy the basic biological requirements of the species in the face of adverse conditions.

## Keywords

Caves, Crocodilians, Alligators, Puerto Arista estuarine system.



# Embryonic communication and synchronous hatching in *Caiman latirostris* eggs

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## Abstract

Synchronous hatching by embryonic communication occurs in many reptiles. Embryos can hatch prematurely, accelerate or retard development, or metabolically compensate for heart rate (HR) adjustments. However, this field is even unknown in crocodilians. The aim was to identify if there is hatching synchronization in *Caiman latirostris* eggs and embryonic communication pathway that facilitates it. Four nests were used (2 early and 2 late) and a total of 127 eggs that were divided into a combined eggs treatment and a control. The combined treatment consisted of incubation of eggs from different nests and stages of development in contact with each other and the control with the remaining eggs of each nest. During incubation, HR were measured every 7 days. After hatching, unabsorbed yolk (V) was measured, and incubation period (IP), duration (HD) and hatching events (HE) were determined. Results of the combined eggs treatment, embryos exhibited higher HR compared to the control on day 14 and 21 of incubation ( $P = 0.0001$ ;  $P = 0.0003$ ). The V was observed in only two nests and did not differ between treatments ( $P = 0.66$ ,  $P = 0.48$ ). The IP of the early embryos in the control was lower than in the mixtures ( $P = 0.003$ ). In addition, one of the late clutches had a lower PI in the mixtures compared to the control. The HD and HE did not differ between treatments ( $P = 0.37$ ,  $P = 0.29$ ) although they decrease in the control (early embryos had HD less than 2 days). Our data suggest that there is some developmental control by *C. latirostris* embryos, mediated by HR adjustments, to hatch together with their incubation partners and that synchronization is even stronger between embryos from the same nest.

## Keywords

Heart rate, Eggs, Embryonic communication, Synchronous hatching.



## Quality and possible use of effluents from caiman farms

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### Abstract

Caiman farms discard large volume of water and suspended solids (rest of food and feces). Those effluents most of the times are stocked in pools without any use. Our objective was to characterize chemical, physical and microbiological residual waters of those lagoons (both at surface and bottom). The effluent presented low content of dry matter and ashes at surface or bottom (0.13% on 0-60 cm and 0.17% on deeper than 60 cm), nutrients were low, pH slightly alkaline, and electric conductivity was a little bit lower than the critical value 2dS/m. Sodium (406.5 mg/L) and nitrogen (about 100 mg/L) were in high concentration, but phosphorus was very low (5.9 mg/L). Content of Ca, Mg, and K was 97.5, 25, and 107.5 mg/L, respectively, and increased with depth. Levels of BOD and COD indicated the water was slightly contaminated (20.6 mg O<sub>2</sub>/L) and under levels of industrial effluents (24.8 mg O<sub>2</sub>/L). Microbiological analysis did not register *Salmonella*, but *Escherichia coli* was present, also we found total anaerobics, and coliforms. Based on results a possible use is for agriculture, production of trees, or species used to feed livestock. For every option amount of pathogens must be determinate and if they exceed regulated values they should be reduced.

### Keywords

Crocodylians breeding, Re-use, Residual water, Water quality.



# Human-crocodile interactions along the central coast of Jalisco, Mexico

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## Abstract

In Mexico, human and crocodile populations are often in contact as both use the same coastal habitats. Jalisco is the state of Mexico with the highest level of negative interactions between people and crocodiles. The municipality of Tomatlán, located along the central coast of Jalisco has a large population of *Crocodylus acutus*, and encounters between humans and crocodiles are reported. In 2008, a crocodile sanctuary (Spanish: cocodrilario) was founded with the aim of conservation, tourism, environmental education, research and management of problematic individuals. Thus, research began on human-crocodile interactions and the relationship between both species. In this study, we conducted 62 interviews with members of the local community (farmers, cattle ranchers, fishermen and inhabitants living close to crocodile habitat). The mean age of interviewees was 47 years old. Interactions were reported from 2003 onwards and were classified as follows: sighting, predation of livestock or pets, and bite or mortality to human. The results obtained indicate that 100% of the people surveyed have observed crocodiles, 55.3% have experienced an interaction, 26.1% have suffered predation of their livestock or pets, and 15.3 have suffered bites (10 people) of which two people died. Based on interview responses, all serious interaction resulting in bites or deaths happened during daylight hours, and crocodiles were estimated to measure an average of three meters in length. It is important to mention that 68% of respondents believe that there is an overpopulation of crocodiles, and 80% think that crocodiles should be relocated or hunted. Although crocodile bites to people are infrequent, community members see all crocodiles as dangerous





and do not know how to coexist alongside them safely. For this reason, a program of attention to human-crocodile conflicts should be implemented in the area, and environmental education campaigns are urgently needed to inform the community of the importance and benefits that crocodiles offer to the local ecosystem.

**Keywords**

American crocodile, Relationship, Conflict, Interactions.



# Evaluation of the level of self-recognition in individuals of Broad-Snouted caiman (*Caiman latirostris*) using the Mirror Test

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## Abstract

Our aim is to find evidence on the level of self-consciousness and the ability of self-recognition in juveniles of *Caiman latirostris* using the “Mirror test” first designed by Gallup in 1970. Captive caimans inside a plastic tank (60 cm long, 40 cm wide and 30 cm high) are exposed to a mirror with a paint mark on a part of their body that cannot be seen by them directly but is visible in the mirror. Their behavior and interactions with the mark (touching the mark, trying to take it off) were registered by a digital camera. The test is considered “positive” if one subject has one of these mirror-directed interactions at least once. Each animal was exposed to five different treatments: no mark and no mirror; no mark and mirror; sham mark and mirror; orange mark and no mirror; orange mark and mirror. The results showed that none of the individuals touched the mark on their jaw while exposed to a mirror. Nonetheless, in every mirror tests, there was some type of interaction with the mark when compared to the control tests. The behavior of touching the surface of the mirror with the snout when looking at the mirror, in some cases accompanied by head movements or walking from one end of the mirror to the other, always with the snout touching it, only occurred in the tests with the mirror and these behaviors that have not been previously described in the literature. However, this does not constitute strong enough evidence to establish whether it is due to self-recognition, so we consider that further studies are required to investigate it.

## Keywords

Ethology, Self-recognition.



# Structure and population dynamics of crocodilians in Estero Prieto, Puerto Arista, Tonalá, Chiapas

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## Abstract

This study was performed in the Estero Prieto wetland within the RAMSAR site Sistema Estuarino Puerto Arista, municipality of Tonalá, Chiapas. The field work was carried out between June 2014 and May 2015 through 6 bi-monthly samplings that considered the rainy and dry seasons. To study the populations of crocodilians in this wetland, the organisms of *Crocodylus acutus* and *Caiman crocodilus chiapasius* were quantified and classified by the method of Chabreck (1966). This method consisted of detecting, during the night, the specimens directing a flash of light towards their eyes. The results showed that the po

pulation of *Crocodylus acutus* was present throughout the study, but it was more evident during the dry season because in this one we obtained an encounter rate of 28.5 ind/km, and the estimated population was  $57.08 \pm 10.17$  crocodiles. The class structure for this species consisted mainly of juveniles. In the case of *Caiman crocodilus chiapasius*, its population increased considerably in the dry season and presented a rate of encounter of up to 42.5 ind/km and an estimated population of  $85.15 \pm 20.38$  individuals. The population of caymans was represented mostly by juveniles. The findings of this study allow us to argue that Estero Prieto is a refuge zone and a priority site for both species, so efforts to conserve it should be increased.

## Keywords

Caimans, Crocodiles, Population density.



# Kinematic and head morphometric characterization of spermatozoa from the Brown Caiman (*Caiman crocodilus fuscus*)

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## Abstract

The development of analytical methods for the evaluation of crocodilian semen is an important component for the assessment of male breeding soundness and the development of assisted breeding technology in this taxon. Computer-Assisted Semen Analysis (CASA) technology is becoming an increasingly common technique in seminal evaluations for animals but there has been no application of this technique for reptilian spermatozoa. The aim of this study was to analyze sperm kinematic and morphometric variables in *Caiman crocodilus fuscus* semen samples and to determine whether there were sperm subpopulations. Four ejaculates from four sexually mature captive caimans were used for this study. ACASA-Mot and CASA-Morph system was used with an image acquisition rate of 50Hz for 2 s of capture. The ISAS®D4C20 counting chambers were used and spermatozoa incubated at 25°C. Total and progressive motilities did not differ among animals ( $P > 0.05$ ). There was a significant animal effect in the model with respect to sperm morphometry, and kinematic indices including linearity (LIN) and straightness (STR) ( $P < 0.05$ ). Results for principal component (PC) analysis indicated variables were grouped into four components: PC1 related to velocity, PC2 to progressivity, PC3 to oscillation and PC4 to sperm path cross-linking. Subpopulation (SP) structure analysis indicated there were four groups, namely, rapid non-progressive (SP1), slow non-progressive (SP2), rapid progressive (SP3) and medium progressive (SP4), representing 14.5%, 45.4%, 18.7%, and 21.4% respectively. Findings in the present study indicate



the importance of continuing development of reliable protocols regarding the standardization of computer-based semen analyses in reptilian species.

**Keywords**

Andrology, Caiman, Sperm analysis, Reptile reproduction.



# Leeches and crocodilians: first record of *Placobdella ringueletti* López-Jiménez & Ocegüera-Figueroa 2009 (Rhyncobdellida: Glossiphoniidae) on *Caiman crocodilus*, Linnaeus 1758 (Crocodilia: Alligatoridae) in Guatemala

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## Abstract

*Caiman crocodilus*, Linnaeus 1758, is a crocodilian distributed from Mexico to Brazil, specifically in Guatemala, can be found in the Atlantic and Pacific slopes. Although, there lack of studies in the country prevents of making accurate decisions regarding their conservation. Since crocodilians inhabit semi-aquatic habitats tend to be hosts for several ectoparasites, which can provoke negative impacts in their health condition. Here, we present the first record of *Placobdella ringueletti* López-Jiménez y Ocegüera-Figueroa, 2009. The purpose of this study is to report ectoparasitic infestation degree of *P. ringueletti* and the areas where large amounts of ectoparasites were found in a private farm at the south coast of Guatemala. Four captive alligators were analyzed for the presence of ectoparasite *P. ringueletti*, 3 males and 1 female. This ectoparasite has been previously reported in other reptiles, such as freshwater turtles from the genus *Rhinoclemmys*, found in the same enclosure with *C. crocodilus*. All the individuals showed a high infestation degree, being the female with the highest parasitic load (a total count of 585 leeches). The body area with the highest prevalence of the largest amount of parasites was the groin, this might be related to be explained by the fact that this is a soft tissue compared to other body zones and it is easier for leeches to attach to it, provides protection from predators, or strong water streams.

## Keywords

Parasite, Infestation degree, Hirudinea

## Introduction

*Caiman crocodilus*, Linnaeus 1758, is a crocodilian distributed from Mexico to Brazil (Balaguera-Reina and Velasco, 2019). Conservation status is Least Concern



for IUCN (Balaguera-Reina and Velasco, 2019) and locally, is in category II of the Endangered Species List of Guatemala, so is seriously threatened (Consejo Nacional de Áreas Protegidas [CONAP], 2009). Although its distribution is wide, research into ecology is needed in Guatemala and other countries (Balaguera-Reina and Velasco, 2019). It has been recorded that alligators in captivity are susceptible to diseases (Hibberd and Harrower, 1993; Ladds and Sims, 1990), which is important for public health, because proximity to humans can result in disease transmission as leptospirosis (Pérez-Flores et al., 2017). The presence of leeches may represent a potential vector of protozoa which pathological effects on alligators are still unknown (Fermino et al., 2015; Lima and Silva, 2004). This study was conducted in farm called Chojojá, located in Suchitepequez, Guatemala where captive caimans and crocodiles lived. The main objective was to report ectoparasitic infestation degree in *C. crocodilus* individuals.

## Methods

Material collection was conducted during September 2019, we collected 1097 helminth parasites. They were counted for each body area and collected manually with tweezers. Then, submerged in a container with tap water and euthanized by adding 5 mL of ethanol 70% each 5 minutes until total fixation. All the specimens were stored separately by individual and registered in the Collection of Invertebrates from Escuela de Biología, Universidad de San Carlos de Guatemala. Taxonomic classification was conducted using López-Jiménez and Ocegüera-Figueroa (2009), and Ocegüera-Figueroa and Pacheco-Chaves (2012) key for the genus and Hirudinea experts support and confirmation for the species.

## Results

Table 1 shows the amount of *Placobdella ringueleti* leeches (figure 1) in four alligators of Chojojá farm. A high infestation degree was obtained for all specimens according to the criteria of Talleklint and Eisen (1999), since all presented more than 15 ectoparasites per individual. The specimen with the least amount of ectoparasites was individual 4 (I4 in table 1) with 28 leeches in total, while individual 2 (I2 in table 1) was the individual with the largest number of leeches, with 585 in total.

\*C= individual, ♂: male/♀: female N=neck, D=dorsal, LU=Left armpit, RU=right armpit, LG= left groin, RG= right groin, RK= right knee, TL= total leeches, ID= infestation degree.





**Table 1. Infestation degree of *Placobdella ringueleti* in *Caiman crocodilus***

Specimen	Body area							TL	ID
	N	D	LA	RA	LG	RG	RK		
11 ♂	58	1	3	8	29	27	-	126	High
12 ♀	74	-	-	-	283	150	78	585	High
13 ♂	-	-	-	-	197	161	-	358	High
14 ♂	-	-	-	-	5	22	1	28	High



Figure 1. Leeches recorded in caimans of Chojojá farm, Suchitepéquez, Guatemala.  
A= dorsal view of *Placobdella ringueleti*. B= ventral view of *P. ringueleti*. C= ventral cephalic view of *P. ringueleti*. D= ventral caudal view of *P. ringueleti*.

## Discussion

This is the first report of *Placobdella ringueleti* in *Caiman crocodilus* from Guatemala, there have been reports of this genre in wild crocodiles from Mexico (García-Grajales and Buenrostro-Silva, 2011), fish, amphibians and turtles (Ocegera-Figueroa and Siddall, 2008) specifically turtles from the genus *Rhynoclemmys* in Costa Rica (Oceguera-Figueroa and Pacheco-Chaves, 2012)



which may have been the source of the leeches since one of the individuals examined shared the enclosure with a turtle from this genus.

As shown in table 1 all the individuals were categorized in high infestation degree (more than 15 leeches in the whole body) according to Tälleklint and Eisen (1999). This may have resulted from enclosure disposition and structure, where there is no constant water flow, and its level did not exceed 12 inches. In addition, there is no vegetation cover above any of the enclosures which favors higher temperatures thus facilitating parasite reproduction, as observed in other leeches' studies (Young and Ironmonger, 1982; Kubová, Schenková and Horsák, 2013). This is in contrast to information from other authors who have not found such high reports in wild crocodiles (Charruau et.al., 2020).

Highest infestation degree was recorded in the groin; this corresponds to the study of García-Grajales and Buenrostro-Silva (2011). Most leeches were found in soft tissues which agrees with reports by Smith Johnson and Voig (1976), and Huchzermeyer (2003). This may be due to its articulated anatomy allowing leeches to attach and be protected from water flow, predators, and sun exposure (Ray, 1980; McKnight et al., 2021). We consider that the structural characteristics of the enclosure system in the farm have a direct effect on several water conditions, such as water depth and temperature, hence favoring an accelerated growth of the leeches' population. In addition, we observed freshwater turtles from the genus *Rhinoclemmys* in the same enclosure as the alligators. This is important as they can be a source of leeches, particularly of *P. ringueleti* (Garcés-Restrepo et al., 2013).

Additionally, tissue exposure due to leeches attachment was observed. This is relevant because not only leeches represent a potential vector of protozoa as trypanosomes and haemogregarines (Siddal and Dessler, 2001), which can cause capillary obstruction in *C. crocodilus* (Lima and Silva, 2004; Fermino et al., 2015) and massive infections may contribute to mortality in young animals, especially those captive and under stress (Ladds and Sims, 1990), but also open wounds may facilitate the entrance of other parasites or produce illnesses like anemia (Leslie, Lovely and Pittman, 2011) compromising overall health condition.

## Conclusion

All the individuals of *Caiman crocodilus* showed a high infestation degree. The female had the highest parasitic load. Highest infestation degree was recorded in the groin.



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# Depredation attempt on a Morelet's crocodile *Crocodylus moreletii* (Crocodylidae) nest in the Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico

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## Abstract

A record by camera traps of an attempted predation on a Morelet's crocodile nest by a raccoon in the Sian Ka'an Biosphere Reserve, Quintana Roo, Mexico. Nests predation is one of the main causes of crocodile egg mortality. The images presented here were captured in a wild nest with a camera trap and show clear evidence of interactions between these two species.

## Keywords

Camera traps, Eggs, Raccoon, Monitoring, Muyil.



# Relationship between body condition and reproduction

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## Abstract

To know patterns of energy destined to reproduction is necessary to understand reproductive ecology of species. In this work we calculated body condition (BC) index of reproductive and non-reproductive *Caiman latirostris* adult females, as an indication of stored energy. We have calculated FULTON and Scaled Mass Index (SMI) of 96 adult females, captured since 2001 to 2018 (except 2009). Females were considered reproductive (R) if they were captured defending a nest or were gravid (n= 75) and non-reproductive (NR) confirmed by echography (n= 21). We tested difference in BC between R and NR females with T test. We also evaluated minimal BC to guaranteed that females beyond that line are reproductive. Reproductive females had better BC than non-reproductive ones (in both FULTON and SMI). Our line separate 70% of the nesting females. Based on our results we could guarantee that a female will reproduce if her BC is beyond the line, but not all the females under the line are non-reproductive, indeed a few females under the line nests.

## Keywords

Body condition index, *Caiman latirostris*, Reproductive female.



# New River pollution crisis: the impact of contamination on *Crocodylus moreletii* in northern Belize

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## Abstract

In early 2017, the Crocodile Research Coalition (CRC) began hearing reports of dead fish and ill, white or pink crocodiles along New River around Orange Walk Town in northern Belize. During nocturnal eyeshine surveys and capture surveys in early 2018 in conjunction with the countrywide Morelet's crocodile population survey, CRC witnessed crocodiles near Orange Walk Town illustrating "white patches" and a bluish tint on their skin. Besides lethargy, some crocodiles were also exhibiting "star-gazing," or short-term paralysis. To date, CRC has conducted necropsies on 2 Morelet's crocodiles (*Crocodylus moreletii*) of 2.2 m and 2.9 m in total length, captured in the most heavily contaminated area of the New River. Necropsies were conducted immediately to obtain the most accurate samples for future pollutant analysis, however, collection of samples proved difficult given organs already appeared in a state of disintegration (especially the kidneys and liver) in both crocodiles. Through our monitoring efforts, we have collected caudal scute samples, in addition to water and soil to examine heavy metal and pesticide concentration to identify key pollutant(s) causing the pollution crisis and consequently impacting the crocodiles. From recent data obtained, we have witnessed a marginal increase in encounter rates within the contaminated area of the New River in addition to increasing mortality rates. We intend to conduct monthly surveys of New River, utilizing the population and health status of *C. moreletii* as an indicator of the state of the river ecosystem as requested by The Belize Government. The CRC hopes that this research can provide stakeholders of the New River the data necessary to ensure the long-term survival and health of this important ecosystem not just for the wildlife, but also for the multiple communities that depend on this river for their livelihoods.

## Keywords

Eco-toxicity, Conservation management, *Crocodylus moreletii*, Belize.





# **Juancho, a wild inhabitant of the Metropolitan Zone of Tampico. Analysis of the perception of basic education students about the Mexican crocodile (*Crocodylus moreletii*)**

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## **Abstract**

The southeast of Tamaulipas is made up of a complex lagoon system. However, the economic and social development of urban growth in the Tampico Metropolitan Zone, within the Altamira, Ciudad Madero and Tampico townships, has achieved that the infrastructure of communication and transport roads, as well as housing units, is they are currently overlapping with this aquatic environment, which turns out to be the natural habitat of the Mexican crocodile (*Crocodylus moreletii*). The presence of crocodiles in this region has become so common, that the inhabitants have colloquially named them as "Juancho", and have even been used as an iconic emblem. What, apparently, has led to the inhabitants have losing their respect as dangerous animals for citizens, and when this reptile walking on the streets of the city, the human curiosity has caused interactions that put them at risk. For this reason, our research focused on knowing what is the perception that elementary school students have over the crocodile. To know this, without any influence of previous information from an expert about the risks that exist, students were asked to draw what they know as crocodile. Based on the analysis of the drawing proposed by previous studies, the drawings were classified into two types: Negative Perception and Positive Perception, each with three categories (feeding attitude, attitude showing teeth and attitude opening mouth; and smiling attitude, accessory nice things and common family environment, respectively). The results indicate that about 70% of children see the Mexican crocodile with a positive attitude of low danger. This perception is confusing



for them, given the limited information they have about the risks that exist, so we suggest that environmental education campaigns be carried out so that the population knows about the respect that the crocodile deserves.

## **Keywords**

Child perception, Mexican crocodile

## **Introduction**

The Wild fauna has been inhabiting different environments since before human societies. However, urban growth tends to expand in areas where wild populations coexist with people, leading to encounters that put the integrity of humans at risk (eg. big cats [Goodrich, 2010; Marchini et al., 2017; Somerville, 2019], apes [Beck et al., 2014; McLennan and Hockings, 2016], or crocodiles [Corvera et al., 2017; García-Grajales and Buenrostro-Silva, 2019; Pooley et al., 2021; Cavalier et al., 2022]). Crocodiles are a group of large reptiles, whose conflict with humans has stigmatized them as ferocity and dangerous (Connolly et al., 2016). Nevertheless, some cultures have changed their perception regarding their coexistence, coming to worship them as deities or even relate them as friendly animals (Cohen, 2019), which could increase the risk of accidental encounters.

The southeast of Tamaulipas is made up of a complex lagoon system (Fig. 1). However, the economic and social development of urban growth in the Tampico Metropolitan Zone, within the Altamira, Ciudad Madero and Tampico townships (Jiménez et al., 2004), has achieved that the infrastructure of communication and transport roads, as well as housing units, is they are currently overlapping with this aquatic environment, which turns out to be the natural habitat of the Mexican crocodile (*Crocodylus moreletii*).





Figure 1. The complex lagoon system from Tampico Metropolitan Zone, within the Altamira, Ciudad Madero and Tampico townships. Southern of Tamaulipas. On the area, all crocodiles are Juancho, in honor to Hanna-Barbera cartoon. In this map shows some records according to iNaturalist.

The presence of crocodiles in this region has become so common, that the inhabitants have colloquially named them as "Juancho" and have even been used as an iconic emblem. What, apparently, has led to the inhabitants have losing their respect as dangerous animals for citizens, and when this reptile walking on the streets of the city, the human curiosity has caused interactions that put them at risk. Considering the above, the aim of the present work was to know the perception of the dangerousness of the Mexican crocodile in the southern of Tamaulipas, in infants of 8 and 9 years.

## Methods

To know out, what is the perception that elementary school students have about the crocodile?, without any influence on them of prior information from an expert about the risks that exist, we ask to 153 students to draw what they know as a crocodile.



Subsequently, for the analysis of the drawings, we apply the evaluation proposed by the studies of Ochando et al. (2011) and Crotti et al. (2004). In this study, the drawings were classified into two main types: Negative Perception and Positive Perception, and each one with three different categories (see Table 1).

**Table 1. Categories based on the analysis of the drawing proposed by the studies by Ochando et al. (2011) and Crotti et al. (2004).**

Positive Perception	
<b>Smiling attitude</b>	Positive perception. Its drawing of the crocodile does not generate or transmit dangerousness but on the contrary happiness or joy.
<b>Accessory things</b>	The crocodile drawing with toys, hearts, houses. It relates it to its environment making it part of it and of daily activities with a positive attitude. Juancho is not dangerous.
<b>In family environment</b>	When its crocodile drawing is shown as part of their family group. It makes sense according to the context. Juancho is affectionate and friendly. Is not dangerous.
Negative Perception	
<b>Eating attitude</b>	Negative perception towards the species, when carnivorous behavior is drawn.
<b>Teeth-baring attitude</b>	The crocodile drawing is in an attitude of fiercely baring her teeth. Juancho has very sharp teeth.
<b>Open mouth attitude</b>	The crocodile drawing responds to the action of eating, with the action of opening his mouth. The child takes on a more analytical sense based on what Juancho eats.

## Results and discussion

In Figure 2, you can see some drawings that the students made about the positive and negative perception they have about the crocodile. In general, the drawings of crocodiles show animals in pleasant and affectionate environments and, also, crocodiles that show their teeth in a semblance ferocious and aggressive.



a)



b)



Figure 2. Some drawings of a) positive attitude and b) negative attitude.

The results (Fig. 3) indicate that about 70% of children see the Mexican crocodile with a positive attitude of low danger. This perception is confusing for them, given the limited information they have about the risks that exist and the misconception they have about Juancho, the crocodile, as a tourist attraction. Therefore, we suggest that environmental education campaigns be carried out so that the population knows about the respect that the crocodile deserves.

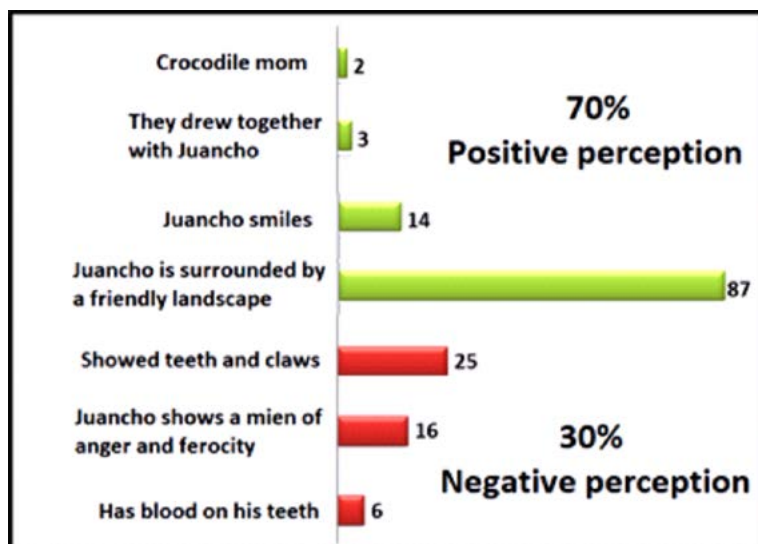


Figure 3. Perception results according to the analysis.

## Conclusion

Most children show a perception is confusing for them for the crocodile danger. Given the limited information they have the children about the risks that exist,





we suggest that environmental education campaigns be carried out so that the population knows about the respect that the Mexican crocodile deserves.

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# Detection of *Trypanosoma* sp. in American crocodile and spectacled caiman by PCR amplification of GAPDH and SSU rRNA

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## Abstract

Although three species of trypanosomes have been reported in two African species of crocodiles and in three South American species of caimans, no molecular studies have been carried out for the detection and typification of trypanosomal species that affect the other Neotropical species of the order Crocodylia. A PCR-survey based on the amplification of SSU (small subunit) of rRNA and gGAPDH (glycosomal Glyceraldehyde Phosphate Dehydrogenase) gene for trypanosomes in caiman and crocodile blood samples, and in leeches taken from caimans revealed unknown trypanosome diversity. In the present study, we surveyed for trypanosomes in blood samples from 270 specimens of American crocodile (*Crocodylus acutus*) and 504 specimens of spectacled caiman (*Caiman crocodilus*), and five leeches. Out of the 779 samples tested, two American crocodiles, 12 spectacled caimans and the five leeches presented a positive amplification band for both genes when the PCR products were run on a 1% agarose gel. Future NGS will be done to molecularly identify the amplified species.

## Keywords

Crocodylian trypanosomes, Molecular identification.



# Delineating gharials, nests, and habitats with drones

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## Abstract

Since 2017, we have been using quadcopter drones as aids in the Gharial Ecology Project, a conservation initiative focused on gharial (*Gavialis gangeticus*), a Critically Endangered unique crocodylian species. We are studying the largest, resident riverine population (>85% of gharial globally) in the National Chambal Sanctuary, north India. We are using DJI Mavic drones (Mavic Pro and Mavic Pro 2), controlled via an iPad and mobile phones, on missions created with DJI Ground Station, and analyses software created by Drone Deploy. The latter allows us to create 2D and 3D maps using geo referenced JPEGs, and fly repetitive missions of selected sections of river, under differing weather conditions and in different seasons, as well as accurately distinguish gharials from crocodiles (*Crocodylus palustris*), quantify gharial numbers, and categorize counted individuals into size classes. Thus, we are able to verify “on the ground” seasonal counts at specific places where resident wild gharial congregate for basking, breeding, nesting, and hatching. With regard to finding and counting nests, aerial methodology is reliable when colony size is midrange, > 5 but < 20 nests. Accuracy is highest within this range, and drops off when nest numbers are higher or lower. At 50m height, drone estimates of nest numbers were about 75% of the total observed. At 80m, estimates by drone were less than half of the number counted manually, in the midrange. With regard to determining the various size/age classes of gharial, our experience suggests that drone disturbance increases when the quadcopter is less than 50m overhead. Gharial quickly habituate to the presence of drones flown at moderate heights. Within large crèches, counting hatchlings accurately, is possible, once the animals become accustomed to a not threatening object hovering overhead.

## Keywords

Acoustic, Gharial, Size class, Drones, Nests.



# Dangerous predator or a farmer's friend? Diet and body condition of headstart and wild Philippine Crocodiles (*Crocodylus mindorensis*)

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## Abstract

Studies of diet are essential to understanding the ecology of a species. For translocations, dietary studies of captive-released populations can yield critical assessments of individual viability and establishment in the wild post-release. With less than 150 mature individuals remaining in the wild, the Critically Endangered Philippine crocodile (*Crocodylus mindorensis*) is one of the most severely threatened species on the planet. We conduct the first analysis of stomach contents and characterize the diet of wild and headstarted Philippine crocodiles in Isabela Province on Luzon Island in the northern Philippines. Our study of diet from a resident wild population acts as a baseline comparison for evaluating the dietary habits of headstarted crocodiles released into the wild over the last decade, from which we found no evidence for dietary differences in prey occurrence, prey composition, and prey diversity. We document the consumption of a wide diversity of at least 17 different aquatic and terrestrial invertebrate and vertebrate prey species. Interestingly, 70% of Philippine crocodiles showed snails as the prominent prey type, including adult crocodiles. Fish were consumed by 36.7% of *C. mindorensis*, birds 33.3%, and reptiles 33.3%. Furthermore, more than 50% of all *C. mindorensis* consumed the invasive



Golden Apple Snail, one of the leading agricultural pests in the Philippines. Finally, we calculate the first body condition index (relative condition factor) for *C. mindorensis* and examine variation in body condition between headstarted and wild crocodiles. Our results show that wild crocodiles have significantly higher condition scores than headstarted individuals. However, headstarted crocodiles exhibit similar dietary habits compared to their wild counterparts and adjust well post-release, even in an agricultural landscape where they face persecution by locals yet are likely playing an ecological importance exploiting an invasive species in high abundance.

**Keywords**

Conservation, Crocodylians, Invasive species, Translocation.





## IUCN Species Survival Commission

The IUCN Species Survival Commission (SSC) is one of six volunteer commissions of IUCN - The World Conservation Union, a union of sovereign states, government agencies and non-government organizations. The IUCN has three basic conservation objectives: to secure the conservation of nature, and specially of biological diversity, as an essential foundation for the future; to ensure that where the earth's natural resources are used this is done in a wise, equitable and sustainable way; and to guide the development of human communities towards ways of life that are both of good quality and in enduring harmony with other components of the biosphere.

The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. It is a science-based network of more than 8,500 volunteer experts, including scientists, field researchers, government officials and conservation leaders from almost every country of the world. The SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions, and conservation organizations

IUCN SSC also publishes an Action Plan series that assesses the conservation status of species and their habitats, and conservation priorities. The series is one of the world's most authoritative sources of species conservation information available to nature resource managers, conservationists, and government officials around the world.

## IUCN SSC Crocodile Specialist Group

The IUCN SSC Crocodile Specialist Group (CSG) is a worldwide network of biologists, wildlife managers, government officials, independent researchers, non-government organization representatives, farmers, traders, tanners, manufacturers and private companies actively involved in the conservation, management and sustainable use of the world's living species of alligators, crocodiles, caimans and gharials in the wild. The CSG is supported financially through the International Association of Crocodile Specialists Inc. (IACS) and operates under the auspices of the SSC of the IUCN (International Union for Conservation of Nature). The CSG members are an international network of experts with the skills needed to assess conservation priorities, develop plans for research and conservation, conduct surveys, estimate populations, provide technical information and training, and to draft conservation programs and policies. The CSG itself keeps its members updated on international events with crocodilians, conducts reviews of country programs, and tries to track and prioritize issues in forums such as CITES that encourage legal trade and discourage illegal trade. CSG Working Meetings are generally held every two years.

