Crocodile Specialist Group, Species Survival Commission

CROCODILES

Proceedings of the 27th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN - Convened at Darwin, Australia, 15-19 April 2024 (Unreviewed)

2024

Crocodile Specialist Group

SSC Species Survival Commission

IUCN

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International Union for Conservation of Nature (IUCN)
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Front cover: Saltwater crocodile (*Crocodylus porosus)* hatchlings. Photograph: Grahame Webb.

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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 27th Working Meeting of the Crocodile Specialist Group (CSG), held in Darwin, Australia, on 15-19 April 2024, was a resounding success. Held every two years, Working Meetings are an important forum that bring together participants from around the world, for an exchange of ideas and experiences on crocodilian conservation, management and research activities from around the world. This meeting was no exception, with attendance by some 300 participants from 30 countries.

The management of Saltwater crocodiles across northern Australia was showcased at the meeting, and Northern Territory Minister Kate Worden took the opportunity to announce the release of the latest Northern Territory "Saltwater Crocodile Management Program 2024-2034". It is almost 40 years since the CITES downlisting of the Australian population of *Crocodylus porosus* (1985) and drafting of the first management program for the species in the Northern Territory (1987). As with American alligators in the USA, the management of Saltwater crocodiles in Australia has set an example for other countries. The "Be Crocwise" public education programs being implemented in Queensland, the Northern Territory and Western Australia, was also of particular interest, given the increasing frequency of human-crocodile conflict in many neighbouring countries. The involvement of Aboriginal people in crocodile management is a key characteristic of the Northern Territory program in particular, where traditional landowners receive tangible benefits from the sustainable use of the wild crocodile resource. An oral presentation from indigenous rangers from the Arafura Swamp Rangers Aboriginal Corporation highlighted the importance of the crocodile program to these landowners.

The CSG is extremely grateful to Sally Isberg, whose company "Centre for Crocodile Research" hosted the Working Meeting, and meeting partners Crocosaurus Cove, Crocodylus Park and Corroboree Billabong Wetland Cruises. The Organizing Committee, chaired by Sally, consisted of representatives from several local authorities, institutions and organisations, who worked tirelessly to coordinate the meeting and plan the various activities associated with it. This included the veterinary and drone workshops that were held before the meeting, a field trip into crocodile habitat on the Adelaide and Mary Rivers after the meeting, and of course the obligatory functions on most nights. We are also grateful to Kayla Robinson and her support staff from Associated Advertising and Promotions (AAP).

Nothing would have been possible without the generous financial support from various sponsors, including the Crocodile Farmers Association of the Northern Territory, Crocodilian Academy, Hartley's Creek Crocodile Farm/Hartley's Crocodile Adventures, the Northern Territory Department of Primary Industry and Fisheries, Walls Gators Farm, TalTech and Charles Darwin University. See page 16 for full list of donors and sponsors. The auction raised a record amount of $US27,897, and we thank contributors big and small for their generosity.

The Working Meeting was also preceded by a meeting of the CSG Executive Committee (13 April), and a meeting of the CSG Steering Committee (15 May), which as usual, was open to all participants. The Steering Committee again addressed a wide range of issues. Of significance, the Executive Committee announced termination of the Future Leaders Program (FLP) as a distinct initiative, and the establishment of an Executive Advisory Group (EAG) to sit between the Executive Committee and the Steering Committee, which it hopes will not only achieve some of goals being addressed by the FLP, but mainly act as a group to work more closely with the Executive Committee at a more strategic level.

The last time a Working Meeting was convened in Darwin, in 2004, saw Professor Grahame Webb take on the position of Chair, and lead the CSG for the next 20 years. We were particularly delighted to see a special session entitled "A morning tea with Grahame Webb" in the program, where he was able to discuss interesting aspects of his work and experiences on crocodilians, now spanning more than 50 years. Some meeting participants have known and worked with Grahame for much of this period and are very much aware of the significant contribution that he has made not only to the CSG, but to the IUCN, SSC, CITES, and wildlife conservation generally.

The year 2023 also saw the retirement of Tom Dacey as CSG Executive Officer, who stepped down after 19 years in the position to spend more time with his family. This was thus the first meeting with new CSG Chairs Alejandro Larriera and Charlie Manolis, and a new Executive Officer Sally Isberg. That year also saw Perran Ross stepping down from the CSG, and his long-time contribution to CSG, SSC and IUCN over several decades, was also recognised. Although no longer formally linked with the CSG, that hope that we can continue to draw on Grahame and Perran's extensive institutional memory and experience as we move forward to achieve our mission with respect to crocodilian conservation.

A meeting of the International Crocodilian Farmers Association was planned to coincide with the Working Meeting, thus allowing key industry people from around the world to participate. At a side-meeting of the CSG Industry/Trade thematic group (18 April), concerns were again raised regarding the market shift away from wild crocodilian skins, despite the role of these sustainable use programs in providing benefits for livelihoods and incentives for conservation.

Like others, this Working Meetings, brought together an exceptional array of people, to share a week with people who are as equally passionate about crocodilians. We now look forward to the next Working Meeting, to be held in Morocco, in 2026.

Alejandro Larriera and Charlie Manolis, *CSG Co-Chairs*.

Summary of the 27th CSG Working Meeting

The CSG's 27th Working Meeting was held at the DoubleTree Hilton, in the centre of Darwin, Northern Territory, Australia, on 15-19 April 2024. It was attended by 298 delegates and 30 accompanying persons. The Centre for Crocodile Research (Associate Professor Sally Isberg) hosted the meeting, with many sponsors and local businesses providing financial support which significantly offset the cost of the registration fees for participants.

The theme for the meeting was "Crocodile Conservation: What Works!" emphasizing the various aspects that work in unison for crocodile conservation in Australia, and particularly the Northern Territory, to remain the success story it has become.

The Organising Committee (Sally Isberg, Cameron Baker, Cathy Shilton, Charlie Manolis, Emily Moyes, Grahame Webb, Helen Truscott, Kristen Hay, Matt Brien, Mike Welch, Paul Beri, Sam Banks, Simon Booth, Tim Clancy, Yusuke Fukuda) ensured that the venue, program, sponsors, entertainment, etc., were in place. A professional conference organizer, Associated Advertising and Promotions (Kayla Robinson, Helene Bakker, Sita Carolina, Natalie Bell), was contracted to assist with the complex logistic arrangements required to bring delegates from 30 countries (Argentina, Australia, Austria, Bangladesh, Brazil, Cambodia, Czech Republic, Denmark, France, Germany, Ghana, Hong Kong, India, Ireland, Italy, Japan, Malaysia, Mexico, Netherlands, Papua New Guinea, Philippines, Singapore, South Africa, Switzerland, Thailand, United Arab Emirates, United Kingdom, USA, Venezuela, Zimbabwe) to the meeting.

As has become tradition, workshops were held prior to the working meeting on 14 April, at Crocodylus Park:

- Drone workshop - coordinated by Matt Brien, Lonnie McCaskill, Simon Booth and Paul Beri. The workshop featured presentations on best practices, and the use of drones for monitoring, tracking, and management applications. After some afternoon tea, demonstrations included how to snare crocodiles with drones as a conflict management tool as well as our exhibition sponsor, Wildlife Drones, showcasing an automated triangulation approach that its drone system can provide. Lunch was sponsored by the North Australian Centre for Autonomous Systems (Dr. Hamish Campbell, Charles Darwin University).

- Veterinary workshop - coordinated by Cathy Shilton, Paolo Martelli and Gowri Mallapur. The workshop began with presentations on anesthesia, imaging, a case study on limb amputation due to cancer and skin quality defects and diagnosis. After lunch, generously sponsored by Boongarry Veterinary Services (Dr. Annabelle Olsson), some wild crocodile carcases had been sourced to allow participants to be instructed on necropsy and sample collection techniques. A special thanks to the staff from Berrimah Veterinary Laboratory (Ayrial Foster, John Bingham) for volunteering to assist delegates.

The CSG Steering Committee (SC) meeting was held on 15 April 2024 and was attended by 28 SC members in person as well as 7 online. There were also 45 observers. CSG Co-Chairs Charlie Manolis and Alejandro Larriera began the SC meeting with 1-minute silence in memory of CSG members and colleagues who had passed away since the previous working meeting in 2022. The SC meeting was followed by welcome drinks at Crocosaurus Cove, sponsored by Charles Darwin University. Those delegates who registered during the SC meeting went into the draw for a free "Cage of Death" dive at Crocosaurus Cove during the event. Matt Shirley, winner of the draw, donated the prize to Jailabdeen Ajji M and Charmaine Mutswiri, ticking an item off their bucket lists. Also included in the welcome drinks was a smoking ceremony by a member of the local indigenous community, at which attendees were invited to walk through the smoke and be "cleansed".

The Working Meeting began on 16 April with a 'Welcome to Country' from local Larrakia man, Lucas James. The CSG Co-Chairs then officially opened the meeting, before a snapshot of crocodile status within the three Australian States/ Territory with crocodiles was presented: Charlie Manolis (historical background), Ben Corey (Western Australia), Tim Clancy (Northern Territory) and Matt Brien (Queensland). Following this session, to celebrate the legacy of Professor Grahame Webb (previous CSG Chair), a conservation-style interview was held where delegates were treated to an insight into Grahame's early years and what helped form the strongly resolved personality that has successfully advocated for crocodilians and their conservation for decades. This was interspersed with videos and photos shared by CSG members with background music chosen from one of the favourite songs of recently departed CSG member, Hank Jenkins.

A session on monitoring and management in Southeast Asia and Oceania was preceded by a session on Australian crocodile management. The Honorable Kate Worden, Northern Territory Minister for the Environment, Climate Change and Water Security, outlined how important crocodiles are to the Northern Territory, as well as the delicate balance that is required to ensure public safety and tolerance. Other sessions included global crocodilian management, living with crocodilians, technology, general biology, toxicology, veterinary/farming, industry/trade, genetic technologies, taxonomy and systematics, zoos and behaviour.

Interspersed between the meeting sessions, working groups and thematic groups met [IUCN Red List Authority (Perran Ross, Sally Isberg), Veterinary Science (Paolo Martelli, Cathy Shilton), Industry and Trade (Christy Plott), Taxonomy and Zoos (Kent Vliet).

On the Wednesday night, the Gala Dinner and auction was held at Crocodylus Park. Dr. Ruth Elsey (USA) was chosen as the recipient of the "Castillo Award for Crocodile Conservation" for her more than 40 years of work with American alligators. Ruth was unable to attend the meeting, but she provided a pre-recorded acceptance speech that was played at the auction night. The CSG "Chair's Encouragement Award" was presented to Yusuke Fukuda (Australia). Both Ruth and Yusuke kindly donated the cash prizes associated with their awards ($US1000 and $US500, respectively) back to the CSG, to be used in the CSG's Student Research Assistance Scheme.

Following the presentations, the inaugural auction was held with auctioneer Shawn Heflick working the crowd to raise funds for crocodilian conservation projects. Assisted by a team of hard-working volunteers, he managed to extricate a record amount of $US27,897 from participants. The funds raised will be divided between:

- Laos Conservation Trust for Wildlife (LCTW), to support captive breeding and reintroduction efforts with the Siamese Crocodile (*Crocodylus siamensis*) in Lao PDR; and,
- a partnership between Threatened Species Conservation Alliance (THRESCOAL, Ghana) and Project Mecistops, where Emmanuel Amoah and Matt Shirley are implementing a conservation science capacity-building program for junior scientists across West Africa.

Thanks to everyone who donated and participated in this record-breaking event.

A cocktail poster session, sponsored by the Crocodilian Academy (Sally Isberg), was held on the Thursday night to encourage delegates to spend time talking to the authors of the works.

A highlight of the meeting was a special small feature length presentation by David White from Solar Whisper Daintree Cruises, who showed a series of short videos of crocodile behaviour he has documented over the last 20 years. These were shown just before the closing plenary, captivating the audience.

At the closing session, student prizes were awarded for oral presentations:

1st Kaitlin Barham: "Crocodile body temperature and behaviour is affected by long-term changes in climate".
2nd Jailabdeen Ajji M: "Chemo-signalling in Gharial - glandular chemistry of representative wild *Gavialis gangeticus* in the National Chambal Sanctuary, India".
3rd Helen Sung: "Out with the old, introgression with the new hybridization dynamics of *Crocodylus* spp. in Belize".

And poster presentations:

1st Clement S.S. Naabeh: "The vulnerable west African dwarf crocodile is worth conserving in urban ecosystems: evidence from Ghana"
2nd Tayhlia Casey, Mariana Campbell, Cameron Baker and Hamish Campbell: "Riparian vegetation vigour correlates with the growth of the Northern Territory estuarine crocodile population".
3rd Sofia Pierini, Melina Simoncini, Alejandro Larriera, Antonio Frutos, Alba Imhof, Florencia Valli, Evangelina Viotto and Carlos Piña: "Not all interactions are negative: Bird assemblages in the Broad-snouted caiman nests".

After the closing of the meeting, delegates were treated to a private tour of the Darwin Museum and Art Gallery and drinks watching the sun going down over Darwin Harbour, before having a banquet meal on the museum lawns. At this event, delegates were treated to Co-Chair Charlie Manolis accompanying local artist Darryl Barba on guitar and backup vocals.

On three mornings during the meeting, the Northern Territory Parks and Wildlife Crocodile Management Team took small groups of people on their routine monitoring routes. Participants were able to witness firsthand the skill and professionalism exhibited by this team as they removed crocodiles from the designated crocodile exclusion zone around Darwin Harbour, which plays a large part in public tolerance of living with an apex predator. Participants were able to talk to the Crocodile Management team members about the techniques, welfare considerations and training that will hopefully be useful in their own local contexts. Huge thanks to Tommy Nichols, Ian Hunt, Kelly Ewin, David Jacobsen, Jaylen Marshall and Kristen Hay for facilitating this unique experience.

The field trip was held on 20 April with two concurrent tours. Spectacular Crocodile Cruises was our field trip sponsor, and participants were treated to a river cruise showing this unique and interactive visitor experience that educates hundreds of thousands of visitors to "crocodile country" each year on the power and magnificence of these animals. Participants

were also treated to a tour on Corroboree Billabong with our conference partners, Corroboree Billabong Wetland Cruises. On this tour, participants were able to watch both Saltwater and Australian Freshwater crocodiles in the wild along with a plethora of birds and other wildlife.

A special mention needs to be made on the group of volunteers who gave up their time to ensure this conference ran smoothly (Michelle Franklin, Eilis Evans, Eva Rettler, Georgia Rankine, Holly Franklin, Jo Leonard, Kade Skelton, Kelly Barker, Saujan Gyawali, Skye Anderson and Tim Palmer). We are so grateful and appreciative of this assistance!

Overall an amazing conference that allowed those present to envisage successful crocodilian conservation into the future.

Dr. Sally Isberg, *Centre for Crocodile Research*

Figure 1. Delegates of CSG2024.

Figure 2. Veterinary Science Group co-Chair, Dr. Cathy Shilton, demonstrating how to conduct a necropsy on a crocodilian. Proper necropsy and data collection techniques will greatly assist in broadening our understanding of crocodilian health and disease in both wild and captive contexts. Photograph: Yusuke Fukuda.

Figure 3. Executive Committee at the Steering Committee meeting (from left: Sally Isberg, Alejandro Larriera, Charlie Manolis and Christine Lippai). Photograph: Yusuke Fukuda.

Figure 4. CSG Co-Chairs Charlie Manolis (left) and Alejandro Larriera (right). Photograph: Yusuke Fukuda.

Figure 5. To celebrate the legacy of ex-CSG Chair Professor Grahame Webb, a series of photographs and videos were shown interspersed with a conversation with Grahame. The session was titled "A morning tea with Grahame Webb" (from left: Sally Isberg, Alejandro Larriera, Grahame Webb and Chalie Manolis). Photograph: Yusuke Fukuda.

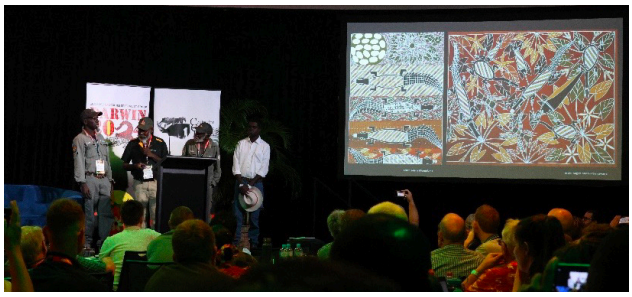

Figure 6. Rangers from Arafura Swamp Ranger Aboriginal Corporation presented on their work with crocodiles, including the impact of a satellite farm that provides employment and economic opportunities for their remote community. Photograph: Yusuke Fukuda.

Figure 7. Student award winners (from left: Co-Chair Alejandro Larriera, Taylia Casey (2nd poster), Clement Naabeh (1st poster), Helen Sung (3rd oral), Jailabdeen Ajji M (2nd oral), Kaitlin Barham (1st oral), Co-Chair Charlie Manolis). Photograph: Yusuke Fukuda.

Figure 8. CSG2024 organising committee (back row left-right: Yusuke Fukuda, Cameron Baker, Emily Moyles, Kristen Hay, Matt Brien, Paul Beri, Jasmin Moran, Michelle Franklin (volunteer co-ordinator), Co-Chairs Charlie Manolis and Alejandro Larriera; front row left-right: Sally Isberg, Kayla Robinson). Photograph: Jasmin Moran.

Figure 9. Delegates during a working meeting session. Photograph: Jasmin Moran.

Figure 10. Matt Brien, co-ordinator of the Drone workshop, introducing the day's agenda to the group.

Figure 11. CSG2024 delegates enjoying the Welcome drinks function at Crocosaurus Cove, sponsored by Charles Darwin University. Photographs: Jasmin Moran. Bottom right: Jailabdeen Ajji M and Charmaine Mutswiri, meeting Baru, one of Crocosaurus Cove's resident adult male Saltwater crocodiles, during a "Cage of Death" dive.

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Organizing Committee
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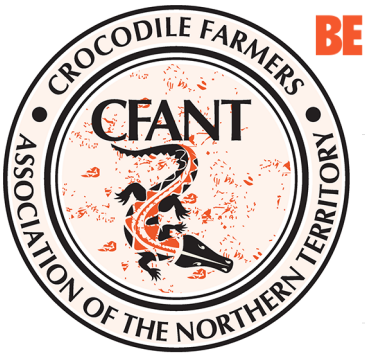
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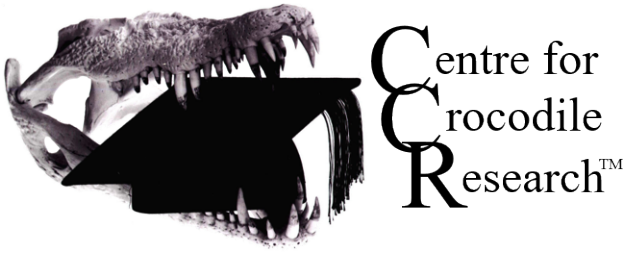
Centre for
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Crocodilian
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Spatial Population Structure of Saltwater Crocodiles in Australia and its Neighbouring Countries

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Abstract

Understanding spatial population structure is important to the management of a species with high mobility and international distributions, such as the Saltwater crocodile, *Crocodylus porosus*. This species is of substantial management interest for conservation, commercial exploitation, and human safety, and therefore, understanding patterns of its gene flow within and among countries is critical for management programs. We sampled *C. porosus* across northern Australia and Southeast Asia and analysed single nucleotide polymorphism data to quantify the genetic structure and identify the geographic features that contribute to it. There was a consistent pattern across a set of analyses that the highest level of population structure involved a split into two groups comprising Oceania (Australia and New Guinea) and Southeast Asia (Borneo, Java, Peninsular Malaysia, Mindanao, and Sumatra), broadly aligned with Sunda and Sahul shelves of the Last Glacial Maximum. Resistance surface and effective migration surface modellings for visualising spatially heterogeneous isolation-by-distance on geographic maps suggested that the genetic structure was affected by barriers such as deep straits and high mountains that effectively isolated the populations. Relatively high genetic connectivity was found between 1) the NT and WA in Australia, 2) QLD (Australia) and New Guinea south, 3) Kalimantan (Indonesia) and Sarawak (Malaysia), and 4) the Philippines and Sulawesi. We found no genetic evidence of gene flow between Australia and Timor-Leste, which has been posited as a possible explanation for apparently increasing crocodile attacks in Timor-Leste. Intergovernmental cooperation, such as strategic partnership agreements, may be beneficial for more effective management of crocodiles where individuals likely migrate between different jurisdictions.

An Update on Philippine Crocodile Conservation in Northeast Luzon

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Abstract

One of the very few areas with a remaining wild Philippine crocodile (*Crocodylus mindorensis*) population is Isabela Province in Northeast Luzon. Here, a research and conservation program for this species has been implemented since 1999 by the Mabuwaya Foundation. There are two distinct separated populations: along the coast of Isabela where the Philippine crocodiles occurs sympatrically with a small remnant population of *Crocodylus porosus*, and in the foothills of the Sierra Madre mountains in Cagayan Valley, notably in the municipality of San Mariano. Philippine crocodile population size has been monitored since 2000. Philippine crocodile habitat use, home ranges, diets and reproduction have been studied during specific targeted research projects, in collaboration with students. Communication and education campaigns are continuously implemented and their impact on community support for crocodile conservation is measured. Eight local crocodile sanctuaries have been established which are being managed by communities and protected by local wardens. A nest protection and head-start program are in place to increase survival rates of eggs and hatchlings. Despite successes with this science-based local conservation program, the crocodile population remains low with about 100 individuals in the wild. This paper presents the current status of the program and discusses continued threats to wild Philippine crocodiles in Northeast Luzon and ways to move forward with Philippine crocodile conservation.

Restoring the Critically Endangered Siamese Crocodile to the Xe Champhone Wetlands in Lao PDR (2019-2023)

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Abstract

The Siamese Crocodile (*Crocodylus siamensis*), classified as Critically Endangered on the IUCN Red List, is considered one of the most endangered crocodilians in the world. Wild populations were decimated by decades of hunting for skins and meat, habitat loss and over-collecting to stock commercial crocodile farms. Fewer than 1000 adults now survive in the wild, and most populations are small, fragmented and of questionable viability. Surveys conducted by Wildlife Conservation Society (WCS) in collaboration with local communities and Government of Lao (GOL) in the early 2000s identified a population of Siamese Crocodiles inhabiting the Xe Champhone Wetlands (XCW) in Savannakhet Province. The survival of this population was attributed to *de facto* protection afforded by local beliefs that crocodiles embody the spirits of dead ancestors. A species conservation program initiated in 2011 was terminated in 2013 when donor support was unexpectedly withdrawn. During the initial phase of the project, 65 crocodiles were successfully head-started and released. In 2019-20, WCS assumed an advisory role to the GOL for the XCW and crocodile conservation efforts resumed. Our objective is the restoration of a functional metapopulation of Siamese crocodiles in XCW. To this end we work closely with Village Conservation Teams to conduct crocodile nest surveys (including the use of drones), collect and incubate eggs, head-start hatchlings, and release larger juveniles. Since 2019, we have collected clutches from 25 crocodile nests. We incubate eggs in Styrofoam boxes (McCaskill Chambers) under ambient temperatures; 272 eggs have successfully hatched. Hatchlings are head-started for 32 months before being transferred to a temporary acclimation pen and later released. A total of 78 head-started juveniles were liberated in 2022 and 2023 with an additional 39 juveniles slated for release in March 2024. Reproduction by a female hatched in 2012 and released in 2014 was confirmed in 2022.

Securing the Future of Siamese Crocodiles: Genomic Conservation and Bioresource Guidelines

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Abstract

Hybridization between the Critically Endangered Siamese crocodile (*Crocodylus siamensis*) and the IUCN-listed Least Concern Saltwater crocodile (*C. porosus*) in captive populations presents substantial challenges for conservation and reintroduction efforts. Previous reliance on microsatellite and mitochondrial DNA data for hybrid identification has limitations due to potential biases and genetic drift within populations. In this study, DArT sequencing identifies genome-wide single nucleotide polymorphisms (SNPs) in both species, confirming genetic distinctions between parental species and hybrid offspring. Comparison with Australian Saltwater crocodiles assesses the distribution of species-specific SNPs. Various analytical techniques determine hybridization extent and validate species-specific SNPs through PCR. The integrated approach addresses methodological limitations and informs conservation prioritization, aiding Siamese crocodile reintroduction into Kaeng Krachan National Park. We emphasize selecting genetically suitable candidates and utilizing bioresources from crocodile farms as genetic stock. Our work establishes five crucial conservation guidelines, considers landscape and habitat suitability for reintroduction, and addresses human-crocodile conflict. These efforts contribute directly to conserving critically endangered Siamese crocodiles in Thailand.

The Next Decade of Management of the Saltwater Crocodile (*Crocodylus porosus*) in the Northern Territory: Where To Now for a Conservation Success Story

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Abstract

The management of the Saltwater Crocodile (*Crocodylus porosus*) in the Northern Territory (NT) over the past 50 years is recognised as a resounding conservation success story. In the time since European Settlement, three distinct phases of crocodile management in the NT can be identified (see Webb 2020). Firstly, there was a period of unregulated hunting which greatly intensified after the Second World War up until the early 1970s. In response Saltwater Crocodile were protected under law in 1971 and there followed a period of recovery up the early 1980s when, due to the strong population rebound concerns were raised about the danger posed by crocodiles. With the rise in both fatal and non-fatal attacks, there was public pressure to reverse protection measures. However, experts like Grahame Webb, argued for a trial and eventually the full-scale adoption of a sustainable use policy that was implemented through a series of Management Programs for the species dating back to 1987. These Programs have underpinned the successful recovery of the species, the development of thriving consumptive and non-consumptive use industries and widespread broad public support for crocodile conservation. However, as we move into a fourth phase characterised by the species being at carrying capacity, it is timely to both re-visit management objectives and the actions required for their delivery whilst maintaining a broad social licence for the Program. The revised Management Program aims to balance conservation and sustainability of any harvest, industry growth and maximizing economic benefits to landowners (especially Traditional Owners), to promote long-term species conservation and the protection of habitat. In addition, it provides the blueprint for the mitigation of risk to humans and livelihoods posed by this iconic species in an increasingly complex regulatory space. A key feature is the need to enhance detection and surveillance activities to protect human safety especially in proximity to population centres.

Introduction

The Management Program for the Saltwater crocodile (*Crocodylus porosus*) in the Northern Territory (NT) is a legal instrument under the Territory Parks and Wildlife Conservation Act 1976 (TPWC Act). Its purpose is to ensure the *"protection, conservation, sustainable use, control and management"* of Saltwater crocodile in accordance with the TPWC Act for the benefit of current and future generations of Territorians. It acknowledges the socio-economic value of the annual harvest of Saltwater crocodile to the NT as well as the very real threat this species poses to human life.

There are two endemic species of crocodile in the NT, the Saltwater crocodile and the Freshwater crocodile *Crocodylus johnstoni.* The Saltwater crocodile has a wide distribution throughout the Indo-Pacific region including through Northern Australia (IUCN 2019). The NT Government recently undertook a review and revision of the Management Program for this species in that jurisdiction. The Management Program covers the conservation and management of wild crocodiles for multiple community benefits and the regulation of the crocodile farming industry including the export of legally sourced product under international wildlife trade rules and procedures. There is currently no farming of Freshwater crocodile; however, some management activities such as monitoring and management of threat to human safety involve both species.

Saltwater crocodile are recognised as a valuable commercial resource, generating wealth and employment which promotes their conservation. The tourism value of crocodiles both in the wild and in captivity also generates significant economic activity. Economic benefits from crocodile harvest and tourism value flow to landowners and particularly indigenous communities, encouraging the protection and management of wetland habitats (Ernst and Young 2016; Clancy and Fukuda 2020; Webb 2021).

Background

The Saltwater crocodile is the largest living crocodilian species. The species has a wide distribution throughout the Indo-Pacific region including through northern Australia (Webb *et al*. 2010). It is an apex predators that will attack humans, and therefore, its co-existence with people presents significant challenges for the NT community. Crocodiles also provide significant economic opportunities, are a valuable resource to both Indigenous and non-Indigenous people in northern Australia, and an icon for tourism within the Top End of the Territory (CFANT 2024).

During period post the second World War up until the early 1970s, degradation of habitat and hunting for the commercial skin trade significantly depleted populations of Saltwater crocodiles throughout the species' range including in Australia (Webb and Manolis 1989; Webb *et al*. 2010). In the NT, intensive hunting depleted the wild population to the point of extinction and consequently, the species was fully protected in 1971 (Webb *et al*. 1984; Webb 2020; Fig. 1).

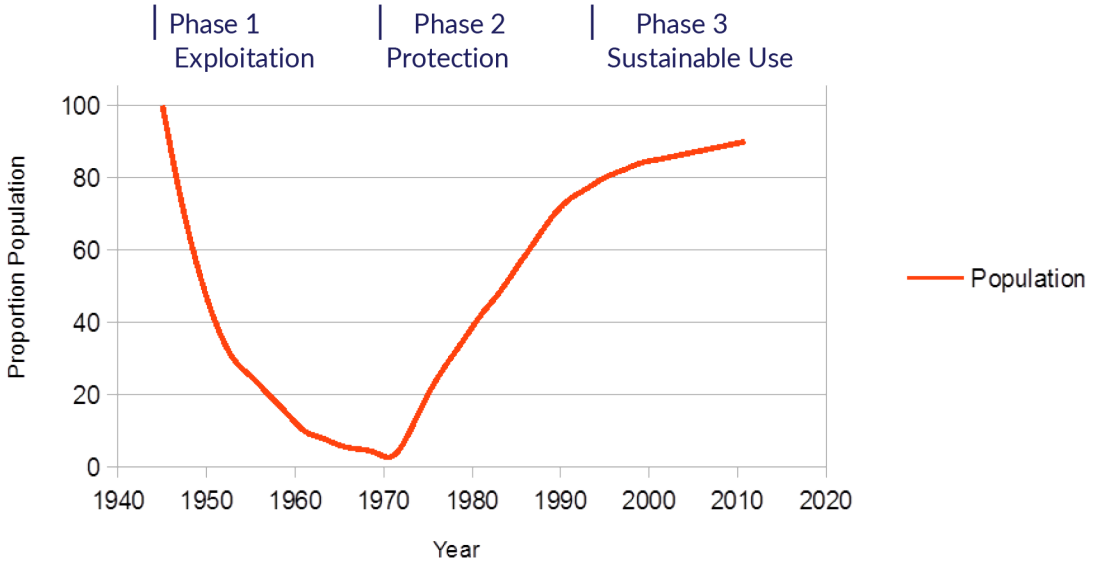

Figure 1. Three phases of NT Saltwater Crocodile Management and representation of impact on relative population size (after Webb 2020).

By the early 1980s the population had increased from an estimated low of perhaps fewer than 3000 to around 30,000 animals. There were calls to end the species protection, following on from a number of attacks (including fatalities) with a proposal to return to widespread culling (Webb *et al*. 1984).

In 1985 Australia was successful in transferring its population of Saltwater crocodile from Appendix I to Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) specifically for ranching, so that farms could export the skins produced from harvested eggs (Webb 2021). In 1987, the first NT Crocodile Management Program was approved by the Commonwealth and skins derived from the ranching program began to be exported. In 1994, Australia obtained an unrestricted CITES Appendix-II listing to allow landowners with crocodiles, but no nesting habitat, to also receive commercial benefits from crocodiles through a wild harvest (Webb 2021).

Saltwater crocodiles are now recognised as a valuable commercial resource, generating wealth and employment which promotes their conservation. The Management Program no longer has as its core aim the recovery of the Saltwater crocodile population, but rather the continued growth of a prosperous, sustainable crocodile farming industry as the key driver for Saltwater crocodile conservation. The tourism value of crocodiles both in the wild and in captivity also generates significant economic activity (Ernst and Young 2016). Economic benefits from crocodile harvest and tourism value flow to landowners and particularly indigenous communities, encouraging the protection and management of wetland habitats.

Actions that favour retaining a high natural abundance of a dangerous predator such as Saltwater crocodiles also bring a heightened responsibility for public awareness and education. As both human and crocodile populations in the Northern Territory have grown, the potential for human-crocodile conflict has increased.

The key drivers for the Management Program are therefore:

i) A vibrant and expanding crocodile farming industry;

ii) A recognition that harvest levels have not been detrimental to the recovery of the species and that the crocodile population has recovered to near carrying capacity;

iii) An increasing demand from landholders, particularly Indigenous landholders, to derive economic benefit from crocodiles;

iv) An increasing trend in the number of negative interactions between crocodiles and people; and,

v) An increasing need for public awareness about crocodiles.

Policy Context

Whilst the management of Saltwater crocodiles in the NT is motivated by multiple drivers, two dominant policy threads are apparent; firstly the sustainable use and conservation of the species, and secondly, the need to minimise the risk the species poses to human life and livelihoods. The IUCN recognizes that the wise and sustainable use of wildlife can be both consistent with and contribute directly to species conservation (IUCN-SSC 2012). This position is dependent on the social and economic benefits derived from use of species providing incentives to conserve species and their habitats. The NT Government has for many years fostered the crocodile farming industry and in recent years, the crocodile industry has invested significantly in crocodile farming infrastructure to increase its capacity. The industry has grown in conjunction with the crocodile population, to the point where the NT now leads the world in the production of high quality Saltwater crocodile skins (CFANT 2024).

The increase in the value in the crocodile industry has been concomitant with the increase in the wild Saltwater crocodile population. A recent review of the impacts of harvesting of the NT Saltwater crocodile population trend found that the species is secure by any IUCN criteria used to assess threatened species status (Clancy and Fukuda 2020). The population is large, although previous unregulated harvest had driven numbers down, and has been increasing and/or stable across its range for a considerable period of time. In the NT, the species has a broad geographic range, or extent of occurrence relative to the IUCN threshold and has around 20 times the area of utilised, good quality habitat (area of occupancy) than would be considered to be of immediate conservation concern (Clancy and Fukuda 2020; IUCN 2019).

The TPWC Act recognises that the protection of the safety and welfare of the public is preeminent eg Section 56 (1)(g) governing the granting and refusal of permits. In a practical sense, the policy position of the NT Government is that any action that is necessary to protect human safety and wellbeing is compliant with the Management Program noting that, where possible, both environmental harm and adverse animal welfare impacts are to be avoided. Further, given the clear risk this species poses to human safety and welfare, management is targeted to mitigate this risk.

Fukuda *et al*. (2014) represents the most comprehensive investigation of crocodile-human interaction in the NT. The key findings included an observed steady increase in the number of non-fatal crocodile attacks over time, which is strongly related to the increasing human and crocodile populations, and the increasing size of individuals in the crocodile population. Fukuda *et al*. (2014) provides recommendations for reducing human-crocodile conflict, including strategic and efficient management of problem crocodiles and continuous public education. The study also highlights the importance of improved communication, especially in remote areas, in reporting and mitigating crocodile attacks.

These two policy drivers may seem to be conflicting, and whilst they are preeminent; they are not the only considerations, as the management program attempts to balance a range of values (eg crocodile based tourism). Therefore, both the development of policies and the undertaking of actions covered by the management program has the potential to be highly contentious. With respect to managing a species like the Saltwater crocodile there is a tendency for stakeholders (and the public more broadly) to gravitate to the extremes of the management spectrum. This sets up a potential false dichotomy between removing crocodiles, the presence of which is undoubtedly a real threat to human life, and the protection of all individual crocodiles, recognising the intrinsic value of the iconic species (Fig. 2). The NT Government has attempted to take a more nuanced approach, recognising all values/stakeholders and a continual improvement mind set as opposed to a (unrealistic) "magic bullet" solution. As part of the process for developing the revised program, in addition to direct consultation meetings with identified key stakeholder groups, a consultation draft program was formally released for public consideration. A wide variety of views were expressed by the public; however, the majority of respondents (58%) agreed with the approach taken under the existing policy framework (DEPWS, unpublished data). A solid minority advocated for a much greater focus on safety to people (*c*. 19%) and that there should be a reduction the crocodile population (*c*. 25%).

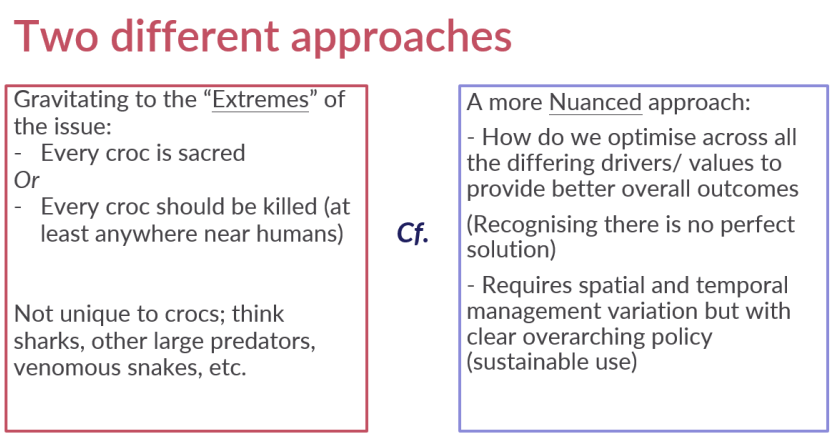

Figure 2. Two different ways at looking at a complex policy problem like Saltwater crocodile management. See text for details.

Management Program for the Saltwater Crocodile (*Crocodylus porosus*) in the Northern Territory of Australia, 2024-2034

To achieve the aims and objectives of the management program, NT Government agencies in conjunction with the crocodile industry and land managers will implement a range of management practices and policies to regulate the harvest, farming and trade of Saltwater crocodiles in accordance with the *TPWC Act* and the *EPBC Act* and manage the risk to human safety whilst meeting the conservation requirements for the species. There are a raft of permitting and reporting requirements that must be complied with by industry to meet not only NT requirements but allow for access to international markets under CITES.

The management program imposes harvest quotas on both the number of eggs and live animals that can be taken by industry. Harvest levels are based on the best available modelling (Fukuda *et al.* 2021) and take a relative conservative approach to allow for the inherent uncertainties due to environmental variation. Whilst Fukuda *et al.* (2021) modelled the impact of environmental stochasticity (variability) and indicated that a higher rate of egg removal may still be within sustainability bounds; they cautioned on the need for better data for estimation of vital population parameters. The full harvest quota may not be allocated in any year where there is insufficient demonstrated demand from industry. Most of the animals taken under problem crocodile management activities may be utilised for commercial return and are included as part of the overall live take. This is to ensure the policy goals of maximising value of any removals to land holders (in the case of live crocodiles removed from Aboriginal and pastoral lands). It also provides options for use of the animals taken by the Department's crocodile removal programs (eg females taken are often used as breeding stock on farms). The maximum number of eggs and live animals that may be used commercially under the Management Program must directly align with the associated Commonwealth Saltwater Crocodile Wildlife Trade Management Plan 2016-2020 [currently set at 90,000 eggs and 1200 live animals; Clancy and Fukuda (2020)].

With respect to management of the risk posed by crocodiles to human safety, there are a number of tools available to managers (Table 1). The NT Saltwater Crocodile Risk Management Framework (Parks 2021) sets the broad guiding principles for the application of tools including delineation of areas with differing management intent. The risk management framework is based on an assessment of:

- Frequency - How often crocodiles are found in the area
- Proximity - How close an area is to known crocodile breeding areas
- Population - The number of people living or recreating in an area
- Probability - The likelihood or chance of a human-crocodile interaction occurring
- Practicality - The accessibility of an area, the risk to staff and the likelihood of a human entering the area

Three spatially delimited tiers of management intent are established. These can be characterised as follows:

a) Barrier and Removal - Identified exclusion zones where there is no tolerance of Saltwater crocodiles (small and discrete/ defendable water points where swimming is permitted/tolerated usually on a park and that is actively managed on a seasonal basis);
b) Active Removal - Intensively managed (strategic cull) areas (Darwin harbour and the like) where active removal occurs; and,
c) General management - Problem crocodiles are removed on a tactical basis to address an imminent threat (e.g. remove a crocodile that is too close to a settlement or targeting livestock on a pastoral property) but there is no expectation of a significant change to the underlying risk profile.

The specific management aims/responses differ across the three zones of management (Table 2).

Based on the review and input from stakeholder groups a number of amendments and enhancements to the previous management program were identified and were integrated into the revised program (Table 3). Importantly, critical areas of research and development have been identified as a priority for investment over the operating period of the Management Program with both high levels of importance and urgency with a recent government commitment to fund such activities.

The objective to enhance Aboriginal livelihoods requires additional R&D to progress. Increasing the capacity for habitat management in priority production areas (pests and weeds) focussing on providing capacity to enhance safety and economic returns from egg collection on Aboriginal land is an area worthy of further investigation with preliminary data suggest feral species like buffalo may be impacting on crocodile nesting habitat.

Table 1. Current toolbox available to deliver management objectives identifying potential tools by broad management class. Not all identified tools are management ready and may require further R&D to determine practicalities of implementation.

Management Action	Description
Assessment	
Point Detection	Sampling of point water sources (usually relatively closed) for presence of crocodile. Includes: eDNA/radar, etc.; floats, spotlighting, camera traps
Site Surveillance	Short-term oversight usually under site specific Work Place Health and Safety protocols, for example Workers needing to enter water to inspect infrastructure. Potential for video and camera trap type approach
Population Monitoring	Gathering information on Saltwater Crocodile density and dispersion. Current river surveys and broad scale flood plain surveys (occupancy modelling). Historically been helicopter surveys of rivers (large croc bias). Future remote sensing, drones, aerial surveillance, etc.
Incident Reporting	Collection on priority information on human-Saltwater Crocodile interactions to better understand risks and drivers
Avoidance	
Signage	Advisory signs in high risk areas
Zoning	Identifying suitable areas in low value Saltwater crocodile habitat
Infrastructure	Provision of Saltwater crocodile safe alternatives to risk activities like foraging and swimming
Prohibition	
Banning high risk activities	Disallowing of specific activities, eg swimming in designated areas/diving
Controlling access to priority areas	Restricting access to high risk areas
Removal	
Fixed traps	Standard trapping and relocation/removal technique
Harpoon Runs	As per standard Croc Team approach
Culling	Actively trying to lower overall Saltwater crocodile population
Barriers	Exploiting natural barriers to movement. Prevention of Saltwater Crocodile from re-entering areas where they can be removed from (usually seasonal) see Parks (2021)
Education	
Training	Upskilling of agents (eg Ranger Groups) to deliver aspects of management program
Be Crocwise	*Be Crocwise* is an established education program see Parks (2021)
Other targeted programs	Compliance advice to impacted stakeholders
Research, monitoring and evaluation	
Research	Research program to address priority knowledge gaps
Review	Ongoing monitoring and evaluation of efficacy (effectiveness and efficiency) of risk mitigation policies/programs

Table 2. Management Aims and approach for the three broad management zones identified in the NT Government's Saltwater Crocodile Risk Management Framework.

	MANAGEMENT ZONE		
	Barrier and removal	Active removal	General management
General management approach	Complete removal and maintain barriers to crocodiles	Maximum removal of all crocodiles	Removal of problem crocodiles only
Level of people-water interaction	High (i.e. predominantly swimming)	Moderate (i.e. water-based recreation e.g. kayaking, surfing, some swimming)	Low (e.g. camping, fishing)
Target crocodile numbers	Absent	Minimal	Natural
Management Activities: • Control public access to water	Yes	No	No
• Level of signage	High	Some	Some
• Public informed when crocodiles seen	Yes	Yes	Problem crocodiles only
• Awareness campaign	Yes	Yes	Yes
Risk of attack following management actions	Low	Moderate	High

Table 3. Overview of changes/enhancements to be implemented in the 2024-2034 Saltwater Crocodile Management Program.

Short Descriptor	Actions Required	Outcome
1. Information for Management	Implementation of robust monitoring and detection program to ensure sustainability and provide relevant data to underpin management	Enhanced detection, surveillance and monitoring program
2. Protect life / Livelihoods	Implementation of revised croc risk framework	Management of crocodiles according to their location (eg urban versus remote areas). Expand and intensify the removal program in key areas. Comprehensive public awareness program to deliver a clear message around living with crocodiles. (ie 'Be Crocwise')
3. Aboriginal benefits	Provision of support to Aboriginal organisations to increase participation in crocodile management and associated economic opportunities	Greater participation in value chain (e.g. new farms). New tourism ventures and other products/services linked to cultural values
4. Appropriate Regulation of both consumptive and non-consumptive uses	Implement changes to permit system to improve allocation of crocodiles/ eggs to farms Implement controls on export of crocodile products Ensure relevant legislative and best-practice requirements for animal welfare and biosecurity are met	Better utilisation of egg quota. Better linkage of landholders with permitted operators
5. Research and Development and Deployment for management /use	Development of comprehensive R, D & D program e.g. Moving eDNA techniques from proof of concept to an at-scale management tool	Improved detection and surveillance programs

Discussion

The management of Saltwater crocodile in the NT aims to achieve a balance between conservation and sustainability of any harvest, wealth generation through industry growth and delivery of economic benefits to landowners, and the mitigation of risk to humans and livelihoods posed by this iconic species. The Management Program meets global best practice standards in sustainable wildlife use. This occurs within the framework of the NT's broader sustainable use of wildlife ethos. It needs to be recognized that the management strategies and policies are context dependent and may not be directly transferrable to other jurisdictions.

The successful implementation of a complex management program for crocodiles which has a diverse set of values and objectives requires a strong social licence. The community must have confidence in government regulatory and management arrangements that protect the species and ensure public safety. There is a need to better understand and track drivers of social licence and to ensure assumptions on community knowledge of risks and appropriate responses are valid and appropriate management responses are in place. The Management Program has been written to cover the next decade of management of the species to provide an ongoing commitment to the core objective. However, there will be a formal review in the fifth year of operation, informed by annual monitoring outcomes and ongoing stakeholder input to ensure the directions and underpinning management actions remain appropriate and can be updated based on new information.

Through this Management Program and the *Northern Territory Crocodile Farming Industry Strategic Plan 2024-33*, the NT Government will continue to support industry to maximise the investment, commercial activity and employment generated through crocodiles. The farming industry's vision is for the NT to continue as the world leader in the reliable production of the highest quality Saltwater crocodile skins, and for the industry to grow its role as a significant contributor to the economic and social prosperity of the NT (CFANT 2024). In doing so, it is hoped that there will be an enduring commitment to maintain crocodile habitat on private lands so the species' conservation is not solely reliant on protection on dedicated reserves.

Acknowledgments

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References

CFANT (2024). Northern Territory Crocodile Farming Industry Strategic Plan 2024-33. NTG and CFANT: Darwin.

Clancy, T. and Fukuda, Y. (2020). NT Saltwater Crocodile (*Crocodylus porosus*) Wildlife Trade Management Plan: 2018-2019 Monitoring Report and Review. Clancy TF and Fukuda, Y (2020).

Ernst and Young (2016). Economic Value of the Crocodile Farming Industry to the NT (Final Report. report to NT Dept. of Trade, Business and Innovation). Australia.

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

Fukuda, Y., Webb, G., Edwards, G., Saalfeld, K. and Whitehead, P. (2021). Harvesting predators: Simulation of population recovery and controlled harvest of Saltwater crocodiles *Crocodylus porosus*. Wildlife Research 48: 252-263.

Webb, G.J.W., Manolis, C., Brien, M.L., Balaguera-Reina, S.A. and Isberg, S. (2019). *Crocodylus porosus*: The IUCN Red List of Threatened Species 2021: e.T5668A3047556.

IUCN-SSC (2012). IUCN SSC Guiding Principles on Trophy Hunting as a Tool for Creating Conservation Incentives (No. Ver. 1.0). IUCN: Gland.

Parks, W.C. (2021). Northern Territory Saltwater Crocodile (*Crocodylus porosus*) Risk Management Framework 2021-2026.

Webb, G. (2021). Saltwater Crocodiles of the Northern Territory: Past, Present and Future. Wildlife Management International: Darwin.

Webb, G.J.W. (2020). History of crocodile management in the Northern Territory of Australia.: A conservation success story (Book Extract). Wildlife Management International: Darwin.

Environmental Influences on the Dispersal by Saltwater Crocodiles in the Northern Territory, Australia

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Abstract

Saltwater crocodiles (*Crocodylus porosus*) exhibit remarkable adaptability to saline, brackish, and freshwater environments, yet their movement and dispersal patterns remain poorly understood. This study focused on their movement in the Northern Territory (NT) of Australia. First, genetic analysis and satellite tracking revealed that geographical barriers, particularly the Cobourg Peninsula, disrupt crocodile homing. Crocodiles relocated across the peninsula showed reluctance to return to their capture sites, leading to potential genetic separation into two distinct groups in then NT. More detailed genetic analyses across the NT indicated that about 42% of crocodiles in each population were migrants from another river within 200 km while some other individuals travelled longer distances up to 700 km. Crocodile dispersal, categorized into emigration, movement, and settlement, was found to be heavily influenced by environmental factors, particularly habitat quality for nesting. Suitable breeding habitat availability in both source and destination locations played a pivotal role in emigration and settlement. Crocodiles were more likely to emigrate from rivers with abundant breeding habitat, indicating resource competition. Conversely, higher immigration rates occurred in rivers with limited breeding habitat, suggesting crocodiles sought new territories with available resources. Given the extensive dispersal range, individual catchments or hydrographic regions that combine two or three adjacent catchments are and appropriate scale for population management.

Implications of Past and Present Genetic Connectivity for Management of the Saltwater Crocodile (*Crocodylus porosus*)

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Abstract

Effective management of protected species requires information on appropriate evolutionary and geographic population boundaries and knowledge of how the physical environment and life-history traits combine to shape the population structure and connectivity. Saltwater crocodiles (*Crocodylus porosus*) are the largest and most widely distributed of living crocodilians, extending from Sri Lanka to Southeast Asia and down to northern Australia. Given the long-distance movement capabilities reported for *C. porosus*, management units are hypothesised to be highly connected by migration. However, the magnitude, scale, and consistency of connection across managed populations are not fully understood. Here we used an efficient genotyping method that combines DArTseq and sequence capture to survey ≈3000 high-quality genome-wide single nucleotide polymorphisms from 1176 *C. porosus* sampled across nearly the entire range of the species in Queensland, Australia. We investigated historical and present-day connectivity patterns using fixation and diversity indices coupled with clustering methods and the spatial distribution of kin pairs. We inferred kinship using forward simulation coupled with a kinship estimation method that is robust to unspecified population structure. The results demonstrated that the *C. porosus* population in Queensland has substantial genetic structure with six broad populations correlated with geographical location. The rate of gene flow was highly correlated with spatial distance, with greater differentiation along the east coast compared to the west. Kinship analyses revealed evidence of reproductive philopatry and limited dispersal, with approximately 90% of reported first and second-degree relatives showing a pairwise distance of <50 km between sampling locations. Given the limited dispersal, limited extent of suitable habitat, low densities of crocodiles and the high proportion of immature animals in the population, future management and conservation interventions should be considered at both regional and state-wide scales.

Estuarine Crocodile (*Crocodylus porosus*) Population Status, Distribution and Changes in Abundance in Queensland, Australia (1979-2019)

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Abstract

Queensland's Estuarine crocodile population was driven to commercial extinction by unregulated hunting for skins in the post-World War II era. We have little reliable information about population numbers when protection was imposed in 1974 but suspect, in hindsight, it would have been driven to very low levels because the population is predominantly riverine and vulnerable to hunters. From 2016-19, Queensland undertook a State-wide assessment of crocodile numbers using well-established survey methods for boat and helicopter counts - the first large-scale and systematic surveys in over a decade. The data was analysed together with all historical survey records collected since 1979. Data from 540 historical surveys and 1327 individual survey transects were evaluated for quality and 514 of high enough quality were selected for analysis. Every sighting record (over 20,000). From 2016-19, 56 boat surveys were conducted on 42 rivers covering 2200 km and 14 helicopter surveys in 27 rivers covering 2500 km. The Estuarine crocodile population has increased in density across its entire range from 0.51 non-hatchlings (NH)/km in 1984-89 to 0.99 NH/km in 2016-19. The State-wide rate of population increase was 2.2% from 1984-89 to 2016-19, corresponding to a doubling time of 31 years. This low rate of increase was influenced by slow increases in climatically marginal regions and early asymptoting of the population after rapid increase in the best habitats. The wide latitudinal range of crocodile habitat influences population density and rates of increase very strongly. Detailed analysis of the extent of crocodile habitat in Queensland allowed a population estimate for 2016-19 of 20-30,000, 40% of them in north-western Cape York.

Estuarine Crocodile (*Crocodylus porosus*) Population along the Queensland Populated East Coast, and Implications for Management

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Abstract

Queensland's human population is heavily concentrated along the east coast between Brisbane and Cooktown. Estuarine crocodiles inhabit waterways along 2100 km of that coastline, from Rockhampton in the south to Cooktown in the north. This 'populated east coast' (PEC) accommodates 48% of Queensland's crocodile-inhabitable waterways and 22% of its Estuarine crocodile population. It has a human population of some 920,000 in 2022 increasing at a simple geometric rate of about 1.3% p.a. between 1996 and 2018. The PEC crocodile population increased by 3.4% p.a. over the same period. Some 70% of the PEC's crocodile population is found between Ingham and Cooktown (the northern PEC region) and about 80% of sighting reports and incidents requiring action arise from there. In contrast, extensive helicopter surveys south of Townsville have shown that crocodiles are at very low densities (except in the Proserpine River) and that there is no resident population and virtually no crocodiles south of the Fitzroy River. The simple geometric rate of increase of the crocodile population in the northern PEC has declined from 0.051 between 1984-89 and 1994-99 to 0.032 between 1994-99 and 2016-19. Some populations show signs they may be asymptoting. Estimates of size-class distribution across Queensland's bioregions show a distinct decline in the proportion of smaller crocodiles as populations have increased, as expected based on the NT's experience. In the northern PEC, however, the proportion of larger crocodiles has not increased - perhaps reflecting the impact of the crocodile management program that selectively targets animals over 2 m for removal from populated areas. With increasing number crocodile sighting reports in Queensland, this has presented a challenging paradigm for Government, balancing public opinion with pragmatic management action.

Preliminary Information from Field Studies of Estuarine Crocodiles

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Abstract

Much of the information on the nesting biology of Estuarine crocodiles (*Crocodylus porosus*) comes from the Northern Territory of Australia, with only scattered data from Southeast Asia and other Australian States. Nesting habitat is typified by riverbanks and swamplands, and nesting materials comprise various species of grasses, sedge, and ferns. We present preliminary data from a study of Estuarine crocodiles inhabiting perched silica sand-dune lakes at the tip of Cape York Peninsula, Queensland, Australia. We undertook nesting surveys for crocodiles inhabiting these and nearby systems, established camera traps on a sample of nests, and fitted satellite tracking devices to six adult specimens (2 males, 4 females). Surprisingly, crocodiles reach relatively high-densities in these sand-dune systems, and are breeding there. During the 2022-23 wet season, we recorded 110 crocodile nests in northern Cape York, with 5 being located on the edge of silica sand-dune lakes. Female crocodiles in the lakes build nests out of sand, leaf litter, and other vegetation growing on the lake edges and appear to have small clutches of eggs (mean= 22) relative to crocodiles nesting in other nearby habitats. Camera traps revealed a range of native and invasive nest predators, such as monitor lizards, birds of prey, and feral pigs. Preliminary satellite data (4 months) indicate that females remain in the lakes, while males walk considerable distances (>1 km) across land through rainforest and tropical woodlands between the different lakes (presumably for the purpose of mating). We present and discuss some of these preliminary data.

The Once and Future Gharial: Retrospective and Future Projections to Improve Headstarting Success in Nepal

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Abstract

Headstarting is a commonly used conservation intervention for Gharial, with at least 14 programs of rear-and-release used throughout their range in India and Nepal. The theoretical underpinning of headstarting is to rear small life stages in captivity, thus avoiding high predation mortality in the wild and improving rates of recruitment into the adult population. Despite the widespread use of the technique in Gharial, there is limited evidence that headstarting contributes to population recovery. For evidence-based Gharial conservation, it is necessary to improve understanding of the past and potential contribution of headstarting as a conservation tool. Our understanding of a population into which headstarts are released can be outlined by a model of that system, representing our current theoretical understanding to create predictions of past dynamics, which can be tested against historical population data. This retrospective model can then be used to develop predictive models on which to base management decisions. To investigate the use of models as part of an adaptive management approach to Gharial conservation, we present a case study of the Chitwan population in Nepal. I will discuss work that uses management, population, mortality and behavioural data to parameterize two models. The first model retrospectively considers how past changes in the management program have led to changing success in the headstarting program in Chitwan. The second model predicts future scenarios under different potential management interventions, identifying changes that should lead to improved population recovery. Taken together, the models show that headstarting alone is insufficient for population recovery in Gharial in Chitwan, but with improved post-release survival it can be an essential tool to restore the adult population to a self-sustaining level. Our models can be used as a key component of a future adaptive management approach, informing management decisions, and identifying areas of uncertainty as key research priorities.

Creating Africa's First Protected Area for the Slender-snouted Crocodiles Upstream of the Tano River, Ghana

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Abstract

The slender-snouted crocodile, one of the most endangered crocodilians globally, has seen a drastic decline in population by 70-90% over the past 75 years due to hunting and habitat destruction. Recent studies have further divided the already dwindling population into two distinct species: the West African slender-snouted crocodile (*Mecistops cataphractus*) and the Central African slender-snouted crocodile (*Mecistops leptorhynchus*). Of these, *M. cataphractus* is more threatened, with a highly depleted and fragmented population. The upstream portion of the Tano River in the Techiman Municipal currently harbours the largest population of M. cataphractus outside of protected areas and a significant proportion of the remaining wild population in West Africa. Our recent population surveys (December 2023-January 2024) recorded 701 direct encounters, with a mean encounter rate of 5.61 crocodiles per km, marking the highest recorded population for the species in the past three decades. The existing traditional protection that prohibits their consumption has helped preserve this population. However, the rapid conversion of nesting habitats into agricultural fields poses a long-term threat to their protection. To address this, we are working on creating Africa's first protected area for slender-snouted crocodiles through grassroots approaches. We aim to establish a community-based crocodile sanctuary that will legally protect a 40-m riparian buffer on both sides of the river. This project is well underway, with all stakeholders, including landowners, agreeing to the sanctuary's establishment. As part of this initiative, 400 landowners will benefit from alternative livelihood schemes to reduce pressure on the habitat and bolster their income. Community patrols will be established to monitor the sanctuary and minimize illegal activities in the area.

An Update on Science-based Management Efforts for American Alligators in North Carolina

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Abstract

Prior to the early 2010s, very few studies on American alligators (*Alligator mississippiensis*) were conducted at the northern extent of this species' range in North Carolina (NC). A growing interest in alligator hunting and concern about potential interactions between people and alligators in developing coastal areas were two of the principal motivators that led to a series of spotlight surveys conducted across the coastal plain in 2012 and 2013. Designed to mirror surveys that were carried out in the late 1970s and document any changes in distribution and numbers of alligators observed, NC State University researchers reported a population growth rate estimate of 1.0156. Continued interest in alligator research and management led the NC Wildlife Resources Commission (NCWRC) to adopt an Alligator Management Plan in 2017 that established goals of maintaining viable populations of alligators in the state and conducting research to support science-based management of alligators. Towards each of these goals, NCWRC has continued to implement a wide range of surveys and applied management projects in recent years. These projects include the standardized marking and data collection of all alligators handled in the state, GPS telemetry of relocated alligators, spatial ecology of reproductive-aged females on state-owned game lands, various types of surveys to locate nests and monitoring of nests with trail cameras, annual spotlight surveys, and a long-term mark-recapture project at Lake Waccamaw that also facilitates training of agency staff and external handlers on the marking and data collection protocol. This presentation will provide a very brief overview of each of these ongoing projects.

Ecological Implications of Allometric Relationships in American Alligators (*Alligator mississippiensis*)

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Abstract

Morphometric allometry, the effect of size on morphological variation, has been of great interest for evolutionary biologist and is currently used in fields such as wildlife ecology to inform management and conservation. We assessed American alligator (*Alligator mississippiensis*) morphological static allometry across the Greater Everglades ecosystem in South Florida, United States using a robust dataset (~22 years) and investigated effects of sex, habitat, and sampling area on morphological relationships. Regression models showed very strong evidence of a linear relationship between variables explaining equal to or above 92% of the variation in the data. Most trait-size relationships (8 out of 11 assessed) showed hyperallometry (positive allometry) with slope deviations from isometry between 0.1 and 0.2 units while the other three relationships were isometric. Sampling area, type of habitat and, to a lesser extent, sex influenced allometric coefficients (slope and intercept) across several relationships, likely as a result of differing landscapes and ecosystem dynamic alterations. We discuss our findings in terms of the biology of the species as well as the usefulness of our results in the context of ecosystem restoration and conservation of the species. Finally, we provide recommendations when using trait-length relationships to infer population nutritional - health condition and demographics.

Le Caïman Noir: An Update on Black Caiman in French Guiana

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Abstract

While being a well-studied crocodilian in other regions within its distribution range, comprehensive data on Black caiman in French Guiana lacks entirely. Although a nature reserve had been created in 1998 to protect the local population, data on its demography and population size remain unknown. In this talk, I will present an update on our ongoing work to fill this large gap in Black caiman distribution, demographic parameters, mercury contamination, and other anthropogenic pressures within and outside the protected area once designated for Black caiman. This research is important to inform the management of Black caiman especially in the Guiana Shield, where the status of the species is poorly documented.

The IUCN Green Status of the Philippine Crocodile

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Abstract

The IUCN Red List of Threatened Species is the global standard for assessing species' extinction risks. The Red List status of a species acts as a warning signal that signifies whether (urgent) action is needed to prevent the extinction of a species. Over the years, a scientific data-based assessment process has been developed to categorize species in various Red List categories. The Red List assesses changes in population size and distribution areas and identifies threats that lead to these changes. The IUCN SSC Crocodile Specialist Group is responsible to conduct scientifically sound Red List status assessments for crocodilians. Ideally, a "negative" Red List assessment is followed by conservation action leading to species recovery. To measure the impact of conservation measures on Red List status, and species recovery, the Green Status Assessment has recently been developed by IUCN. The Critically Endangered Philippine crocodile (*Crocodylus mindorensis*) was the first crocodilian to undergo a Green Status Assessment, and its results have been published on the IUCN Red List page of this species. Similar to the Red List, the Green Status Assessment uses detailed metrics to assess whether conservation actions have contributed to distribution and population size recovery of a threatened species. A species is fully recovered if it is present with a viable and ecologically functional population in all parts of its indigenous range. This is reflected in a Green Score (0-100%). Not many, if any, threatened species will fully recover but the Green Score is an evidence-based indication of how much conservation actions have contributed to species survival or recovery. Most importantly, the Green Status Assessment can be repeated and the score monitored to assess the impact of conservation actions in time. This paper outlines the green status assessment procedure, illustrated with the Philippine Crocodile case.

Croc Attacks & Conflicts: Commonalities and Variations

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Abstract

This paper will provide an overview of published views on the incidence, causes and recommended responses to crocodile attacks and resulting conflicts. Focusing on the literature of the past 20 years, approximately, it will (while noting gaps and biases) draw out both commonalities from across the full geographic range of the literature on attacks and conflicts, while also noting some regional differences. The aims of this paper are both to demonstrate the commonalities as a basis for producing a shared resource for those dealing with crocodile attacks and conflicts, and to acknowledge the differences and ensure these are taken into account. This paper is a work in progress. The longer-term aim is to produce a CSG resource on Human-Crocodile Interactions which embraces this diversity while offering a tried-and-tested range of options for practitioners to draw on, some cross-cutting, some proven in certain areas and available for testing elsewhere.

Will Culling Crocodiles Reduce Attacks on Humans?

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Abstract

Although rare, attacks by large carnivores can illicit intense media and public attention, prompting calls for population culling despite little evidence supporting a consistent link between large carnivore density and attacks on humans. Our study assessed this link by examining how the density of Estuarine crocodiles (*Crocodylus porosus*) was correlated to the frequency of attacks in the Northern Territory (NT), Australia. Over the last 50 years, the NT Estuarine crocodile population has been closely monitored to track its recovery from only a few thousand to over 100,000 non-hatchling individuals, providing us with a unique opportunity to examine how attack frequency shifts over a wide range of crocodile densities. We found that during the population's initial recovery, the frequency of crocodile attacks was correlated with crocodile density. However, once the population reached a threshold where crocodiles occupied most waterways, the frequency of attacks plateaued despite continuing crocodile population growth. We argue this shift from density dependence to independence was due to a combination of factors, including changes in human behaviour around waterways, concurrent government initiatives created to educate the public about the risks posed by crocodiles, the removal of bold individuals and crocodiles from around urban centres, and the saturation of crocodile habitat (ie one crocodile in a waterbody poses a similar risk of attacks to humans as three crocodiles in a waterbody). By further modelling the relationship between crocodile density and attack frequency, we show that it would be necessary to cull 90% of the current crocodile population to prevent a single crocodile attack per year. Altogether, this study highlights the importance and effectiveness of management strategies that promote coexistence between humans and large carnivores (ie public education, removal of problem individuals) for mitigating the inherent risks posed by large carnivores such as crocodiles.

Baru (*Crocodylus porosus*) Risk Assessment in Remote Northern Territory: Causal Drivers, Potential Tools and Proposed Management Responses

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Abstract

Management of risk to human safety from crocodile attacks is a complex policy and management area with all the features of a "wicked problem". There is a need to mesh ecological and socio-economic dimensions, deal with hysteresis, lags between management actions and responses (eg between crocodile detection and removal) and, importantly, the potential for perverse outcomes (eg risk reduction activities causing an increase in risk taking). Baru (local name for Saltwater Crocodile) are an extremely important species to local Yolngu people of the Gove Peninsula region and there exists a complex system of totems and ceremonies that are still practiced by Yolngu communities. The community is concerned regarding the growth of water based recreation activities around Nhulunbuy (the largest population centre). This paper reports on a technical risk based assessment of the potential for adverse baru-human interactions focusing on itinerant and tourism based visitors to the area. The two most significant causal drivers of exposure to baru (in/near water recreation events and presence of large crocodiles in overlapping areas) and the specific risk mitigation interventions focussing on removal programs and public education (Be Crocwise programs) are examined to identify management /policy options. The use of direct acyclic graphs to design and evaluate mitigation programs is discussed. This approach allows for incorporation of differing data types and the identification of key information gaps that should be addressed to inform future management.

Saltwater Crocodile (*Crocodylus porosus*) Attacks on Humans in Papua New Guinea: Currently Known Trends and Future Research

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Abstract

Reports of Saltwater crocodile (*Crocodylus porosus*) attacks on humans have increased significantly over the past decade, particularly in Indonesia, India, and Timor-Leste. The status of human-Saltwater crocodile conflict in Papua New Guinea is poorly known, though it is expected to be a serious problem in many areas. The reasons for increased numbers of attacks are many, including human population growth, encroachment, habitat destruction, poverty, reduced prey abundance, and recovering crocodile populations. Inaddition, it is likely that increased cellular coverage and access to the internet has resulted in more frequent reporting from areas in which attacks were previously only reported at alocal level. Known problem areas in Papua New Guinea include Gulf province along the southern coast, where at least 49 attacks and 32 deaths have been recorded over the past decade, 9 deaths of which occurred in 2022 alone. Other known hotspots include Manus Island and the Huon Gulf of Morobe Province. Anecdotal reports suggest a high level of conflict in Western Province, which contains the Fly River and borders the aforementioned Gulf Province, but few details are available. In 2024 and 2025 human-crocodile conflict (HCC) surveys will be conducted in several areas where attacks are suspected to be a major problem. The currently identified areas include roughly 14 villages in the South and Middle Fly districts of Western Province, Manus Island, East Sepik Province, and, if financially feasible, select locations on Bougainville, New Britain,and New Ireland. These surveys will include the collection of attack data, resident questionnaires to determine local attitudes towards crocodiles, and village assessments for any factors that may be contributing to HCC.

Killer Tin - Human-Saltwater Crocodile Conflict in the Bangka-Belitung Islands

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Abstract

Bangka-Belitung Province consists of the Bangka and Belitung islands off the coast of South Sumatra in Indonesia. The province is the source of more than a third of the world's tin supply, with over 100,000 tons exported annually. This tin-mining is largely unregulated and involves up to 50,000 small tin-mines known as artisanal small-scale mines. The lack of regulation results in hazardous on-site conditions for workers, as well as severe damage to the province's environment. The large number of tin-mines have caused loss of biodiversity, reduced fish populations, water pollution, and more. Over the past two decades, another issue has become increasingly associated with tin mines: human-crocodile conflict (HCC). Since 2014, at least 97 people have been attacked by Saltwater crocodiles (*Crocodylus porosus*) in the province, resulting in 41 deaths. 70.1% of these incidents occurred on Bangka Island, though the highest number by regency occurred in East Belitung (26 attacks, 13 fatal), followed by Bangka Regency (25 attacks, 11 fatal). It is believed that damaged habitat (including loss of natural prey) due to tin-mining is to blame for increases in attack frequency. Despite the rather severe level of conflict, a recent survey of the Antan River (a location of frequent HCC) in Bangka revealed only 10 individuals, three of which were juveniles or hatchlings, for a density of only 1.13 individuals per kilometre (including juveniles and hatchlings). This is similar to the results of surveys in West Timor (East Nusa Tenggara Province) and Sumatra that yielded similar low densities of crocodiles in areas where conflict is frequent.

Crocodile Predation on Humans in the Indonesian Archipelago with an Attack Rate Correction Factor

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Abstract

Large carnivore attacks on humans are an increasing challenge for conservation and management efforts across many regions of the world. Saltwater crocodiles in southeast Asia are responsible for one of the highest attack rates on humans of any large carnivore and the Indonesian archipelago is at the geographic epicenter of rising attack occurrences. The recent construction of a crocodile attack database has elucidated many temporal and spatial attack patterns; however, it remains unclear what proportion of attacks go unreported. Collectively, 2377 Saltwater crocodile attacks were reported from the Indonesian archipelago between 1845 and 2021, and 1416 between 2012 and 2021. Between 2012-2021, 378 attacks were recorded in Borneo and only 73 attacks were recorded from New Guinea, even though New Guinea covers a larger geographic area. In 2023, we travelled to one of the more remote regions of Indonesia, West Papua, to compare documented attack rates in the crocodile attack database with undocumented attacks to calibrate an attack rate correction factor for remote regions. We travelled through the Raja Ampat island system of West Papua and conducted surveys with locals at six settlements to cross reference known crocodile attacks throughout the area. For every 200-400 km of shoreline, we estimate there could be at least 7 times more crocodile attacks on humans than are currently documented in the Raja Ampat area over the last decade. Although this is only a case study, this could be a conservative estimate considering we could not visit all remote areas, interview all potential witnesses, and we could not account for the disappearance of solo travellers with unknown fates. If a seven-fold correction factor is applied to documented attack rates in other remote regions, there are likely hundreds of undocumented attacks that have occurred in the last decade, at a minimum.

Sharing a Pond with Grandfather Crocodile: Human-Crocodile Interactions in Timor-Leste

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Abstract

On the IUCN Red List, the Saltwater crocodile (*Crocodylus porosus*) is categorized as Least Concern with national populations ranging from fully recovered to extinct. The Saltwater crocodile population of the Southeast Asian island nation of Timor-Leste was severely depleted by colonial hunting but has recovered since independence in 2002. During 2007-2014 there was a 23-fold increase in reported crocodile attacks (130 documented attacks), concomitant with a 2% annual increase in the human population. Public tolerance to attacks and the reluctance to harm crocodiles are entwined with reverence of crocodiles as sacred beings by most but not all Timorese people. In 2022, 7-8 years after our previous assessment, we visited five sites on the south coast of Timor-Leste in Lautém, Viqueque, Manufahí and Cova Lima municipalities. High rates of crocodile attacks continue. We obtained 35 records of attacks for 2015-2022 (34% fatal). In the municipalities where crocodile attacks occurred (Lautém, Viqueque, Cova Lima), the sacred status of crocodiles prevented inhabitants from harming them in retribution. In Manufahí, where no attacks were reported, such traditional values never existed and crocodiles were hunted for subsistence and to improve safety. For the Government of Timor-Leste, the ability to formulate a context-specific crocodile management programme that respects the reverence attributed to crocodiles by most people but reduces the risk of people being attacked by crocodiles is a conservation management challenge. The developing tourism industry, which exploits coastal beaches and reefs, is jeopardized by the risk of crocodile attacks.

Singapore, a Tiny Island State with 6 Million Humans and Saltwater Crocodiles in the Backyard

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Abstract

In the last two decades or so, Saltwater crocodiles have made a reappearance in Singapore. Through his lenses, Bernard is helping to bring the story of the Saltwater crocodile in Singapore to her 6 million urbanites, conveying the beauty, danger and lives of these animals in inspirational stills and footage. This is further brought to life when he meets with park visitors during outreach sessions, introducing them to their unforgettable first encounters with wild crocodiles. In the end, he hopes to bring about both a deeper appreciation and respect for Saltwater crocodiles that is now part of Singapore's landscape.

Preparedness to Potential Human-Crocodile Conflicts from Siamese Crocodile Reintroduction in Kaeng Krachan National Park in Thailand

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Abstract

Several attempts to reintroduce pure-bred Siamese Crocodiles (*Crocodylus siamensis*) from farms in Thai protected areas (PAs) have failed mainly due to negative attitudes toward the crocodiles. This situation revealed a hidden human-crocodile conflict in Thai society, but little research on the human dimensions of those sharing space with the crocodiles exists. We therefore conducted a survey of 208 local people living in five villages along Petchaburi River in Kaeng Krachan National Park (KKNP). We disclosed positive attitudes toward Siamese crocodiles and its conservation and the possibility of mutualism of crocodiles with local people, although their fear of crocodiles exists. Even with these positive signs from human dimensions, over 50% of respondents opposed both soft and hard releases of the purebred crocodile from farms despite being the preferable reintroduction methods by park managers. To avoid hidden conflicts of crocodile reintroduction, we aligned our results to IUCN SSC guidelines on human-wildlife conflict and coexistence to suggest preparedness for potential conflicts after reintroduction. Elements of good governance can nurture local support through stakeholder inclusion, transparency, equity, accountability and fairness. Sincere communication about the reintroduction and integration of local concerns and local participation into a plan can show respect toward local people and signs of project good governance. We suggest engaging male fishermen, who are less likely fearful of the crocodiles, to become citizen scientists to report sightings and interaction of reintroduced crocodiles with local people. Simultaneously, conservation education and campaigns for students and in local communities to maintain current tolerance level toward fear of crocodiles should be implemented. A long-term socio-ecological monitoring is essential for facilitating sound decision-making and to connect the science with practices for managing human-crocodile conflict after reintroduction and for measuring a long-term socio-ecological success.

Aversive Conditioning of Estuarine Crocodiles (*Crocodylus porosus*) in Queensland and the Remote Attachment of Transmitters

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Abstract

Within increasing public pressure from some sectors of the community to avoid removal of problem crocodiles from the wild, alternative measures were investigated to assist with *in-situ* management. Aversive conditioning has been used with terrestrial predators to reduce conflict with human by changing behaviours or discouraging presence in a discrete area. In this study we assessed the interaction between presence and sightability of Estuarine Crocodiles (*Crocodylus porosus*) after a period of aversive conditioning. Crocodiles >2 m in length were subjected to aversive conditioning using two non-lethal beanbags fired from a 12-gauge shotgun. Traditional night-time surveys were conducted prior to and after aversive conditioning to determine any changes in crocodile sightability. To detect crocodiles underwater and their movement, we attached acoustic transmitters with a hand-held pole harpoon, which were monitored with an acoustic receiver array. This technique allowed for transmitter attachment without the need for capture. Immediately after aversive conditioning, there was a significant reduction in the sightability of larger Estuarine Crocodiles (>2 m) using traditional spotlight survey, and a detectable change in the movement patterns of two of the three tagged individuals. The two tagged crocodiles resumed normal movement patterns soon after (42 h, 15 d) and no crocodiles left the area in response to the treatment. Aversive conditioning has limited use in moving crocodiles away from a discrete area; however, it did have a short-term impact on crocodile behaviour and crocodiles became more challenging to detect by traditional spotlight survey. The reduced sightability may indicate an increased wariness of people, which may be a suitable outcome for wildlife managers to reduce the likelihood of negative human-wildlife interactions.

Holland Bay Crocodile Sanctuary, One Hope for Crocodile Conservation in Jamaica

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Abstract

Jamaica is a popular tourist destination and one of 17 countries/islands inhabited by American crocodiles, *Crocodylus acutus*. There have been several island wide population studies in Jamaica over the years, beginning in the 1960s to the present. However, to date, there is no general consensus of the island-wide population number, although the current study is nearing completion. Historically, crocodiles were a huge part of the local culture, with the crocodile prominently placed on the official coat of arms and the mascot for the national cricket team. In recent times, crocodiles are treated as vermin by the Jamaican people and typically ignored or battered. Their range has been fragmented along the south coast, as resorts and other construction projects place a high value in beach front property. Besides a fragmented population, locating valuable nesting areas are becoming more difficult for adult females. Charcoal producers have been methodically cutting and burning valuable coastal vegetation such as mangroves and buttonwoods. In recent times crocodiles have been prized as a meat source as well as a source of income by selling the meat. In April 2019, the Holland Bay Crocodile Conservation Sanctuary opened its doors as a venue for which to place injured and nuisance crocodiles. The capacity of the facility depends on the sizes of crocodiles, but it has room for as many as 50 adults and a hundred juveniles. In the future, if more animals need to be placed, the sanctuary has room to expand. As a result of several dedicated people and agencies working together, the future of crocodiles in Jamaica is much brighter than years ago.

Gods and Monsters: The Global Cultural Significance of Crocodylians

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Abstract

Crocodylians - large, dangerous, awe-inspiring, terrifying - have long held high cultural significance to peoples worldwide, across diverse worldviews and knowledge systems. In many societies, who have coexisted with crocodylians for millennia, crocodiles play prominent roles in belief systems, including sacred roles in fertility, the coming of rain and waters, connecting this life with the next, and in placing judgement. More broadly, crocodylians and their parts have contributed to foodways, healing systems, artistic expression, histories, folklore and religious practice across their range, and beyond. Historically, such beliefs and knowledges between people and crocodylians led to tolerant, or even reverent or fraternal, relationships. The fall from grace of many crocodylians species - from god to monster - has invariably been associated with colonialism, and as such, the cultural role of crocodylians in European and European colonial societies. Using examples from the published literature, and collaborations with researchers working on crocodylians, we have collated representative examples of 5000 years of human-crocodile relationships - from the Gharial seals of the ancient Indus Valley Civilisation, Cipactli of Aztec cosmology, the black caiman as the 'queen of the marshes' to indigenous peoples of French Guiana, and the Saltwater crocodile as the 'spirit of the water' to indigenous Mentawaians on Siberut Island, to the crocodile as a contemporary popular figure in children's media, a classic 'creature feature' movie villain, or as a character in satirical news coverage. In this presentation, I will discuss the remarkably consistent patterns of cultural significance of crocodylians across pre- and post-colonial societies, and consider the implications of these types of significance for conservation of crocodylians, the complex biocultural relationships of crocs and people, and the socio-ecological systems humans share with them. In particular, we will consider the applied contexts in which the cultural role of crocs is essential for ethical and appropriate conservation and conflict management.

Attitudes, Perceptions and Knowledge of Crocodylians Amongst Diverse West African Residents of Côte d'Ivoire

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Abstract

Since its initial recognition as the least known global region for crocodylians in 2006, research and conservation efforts for crocodylians have been improving across West Africa, with dedicated individuals driving efforts in Benin, Burkina Faso, Ghana and Côte d'Ivoire. Local communities throughout this region have diverse attitudes, perceptions, and knowledge of the five (5) species that occur here, all of which can significantly impact the success of these research and conservation efforts. To better understand the relationship between local people and crocodylians, we carried out focus groups, participatory ethnography, and semi-structured interviews in 10 villages with over 200 respondents around Taï National Park and the Voluntary Reserve of Grand-Béréby. Respondents originated not only from all main regions of Côte d'Ivoire, but also from other countries, like Burkina Faso and Mali. We found that regardless of their origin, most people are less tolerant of crocodiles due to their perception of them as dangerous species. However, people most tolerant are those with crocodiles as their totem and this relationship existed across respondent's regardless of country of origin. Most respondents knew very little about the role that crocodiles play in the environment, their potential value as tourist attractions, or their conservation status. For almost all people, crocodile bile is believed to be very poisonous, and an extant local law

requires to inform local authorities about any captured or hunted crocodylians so that the bile can be destroyed in a public ceremony. These traditional beliefs can limit threats to crocodiles and promote their indigenous conservation, which is of particular importance for the Critically Endangered *M. cataphractus* and the threatened *C. suchus*. Here, we discuss the conservation implications of the deep seeded relationship between crocodiles and communities in this important, but still relatively unknown, region for crocodile conservation.

The Social Media Era - Mitigating Human-Crocodile Conflict through Community Education and Responsible Media Portrayal

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Abstract

Crocodilians are charismatic megafauna with enduring public fascination that generates media attention. While the population recovery of many crocodilian species stands as a conservation success, it also sharpens the focus on reducing human-crocodile conflict. Community education remains a crucial tool for conflict mitigation, however messaging consistency and delivery to a broad audience present ongoing challenges. Despite the clarity and conciseness of safety guidelines for individuals in crocodile habitats, some individuals persist in disregarding advice and engage in risky behaviours that can escalate into conflict situations. As experienced with fellow toothy predators sharks, media sensationalism can exacerbate fears and obscure scientific facts from reaching the general public. This also leads to persistent arguments at a political level that may counter efforts toward conservation. The depiction of crocodiles in media has typically highlighted their perilous predatory characteristics, notably through high-risk encounters with celebrity wranglers showcased on television and social media platforms. The rise of social media platforms means anybody can make a video, and reach an audience leading to social media users and influencers using wildlife interactions for content and clicks to increase their following. In Australia, despite local laws protecting wildlife, it is common to find online video content depicting people illegally interfering with wildlife, thus perpetuating myths and enabling risky behaviour. This behaviour either attracts further risky situations or fosters a perception that the dangers outlined in community education messaging are exaggerated, leading to a false sense of security in crocodile habitat. As social media platforms dominate as a preferred content provider, the miscommunication to a significant broad audience continues, undermining outcomes towards reducing human-crocodile conflict. Consensus on how crocodiles are best portrayed across media platforms from the scientific and wildlife experts, as well as agencies involved with the management of crocodiles, will help to influence a more responsible stance on crocodile messaging. This consensus would be beneficial across the many countries with crocodilian populations where social media is the main source of crocodile education, and human-crocodile conflicts remain high.

Using Active Multibeam Sonar to Detect Large Marine Life - A Case Study

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Abstract

Using active sonar to detect life or objects in freshwater and marine environments is not new, though recent innovations have supported the adoption of novel applications for its use in science and management. Active multi-beam sonar addresses many of the common pitfalls of underwater acoustics with high resolution imaging, providing great utility as a non-invasive monitoring tool. Early examples of this include the prevention of seal interactions with offshore wind farms in the North Sea, surveys of wild manatee populations in regions of Florida and Mexico. Over the past 7 years we have been building upon the utility of this tool in response to the evolving fauna management requirements of several government bodies in Australia and overseas. The application of machine learning-based image classification to sonar imaging addresses the issue of processing large amounts of data to identify objects of interest and provide near real-time information to users. We first employed this approach with the development of a shark monitoring system to help address growing concerns around a spike in shark-human interactions in our home town of Perth, Western Australia. After rigorous testing over several iterations of the system beginning in 2015, it was deployed at several beaches in NSW, WA, South Africa and California in the interests of public safety during summer seasons and at high profile sporting events. Following a range of public coverage on these deployments in the media, the Queensland Department of Environment and Science expressed interest in extending development towards detection of crocodiles. Here, we present details of the last 4 years of collaborative research and development towards the goal of automatic detection of Saltwater crocodiles in river and estuarine systems throughout upper north Queensland.

Detection and Deterrent of Saltwater Crocodiles (*Crocodylus porosus*) as a Management Tool

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Abstract

The reliability of multi-beam sonar (sonar) placed under water to detect and monitor Saltwater crocodiles was tested in a semi-natural and natural freshwater environment along with light and acoustic deterrents. Digital video surveillance systems (DV) placed above water were used to correlate surface movements with subsurface sonar detections. A total of 29 captive crocodiles were detected within the study area using DV, and 28 with sonar. The length of time that crocodiles were detected was longer on average for sonar (4 min 27 s) compared with DV (2 min 50 s). The data was then used to develop Deep Learning algorithms for the automated detection of crocodiles. Detectability on sonar depended on crocodile size, its orientation in the sonar beam and distance. In a later field trial, 8 wild crocodiles ranging from 2 to 5.2m total length were captured and fitted with acoustic tags at Seven Mile Waterhole, Rinyirru National Park. Of the 8 crocodiles, 5 were detected by the multibeam sonar over 7 days during which it was active. Over a 12-hr period at the end of the trial, the use of manually triggered flashing lights and alarms appeared to successfully deter 3 tagged crocodiles (3-5.2 m TL) from taking baits set close to the sonar system. The use of multibeam sonar accompanied by automated detection software and light and audio deterrents may provide a management tool for detecting, alerting, and deterring Saltwater crocodiles in areas frequented by people (eg beaches, boat ramps, upper freshwater areas). However, further research is required to determine the longer-term effectiveness of deterrents and the viability of a detection, alert, and deterrent system in diverse real-world settings. Detection range appears likely to be a limiting factor in deployment as detectability appears likely to be too low to be useful at distances beyond some 20-30 m.

Advances in Drone Radio-telemetry for Invasive and Native Species Management across Wetlands

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Abstract

Wetlands are some of the most rapidly declining and threatened ecosystems in the world, yet they provide some of the most biologically diverse habitats for wildlife. Effectively managing both wildlife and invasive species across saltwater and freshwater wetlands poses significant challenges for wildlife biologists and natural resource managers. Radio-telemetry is often the only way to shed light on the movements and habitat use of many small wetland dwelling species, however it can also be valuable when needing real-time information on larger species such as crocodiles and alligators as well as their hatchlings. This can be particularly important for those working in areas where human-wildlife conflicts require immediate management action on the ground. However, gaining access to sites on the ground and getting enough elevation to be able to detect radio-tag signals in very flat, wet landscapes is particularly problematic. Therefore, wetland biologists are increasingly turning to drone-based technologies to assist with collecting data on a range of species, including those that are often submerged and otherwise prohibitively difficult to obtain. We provide examples of how advances in innovative drone radio-telemetry technology are enabling an increasingly diverse array of native and invasive species to be efficiently tracked across some of the most challenging wetland landscapes in the United States and Australia.

Illuminating Factors Affecting Occupancy and Detection of Alligators during Annual Spotlight Surveys in North Carolina

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Abstract

North Carolina (NC) is the northern range limit of the American alligator (*Alligator mississippiensis*), where populations occur in much lower densities than those at warmer, lower latitudes. Like many other species dependent on coastal ecosystems throughout the world, they are subject to increasing anthropogenic pressures, such as human development, harmful contaminants, and climate change. To address uncertainties about potential impacts of threats, a robust survey design is needed to detect changes in alligator populations, but is difficult to implement due to patchy distributions and challenging survey conditions. We are evaluating use of standardized spotlight surveys to monitor alligators in NC's 10 Alligator Management Unit 1 (AMU1) counties, and quantifying factors affecting local occupancy and detection. All survey route locations were selected to maximize surveyors' likelihood of observing alligators and potentially detect changes in local trends when comparing numbers observed across years. From 1 May to 15 June 2021, 2022, and 2023, NC Wildlife Resources Commission staff conducted spotlight surveys on 2-3 routes in each of the 10 AMU1 counties. Each 16-32-km route was divided into 4-km transects. All routes were surveyed by boat on two consecutive nights each year. Time, GPS coordinates, and environmental covariates were recorded at both ends of each transect, and each alligator observation was classified in one of six size categories or unknown. In 2021, 2022, and 2023 respectively, alligators were detected in 70%, 71%, 61% of transects and surveyors estimated that 64%, 70%, and 61% were juveniles and subadults and 14%, 12% and 16% were of reproductive size, while 21%, 19%, and 22% were of unknown size. Factors influencing detection are being investigated to evaluate if changes in alligator observations are linked to changes in survey conditions or changes in local alligator space-use or abundance. Occupancy modeling results will be presented during this talk.

The Prey Required to Nourish and Grow the Northern Territory Estuarine Crocodile Population

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Abstract

A reduction in hunting pressure has enabled numerous crocodilian populations to recover across the globe. In many cases, this recovery has been so significant that it has sparked questions regarding the broader ecological implications of these population rebounds. To tackle this issue, we examined the quantity and types of prey ingested by Estuarine crocodiles *(Crocodylus porosus)* in the Northern Territory (NT) as the population expanded from a few 1000 to over 100,000 individuals. To accurately estimate historic crocodile population prey consumption, we utilized bioenergetic models based on 50 years of annual survey counts collected by the Northern Territory Government. We then analysed the diet by studying the stable isotope composition of crocodile bone museum specimens collected from individuals who perished between the 1960s and the present day. We observed that to meet the ever-increasing energy demands of the growing population, crocodile prey consumption increased from around 20 kg km^2 of wetland in 1979 to approximately 180 kg km^2 of wetland in 2019. There was also a gradual shift in prey preference from aquatic to terrestrial food webs as the population expanded (shift from ~30% in 1970s, to ~70% terrestrial by 2018). We suggest that this emerging trend towards terrestrial prey consumption arose due to intra-specific competition for aquatic food, and a rise in the abundance of feral pigs in the wetlands. It has been suggested that due to their low energy requirements, crocodilians do not fit the traditional concept of an apex predator and are unlikely to have a comparable impact on lower-order prey. However, our findings indicate that the sheer volume of crocodile biomass in the NT wetland ecosystem and its rapid rate of growth rate would result in prey consumption rates comparable to or higher than those of most endothermic carnivore populations. This suggests that both top-down and bottom-up impacts of the Estuarine crocodiles on lower-order trophic levels could be substantial.

Apex Predator Contributions to Blue Carbon Dynamics: Evidence for American Alligators (*Alligator mississippiensis*) as Wetland Ecosystem Carbon Sequestration Regulators

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Abstract

Blue carbon refers to organic carbon sequestered by oceanic and coastal ecosystems and this stock has gained global attention as a disproportionately high organic carbon repository relative to other ecosystems. Within blue carbon ecosystems, tidally influenced wetlands alone store a disproportionately higher amount of organic carbon than other blue carbon systems. North America harbors 42% of this global wetland area, which has been identified as a critical carbon stock in the context of climate change mitigation. Quantified associations, however, between vertebrate biota and carbon sequestration within ecosystems is in its infancy and, when quantified, has been incidental given that microbial trophic levels are thought to drive nutrient dynamics. Here, we assess the relationship between American alligator (*Alligator mississippiensis*) demography and tidally-influenced wetland soil carbon stock among habitats at continental, biogeographically-relevant and local scales. We used soil core profile data mined from the Smithsonian's Coastal Carbon Network and filtered for continuous core profiles in tidally influenced wetland areas along the Gulf and Atlantic Coasts of the United States. Results indicate that American alligator presence is positively associated with soil carbon stock within the distribution of the species among habitats. Additionally, it was found that American alligator demographic variables are positively associated with soil carbon stock at local scales. These results are consistent with other evidence that apex predators regulate soil carbon stock via trophic cascade.

Monitoring Stress Physiology of Free-ranging Mugger Crocodiles (*Crocodylus palustris*) Across Diverse Habitats within Central Gujarat, India

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Abstract

Mugger crocodiles are distributed across 50 small pockets in India and the subcontinent. Living in diverse habitats, for example, urban drainages, agricultural fields, semi-arid deserts, dry and deciduous forests, they face diverse challenges in terms of habitat degradation and anthropogenic disturbances. Coping with such challenges has often been studied using behavioral, physiological, and morphological readouts. In this study, we assessed physiological conditions, via measurements of fecal glucocorticoid metabolite (fGCM) concentrations, for free-ranging populations of Muggers inhabiting three diverse habitats (defined as "a", "b", and "c") in central Gujarat, India: (a) Rural area with a non-industrial zone and low conflict, (b) Urban area with high conflict, and an industrial zone (c) Rural area with no industrial zone and high conflict. The fGCM measured used an assay targeting 5b-3α-ol-11-one structure and a focal population of captive Muggers was used to biologically validate (via capture and restrain process) the selected fGCM assay (11-oxoetiocholanolone assay). Assay results showed a significant ($P<0.05$) 11-fold increase in fGCM levels between pre- (540.9 ± 149.2, N=11) and post-capture (6259.7 ± 1150.5, N= 11) samples. The validated fGCM assay was then applied to free-ranging populations (n= 107 scats from habitats 'a', 'b' and 'c'). During the breeding season, zone A showed significantly ($P<0.05$) lower fGCM levels (542.03 ± 71.3) when compared to Muggers in zone B (1699.9 ± 180.8) and C (1806.4 ± 243.2). A similar contrast in fGCM levels was also observed during the non-breeding season. The study demonstrated that fGCM levels in Muggers varied across habitats, and such variation could be due to a combination of ecological and anthropogenic factors that the species experience in their immediate local environment. Overall, the study aims to implement an efficient method for long-term monitoring of the wellbeing of Muggers that can aid in improved conservation management.

Developing an Epigenetic Age Predictor in the American Alligator to Advance Conservation, Management, and Ecology

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Abstract

Determining the age of organisms is critical for assessing population age structures and life history. Yet estimating the age of individuals remains challenging in many species. For some species, accurate age estimates can be made, but require invasive or lethal sampling approaches (eg otolith growth rings in bony fishes). In other species, including most reptiles, age is estimated based on individual size, which is confounded by variable growth rates occurring across individuals and populations. Furthermore, many reptiles display determinate growth and thus age estimates based on animal size are compromised in older individuals. Within the genome, certain nucleotides have the potential to be methylated, a phenomenon known as DNA methylation. The patterns and frequency of DNA methylation change with age and recent advances have demonstrated that the stereotypical nature of these changes can be modeled to predict individual age with high accuracy. For example, epigenetic age predictors, or "epigenetic clocks", developed in humans can predict individual age with a mean absolute error of 3.4 years. The present study will develop an epigenetic clock for the American alligator by generating whole genome DNA methylation data from whole blood in a cohort of known-aged individuals, encompassing both captive and wild alligators. Subsequent work will apply this model to estimate ages of individuals for which this information is unknown and pursue efforts to expand the utility of this tool in research, management, and conservation contexts.

Characterization and Comparative Analysis of the Parasite-microbial Community in the American Crocodile (*Crocodylus acutus*)

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Abstract

The microbiome is a bio-ecological community composed of multiple symbiotic, commensal, and even pathogenic microorganisms – known as microbiota – residing in or on a living host. The composition and diversity of bacterial populations in host microbiomes are known to contribute to crucial hosts' physiology and functions. For example, host microbiomes have been documented to activate host immunological responses affecting host resistance, parasite virulence, and parasite-associated diseases. However, similar to symbiotic microbiota, symbiotic parasites such as gastrointestinal (GI) nematodes may also play essential roles in modulating host immune systems. In crocodiles, studies have evidenced a potential symbiotic relationship between them and their GI nematodes. These nematodes were observed to sequester heavy metals from their crocodile hosts that had been accumulated from the host's environment. Environmental conditions not only affect the crocodiles' relationship with their parasites and their microbiome, but the nested symbiotic structure between crocodile, parasite, and their respective microbiomes, can have potential interactions with the parasites' microbiomes as well. Currently, there is a paucity of data studying the role of microbes in host-parasite interactions, or the mechanisms driving microbiome variation in parasites and infected hosts. In our study, we examined and characterized the bacterial (16s) microbiome composition of nematodes (*Dujardinascaris helicina*) collected from the gastrointestinal tract of wild American crocodiles (*Crocodylus acutus*) across three sites with varying degrees of human activity in Belize. Our results revealed significant statistical differences between the nematodes' microbiome community composition across the crocodile host sites. Particularly, we found stronger microbiome similarities occurring between the more anthropogenically perturbed sites rather than by geographic proximity. While host microbiome composition can provide information about host's physiology and health, differences between composition relative to the hosts' environment may be crucial in providing insight into potentially changing ecological dynamics.

Out with the Old, Introgression with the New: Hybridization Dynamics of *Crocodylus* spp. in Belize

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Abstract

A central aim of conservation is to preserve existing biodiversity and the ecological and evolutionary processes that support it. With the rise of genome-scale data, inter- and intraspecific hybridization in wildlife has widely been recognized as a common and naturally occurring phenomenon that facilitates both species adaptation and evolution. Yet, hybridization still constitutes one of the most challenging problems for legal protection and species management due to its perceived biological risk and the variable outcomes influenced by the specific hybridizing populations. When dealing with rare or threatened hybridizing species with unequal legal protection, management strategies risk being inaccurate or unsuccessful if not contextualized with the species' genetic and evolutionary backgrounds. In this study, we investigated hybridization dynamics and genetic diversity of American crocodiles (*Crocodylus acutus*) and Morelet's crocodiles (*Crocodylus moreletii*) from Belize to ascertain whether genetic exchange through admixture displayed signs of evolutionary significance. We analysed 242 crocodile samples using genomic reduced representation (3RAD) datasets ranging from 12,866 to 37,843 SNPs. We found evidence of population structure among *C. acutus*, as well as ancient bidirectional gene flow that had occurred between *C. acutus* and *C. moreletii*. Notably, we also found evidence of high levels of recent admixture along the coastal populations of *Crocodylus* spp. in areas with extensive habitat modification due to human impact. These findings, as well as a discovered disconnect between morphological and physical species assignments used to identify unadmixed populations, have implications for conservation management practices and suggest a range of additional genetic investigations to understand the natural and anthropogenic role of hybridization in crocodilians.

Variations in the Pattern of Post-occipital and Nuchal Scales in *Crocodylus intermedius* (Orinoco Crocodile)

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Abstract

One of the main characteristics of crocodile species is the patterns of the post-occipital and nuchal scales. These are different for every species, and only for *Crocodylus acutus*, a species with great variability have been studied in detail. To determine the pattern of the post-occipital and nuchal scales in the Orinoco crocodile (*Crocodylus intermedius*), 530 individuals were photographed and each photograph was vectorized by drawing the pattern of the post-occipital and nuchal scales. Ten post occipital scale patterns and 27 nuchal patterns were identified. The post-occipital pattern most frequently found (54.34%) consisted of four scales in a row, two on each side of the head. The most recurrent nuchal pattern (70.00%) entails two rows of large scales, the anterior one with four scales and the second one of only two (4-2). The rest of the patterns obtained were variations due to the presence of additional scales for each case. The combination of post-occipital and nuchal patterns is confirmed by definition 2-2 and 4-2, respectively. The study confirms the patterns defined by Brazaitis (1973) for the post-occipital and nuchal scales.

Natural and Anthropogenic Factors Influencing Nesting Ecology of the American Crocodile in Florida, United States

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Abstract

Nesting ecology of American crocodiles (*Crocodylus acutus*) in Florida has been both positively and negatively influenced by anthropogenic and natural factors since the species was placed on the federally endangered species list in 1975. This includes a shift in nesting sites and an expansion of nesting to anthropogenic habitat. Using a 50-year record of monitoring data (1970-2020), we assessed factors influencing nesting ecology (number of nests, nest morphology, success rate, and habitat use) from a total of 3,013 nests recorded across South Florida. We detected a change in nesting success rate, increasing from 61% in the 1970's to near 90% since 2010. Our hot spot analysis illustrates that nesting sites in northeastern Florida Bay and Flamingo/Cape Sable (Everglades National Park) were important for American crocodiles. Anthropogenic habitats, such as canals provided vital habitat nesting in areas such as Flamingo/Cape Sable (Everglades National Park), Turkey Point Power Plant, and Crocodile Lake National Wildlife Refuge for the current Florida population. Environmental parameters suspected to affect nesting success have shown an increasing trend over the past 50 years and minimum temperature and rainfall, during the summer season, are correlated with increased nesting success and temporal variation across South Florida. The adaptive capacity that American crocodiles exhibited in Florida gave the species advantages to face changes in climate and landscape over the last 50 years, however, it does not imply that the adaptive capacity of the species to face these changes (evolutionary potential) cannot reach a limit if changes continue. Here, we document *C. acutus* nesting ecology population responses to ecosystem restoration efforts in Florida; and further demonstrate the value of protecting and restoring habitat to support recovery of listed species.

Assessing the Ecological Relevance and Selective Pressures on Incubation Temperature-dependent Traits in the American Alligator

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Abstract

The developmental environment can have lasting consequences for organismal form and function, ultimately driving ecological and evolutionary outcomes. In American alligators (*Alligator mississippiensis*), incubation temperature determines hatchling sex and influences additional hatchlings traits, including juvenile survival. Specifically, animals incubated at warmer, male-promoting temperatures are larger and have increased survival relative to those incubated at cooler, female-promoting temperatures. However, most of the work examining the influence of incubation temperature has utilized constant temperature incubations in the lab. These lack ecological relevance as they are not representative of fluctuating, natural nest thermal profiles. Further, despite associations between phenotypic traits and survivorship, the selective pressures driving temperature-biased survival are currently unknown. To address these gaps, we present on two, ongoing experiments. In the first experiment, we test whether thermal conditions experienced in nature can produce temperature-dependent phenotypes and survivorship. To do this, we incubate eggs in their natural nests until hatching and assess relationships between components of nest temperature and hatchling traits. In the second experiment, we determine whether predation or resource limitation is a larger driver of survivorship differences between incubation temperatures by manipulating the presence of predators under semi-natural conditions. Overall, forthcoming results from these two studies will provide important insight into the ecological and evolutionary significance of incubation temperature in the alligator.

Impacts of Severe Lead Poisoning in Nile Crocodiles (*Crocodylus niloticus*) from Lake St Lucia, South Africa

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Abstract

Exposure to lead (Pb) poses a major threat to wildlife globally, but impacts on crocodilian populations remain poorly documented. Nile crocodiles (*Crocodylus niloticus*) at Lake St Lucia, South Africa, have some of the highest blood Pb concentrations ever recorded in a wild species. Exposure to Pb occurs primarily through direct ingestion of Pb fishing weights, which crocodiles likely swallow through normal gastrolith acquisition or occasional theft of fishing bait. While crocodiles at Lake St Lucia appear to exhibit a high degree of resistance to the acute toxic effects of Pb, long-term exposure results in anaemia and severe deterioration in tooth condition. We discuss investigations that are currently underway to evaluate the reproductive health consequences associated with Pb exposure, with initial results suggesting that it may compromise reproductive potential in males. Using examples from Tanzania and Australia, we discuss the relevance of our findings from Lake St Lucia for other crocodilian populations, and present a case where a simple and easy intervention could solve an important ecological problem.

Experimental Study on the Effect of Lead in Nile Crocodiles: A Brief Haematological Assessment

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Abstract

Recent research has revealed that Nile crocodiles (*Crocodylus niloticus*) in the St Lucia estuarine system have been exposed to lead with the ingestion of fishing sinkers being the primary source. With the high levels of blood lead measured, one would expect to see negative health effects, with one of the most well-known being anaemia. We initiated a 52-week long experimental study in which we orally dosed captive farmed crocodiles with three different dosages of lead. Blood was drawn from each animal prior to and at specific intervals after dosing. Erythrocytic parameters were measured at baseline and after the first 3 months of dosing. Haematocrit and erythrocyte maturity fractions were measured via microhaematocrit centrifugation and blood smear evaluations respectively. The relative haematocrit of treatment groups were lower than controls at month 3. Differences in the proportions of immature erythrocytes between dosed and control animals after the 3 months likely indicates that there was some degree of red blood cell regeneration during this time. While the erythrocyte line appears to have been affected by lead intoxication, the degree of the effect has been less than expected. It is possible that more severe effects may only become apparent further on into the study. Work to try and understand how lead may affect the circulating white blood cells is ongoing, and is being done by estimating the total white cell counts and differentials from the blood smears made at the same sampling periods.

Beneath the Scales: A Deep Dive into Mercury Monitoring and Impacts on Caimans

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Abstract

All over the globe, anthropogenic activities release a variety of pollutants into ecosystems. Mercury (Hg) is one of the most concerning contaminants as it originates from both natural and anthropogenic sources, with artisanal small-scale goldmining being responsible for more than one third of atmospheric Hg emission. Mercury biomagnifies through the trophic chain and bioaccumulates particularly in top predators. Its chronic effects on humans and wildlife impact reproduction, offspring quality, hormonal synthesis and secretion, metabolic processes and immune functions, and further cause neurobehavioral and neuronal dysfunction. While being well documented in mammals and birds, the deleterious effects of Hg on reptiles remain understudied, even more in crocodylians. Being top predators, crocodylians accumulate high levels of mercury and can be used as bioindicators of environmental Hg contamination. In addition, knowledge on the impact of mercury on the taxon is extremely limited, and highlights the need to further investigate the threat that mercury contamination represents to them, considering that many crocodylids overlap with elevated mercury concentrations in their ecosystems. During this talk, I will present the monitoring of mercury contamination in caimans from French Guiana and the effects of Hg on the Smooth-fronted caiman (*Paleosuchus trigonatus*) and the Spectacled caiman (*Caiman crocodilus*).

Integrated Assessment of Chemical Pollution and Its Effects on Wild Mexican Crocodiles - Preliminary Insights from Interdisciplinary Research

Asela Marisol Buenfil-Rojas[1,7], Kei Nomiyama[1], Mari Ochiai[1], Izumi Watanabe[2], Midori Iida[3], Mauricio González-Jáuregui[4,7], Sergio E. Padilla-Paz [4,7], José António L. Barão-Nóbrega[5,7], Teresa Álvarez-Legorreta[6] and Hisato Iwata[1]

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Abstract

We, an international and interdisciplinary team from Japan and Mexico, have focused on the toxicological research of the Morelet's crocodile (*Crocodylus moreletii*) in Mexico, because the species is an apex predator in the trophic web, which potentiates the high accumulation of metals and persistent organic pollutants (POPs) in their tissues, which may lead to toxicological effects. Crocodiles are territorial long-lived organisms**,** that are vulnerable to anthropogenic activities, and likely to reflect local chemical contaminations**.** However, research on their exposure and effects is still limited. Also, studies using biomarkers in internal tissues and organs of *C. moreletii* have been hampered due to legal and ethical constraints. As an alternative, we collected non-destructive samples such as blood, caudal scutes and claws for assessing exposure to pollutants. We have also incorporated transcriptome and metabolome profiles into our research to identify disturbed biological networks in wild crocodile populations. To date, we have monitored and collected samples from 115 wild crocodiles and 10 captive crocodiles (as reference) from 16 sites, and in October 2022, the first batch of 203 samples (n= 30) was exported to Japan. In 2024, we expect to transport the second batch of 654 samples (n= 95) from Mexico. Currently, we have measured 34 metals and trace elements in whole blood, caudal scutes, and claws, whereas we have measured POPs in blood plasma. For the transcriptome, we have obtained high quality libraries from caudal scutes of 16 crocodiles, and we are aiming to obtain those from another 10 animals for this first set. For the bioinformatics, we will perform two different approaches for the mappings to obtain the expression levels of genes and will then expect to determine the biomarkers and the biological pathways affected by contaminants. Consequently, this project will provide an important insight into the current status of contaminant exposure and their effects on the wild crocodile populations in Mexico, paving the way for new guidelines, risk assessments, and strengthening the future monitoring and conservation of crocodylian populations worldwide.

The Ecotoxicology of Harvested and Protected American Alligators in Southeast Texas

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Abstract

Crocodylians have an extensive history as toxicological indicators and sentinel species given their long lifespans, considerable ontogenetic changes in body size (<30 cm in total length as hatchlings to >3.0 m in total length as adults in most species), ontogenetic transitions between trophic levels, and apparent hardiness with high pollutant body loads. Alligators are one, of if not the most studied, crocodylian, their toxicology included, but most research is concentrated in their most populous US states of Louisiana and Florida. To examine the toxicology of two particularly toxic heavy metals, lead (Pb) and mercury (Hg), as well as selenium (Se; a common elemental mitigator of mercury toxicity), in alligators from southeastern Texas, we sampled blood, caudal scute, and intramuscular caudal fat from live animals caught in Brazos Bend State Park (BBSP) and compared their trace element concentrations to caudal scute and fat tissue from legally harvested animals near the Houston metropolitan area. We also regressed analyte trends against every animal's distance to the nearest coal power station, one of the primary anthropogenic sources of Se, Pb, and Hg, as well as against several body condition formulas. Results showed that BBSP animals boasted higher pollutant loads, on average, than harvested animals, including far higher fat-Se:Hg ratios (t= 42.679, df= 24.298), which may be a function of their proximity to the nearby WA Parish Generating Station (Adj. R^2= 0.3214, df= 33 for fat-Se, Adj. R^2= 0.1274, df= 33 for fat-Pb, and Adj. R^2= 0.6795, df= 33 for fat Se:Hg). Body condition metrics, however, did not explain significant variation in pollutant concentration beyond those in fat-Hg (Adj. R^2= 0.1639, 0.1670, 0.1539, df= 31, 21, 21 for the crocodylian Body Mass Index, Fulton's Condition Factor, and Relative Condition Factor, respectively).

Leveraging Alligator Management to Explore Regional Alligator Diet and Contaminants of Emerging Concern

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Abstract

Anthropogenic contaminants, including per- and polyfluorinated substances (PFAS), and microplastics, pose risks to water resources and wildlife. Despite national and international pressures to curb environmental contamination by PFAS and microplastics, data regarding contamination by, and toxic effects of, these pollutants on wildlife are lacking, particularly in freshwater systems. Therefore, research on these contaminants of emerging concern is critical for addressing data gaps and understanding potential impacts on wildlife. One management strategy to assess and monitor environmental impacts is using indicator species that reflect the biotic or abiotic state of a particular environment or habitat. American alligators (*Alligator mississippiensis*) are ubiquitous in wetlands throughout the southeastern United States (U.S.). Alligators are long-lived, top predators with high site fidelity and broad diets, positioning them as candidate indicator species. Throughout their range, management programs use alligators as bio-monitors for aquatic contaminants, including metals and persistent organic pollutants. In addition to their role as indicators of ecosystem health, alligators have commercial and recreational

value through state-managed harvest. Our project leverages ongoing state- and university-led research and the legal harvest of alligators across the region to collect alligator tissue and stomach content samples range-wide. Our objectives are to assess regional patterns in alligator diet, mercury contamination, and elucidate patterns of PFAS and microplastic contamination in alligators across the southeastern U.S. To do this, we have developed a collaborative network among state agencies, non-profits organizations, universities, and private stakeholders to collect diet and tissue samples from 300 alligators across the range. While sample analysis will occur later in 2024, preliminary observations of diet items indicate dietary variance between inland and tidally influenced habitats and between Atlantic and Gulf Coast states. We anticipate continued analysis will provide meaningful insight into alligator diet its influence on PFAS, mercury, and microplastic contamination in alligators throughout the southeastern U.S.

The Implications of Physical and Chemical Restraint for Best Welfare Practice in Both Free-living and Captive Crocodilians

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Abstract

Chemical restraint in crocodilians is often considered dangerous or unnecessary. Welfare considerations are often overlooked when planning crocodilian restraint options and are frequently poorly met. This paper addresses the relative welfare implications of physical and chemical restraint by reviewing how these actions invoke a stress response and what effects this has on normal reptile physiology. It also discusses the implications of thermal stress, concurrent disease and pain when undertaking restraint of an animal. Physical restraint evokes an acute stress response which is a normal response to a threat and returns the body to homeostasis once the threat (the restraint) has passed. If the restraint is for a long procedure, or induces heat stress or hypoxia (by interfering with voluntary respiration), the stress becomes more chronic and non-adaptive. Chemical restraint may exacerbate stress or minimise it depending on drug choices. Chemical restraint should be tailored to the species, purpose for which the animal requires restraint, duration of restraint, conditions under which restraint is being undertaken and the skill and knowledge of the team undertaking the task. The relative reliability and repeatability of sedation or anaesthesia drugs, and their safety for both animals and personnel are very important. A number of options for chemical restraint are discussed in the context of common restraint scenarios and suggestions for further research opportunities are outlined.

Developing a One Welfare Assessment of American Alligators (*Alligator mississippiensis*) in the United States

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Abstract

Although animal welfare science has continued to grow since its inception in the 1960s, much of the focus has remained on charismatic, mammalian species. Reptiles, including crocodilian species, remain an understudied taxonomic group in this field. This is especially of concern given the prevalence the American alligator (*Alligator mississippiensis*) housed under human care settings across the United States, both in the commercial farming industry and zoological industry. As these industries continue to evolve, we must prioritize the welfare of animals in their care, as well as understand the impacts of these facilities on the surrounding environment and human communities. This may be achieved through using a One Welfare approach. Across multiple host farms and collaborating zoological institutions, we will assess the One Welfare impacts of housed crocodilian species across the United States through evaluation of animal welfare, environmental conservation, and human wellbeing. Animal welfare will be assessed using animal behavior, physiological indicators, and resource-based indicators. Environmental welfare will be assessed through these facilities' carbon footprint and contributions to crocodilian conservation. Finally, human/societal welfare will be evaluated by assessing each facility's impact on the local community through measuring the value of employment, community involvement, educational, and/or recreational visitor-animal interactions (direct or indirect). Together, the three components described here could offer a holistic, One Welfare assessment of housed crocodilians in the United States. This project represents one of the research arms of the One Welfare & Sustainability Center at The Ohio State University. OWSC is a new initiative aimed at conducting multi-disciplinary research, education, and outreach to promote positive relationships between animal welfare, human wellbeing, and environmental conservation across many domestic and wildlife landscapes.

Farm-side Assessment to Determine Death in American Alligators (*Alligator mississippiensis*)

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Abstract

Reptiles often present a challenge to confirm permanent loss of consciousness and death due to both persistence of some clinical signs after death (eg heart beat) and absence antemortem (eg blink reflex). Consequently, ensuring a humane euthanasia experience of reptiles can be difficult to determine. However, there are simple on-farm or in-the-field assessment tools that can be used to increase the likelihood that death can be accurately confirmed. We examined six clinical signs of life in 61 American alligators harvested on-farm using one of three methods of euthanasia. Clinical signs of life included detection of (i) heartbeat, (ii) blink reflex, (iii) pupillary light response, (iv) jaw tone, (v) respiration, and (vi) withdrawal reflex. Euthanasia methods included (i) captive bolt and spinal cord severance, (ii) electrostunning, spinal cord severance and pithing, and (iii) spinal cord severance and pithing. Slaughter methods are compliant with the AVMA Guide for Humane Slaughter and performed by experienced operators. Evidence of irreversible unconsciousness and death were assessed at Time 0, 0.5, 1, 2, 5, 10, 20, and 30 minutes post slaughter. A combination of loss of blink reflex, pupillary light response, jaw tone and respiration are a reliable on-farm tool for determining death. Heartbeat and withdrawal reflex persisted. It is possible to reliably determine permanent loss of consciousness and death on-farm and in the-field using a simple combination of clinical sign assessments. This gives the operator confidence they are achieving a welfare-oriented slaughter.

Improved Disease Diagnosis and Management Due to On-farm Veterinarians in Crocodile Producers Consortium Farms

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Abstract

The Crocodile Producers Consortium comprises a collective of 9 crocodile farms spanning across Zambia, Zimbabwe, and Kenya. This consortium is dedicated to advancing research aimed at refining crocodilian husbandry techniques and augmenting productivity among its member establishments. This study delves into the influence of on-farm veterinarians on disease diagnosis and management within crocodile farms affiliated with the Crocodile Producers Consortium. By scrutinizing the impact of veterinary expertise on farm operations, the research endeavors to gauge enhancements in the identification, treatment, and overall health maintenance of crocodiles. Through data analysis and thorough farm evaluations, the investigation assesses the effectiveness of veterinarian participation in bolstering disease control strategies and streamlining farm productivity within the consortium. Additionally, it delves into the integration of laboratory diagnostic techniques for pathogen identification, further enhancing the diagnostic capabilities and treatment modalities available to crocodile farms within the consortium.

Development of Anti-crocodile Antibodies and their Application in Diagnostic and Research Platforms

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Abstract

In the crocodile farming industry pathogens such as West Nile virus (WNV), herpesvirus, *Providencia rettgeri*, and *Mycoplasma* are a threat to productivity through degrading the final product or inducing morbidity and mortality. The lack of species-specific reagents often hinders the investigation of these diseases. This study aimed to isolate, purify, and characterise *Crocodylus porosus* immunoglobulins (IgM and IgY) and generate anti-immunoglobulin reagents. In addition, the study explored the use of these reagents in diagnostic platforms. We isolated and purified *C. porosus* immunoglobulins through sequential precipitation followed by size exclusion chromatography. Obtained fractions were characterised by electrophoresis under reducing and non-reducing conditions, transmission electron microscopy, and immunoblotting. BALB/c mice were immunised with purified *C. porosus* immunoglobulins to generate anti-immunoglobulin monoclonal antibodies (mAbs). Produced mAbs were characterised and compared with a commercially available goat anti-alligator antibody in an antigen capture ELISA and lateral flow assay (LFA) on *C. porosus* serum samples previously characterised by WNV neutralisation test. Mouse anti-crocodile immunoglobulin mAbs had equal sensitivity but far superior specificity compared to a commercially available anti-alligator polyclonal antibody in the LFA and capture ELISA regardless of the capture antibody, ie anti WNV non-structural protein 1 (NS1) or anti-envelop (E) protein antibody. The mAbs are now available for development of diagnostic tests for infectious and non-infectious diseases of crocodiles, thereby aiding management strategies for the crocodile farming industry.

An Insect-specific Chimeric Vaccine Protects Saltwater Crocodiles (*Crocodylus porosus*) Against West Nile Virus-induced Skin Lesions and Viremia

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Abstract

Saltwater crocodile (*Crocodylus porosus*) farming is a socio-economically important industry conserving both the species and providing rural employment opportunities that include First Nation peoples. Crocodiles are farmed for their skin, but West Nile virus (WNV) infection causes skin lesions, known as "pix", that that reduce their quality and value leading to economic losses estimated to be $AUD20 million annually due to hide rejection. This study aimed to develop a vaccine preventing WNV-induced skin lesions in farmed Saltwater crocodiles. We assessed the efficacy and safety of a flavivirus chimeric vaccine comprising the genome backbone of the insect-specific Binjari virus (BinJV) and genes for the structural prM and envelope (prME) proteins of WNV. The BinJV/WNV-prME chimeric virus vaccine is antigenically similar to wild-type WNV but replication-defective in vertebrates. Crocodiles were vaccinated with two doses of BinJV/WNV-prME administered at a four-week interval and WNV-challenged four weeks after booster-vaccination. Serum samples collected at different time points were tested in a pan-flavivirus blocking ELISA and virus neutralisation test (VNT). Vaccinated crocodiles developed a robust neutralising antibody response, regardless of whether the vaccine was adjuvanted or not. Vaccinated crocodiles showed no adverse effects and were fully protected from viremia and skin lesions when challenged with a Kunjin strain of WNV. Mock-vaccinated crocodiles became viraemic, and 22.2% exhibited WNV-induced skin lesions. Our findings suggest that the BinJV/WNV-prME chimera is a safe and efficacious vaccine that prevents WNV-induced skin lesions in farmed crocodiles. This is the first vaccine that provides protection against a viral disease in a reptile. A longitudinal study is about to commence in mid-2024 to extend the safety and efficacy data required for the commercialisation of the vaccine.

Whole Genome Sequencing of Crocodyline Herpesviruses

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Abstract

In recent years, two novel crocodyline herpesviruses (CrHV1 and CrHV2) have emerged as potential pathogens of significant economic importance in farmed Saltwater crocodiles (*Crocodylus porosus*) in Australia and farmed Siamese crocodiles (*C. siamensis*) in SE Asia. The viruses are associated with several diseases, including conjunctivitis-pharyngitis syndrome, systemic lymphoid proliferation and encephalitis syndrome and various manifestations of skin lesions. A probable third crocodyline herpesvirus (CrHV3) has been detected in association with ulcerative skin disease and systemic lymphoid proliferation in a captive population of Freshwater crocodiles (*C. johnstoni*) in Australia. The significance of the viruses to wild crocodile populations is unknown. Identification and phylogenetic placement of the viruses was originally performed through virus isolation in crocodile cell lines and sequencing of the DNA-dependent-DNA polymerase gene. In order to improve our understanding of the phylogeny of these viruses and facilitate development of more effective diagnostic tools, we undertook whole genome sequencing of isolates representing the three CrHVs. Information from the whole genome sequences will facilitate development of PCR primers suitable for quantitative PCR testing for each of the CrHV variants, and generation of antibodies for use in diagnostic assays such as immunohistochemistry. Using a combination of short and long read sequencing, we successfully assembled draft genomes for each of the three species. Across the 'unique long' genomic region, CrHV2 and CrHV3 had approximately 85% nucleotide similarity, while CrHV1 was more dissimilar with less than 50% nucleotide similarity. All the crocodyline herpesviruses clustered within the subfamily Alphaherpesviridae.

Preliminary Investigation into *Providencia rettgeri* Antibiotic Resistance Genes on Australian Crocodile Farms

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Abstract

Of the hatchling crocodiles submitted for pathology from Australian crocodile farms, *Providencia rettgeri* is the predominant isolate recovered. The crocodiles most likely to be affected are in good body condition, often characterised as fast growers. When necropsied, their stomachs are empty despite being offered food five days per week, indicating that clinical cases have ceased eating. Despite this, antibiotics are fed in an attempt to prevent more deaths but could also have the unintended consequence of developing resistance. The purpose of this study was to determine the presence of antibiotic resistance genes using qPCR. Sulphonamides and tetracyclines are available for oral treatment of food-producing species in Australia. Using the accepted disc diffusion method, the reported resistance was 10% to both sulphonamides/tetracycline and 30% to tetracycline with the other 60% sensitive to both. By comparison, qPCR found that 30% had antibiotic resistance genes for both sulphonamides/tetracycline, 10% for sulphonamides and 40% for tetracyclines with only two isolates not having the genes tested. Preliminary interpretation of these results suggests that the isolates contain the potential to express antibiotic resistance even if they are currently exhibiting sensitivity using the disc diffusion method. The majority of cases occur between June and September ("dry season"), characterised by cool, dry conditions. Farms attempt to counter these adverse conditions by providing environmentally controlled housing. However, another major change occurs during this same period, known as the "window of susceptibility", when the final absorption of yolk sac, the last of the maternal antibodies are catabolised and the reliance on self-immunocompetence begins. Given this, farms are advised to investigate possibilities to enhance immunocompetence rather than rely on antibiotics due to the potential for resistance, particularly as no alternatives are currently available for food-producing species in Australia.

Age, Size or Dominance? What Cues Influence Female Alligators to Start to Breed?

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Abstract

The literature suggests American alligators (*Alligator mississippiensis*) are capable of breeding when they reach 6' (1.8 m) in length, which in the wild requires 12-15 years. We are investigating the reproductive potential of a contained group of American Alligators with the objective of understanding and improving their *in-situ* breeding output. The population consists of approximately 130 animals ranging between 13 and 16 years of age. These animals experienced initial rapid growth to 2.0 m in length during the first 3 years of life in a commercial facility before being transferred to a 3-acre pond. The stocking density of these animals is high (93.4 m^2 per animal), presumably inducing spatial resource competition. Since introduction to the pond, this herd has reach full reproductive potential (size and age) with minimal numbers of nests being laid in the two years prior to the start of this investigation. In the lead up to mating (at the point of bellowing), 21 animals were sampled. All were of adult size >2 m with a sex ratio of 2 females to 1 male. Based on laparoscopy, 17 animals were classed as adult (81%), one was pubescent (5%) and three were pre-pubescents (14%). Of the examined adults only 35% of them were preparing to breed. During this same season, 23 nests were collected from this pond with an overall hatch success of 72.4%, which was significantly different from wild nests collected at other non-controlled areas (approximately 85%). These data indicate that size is not the only driver influencing breeding rates. Other forces, eg time to reach maturity, density and/or dominance related suppression of reproductivedevelopment of both males and females, contribute to the reproductive capacity of this group.

Crocodilian Skin in 3D: The Implications of Skin Defects on Finished Crocodilian Leather

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Abstract

The primary product of the crocodilian industry is the skin. The aesthetic appeal of the scale pattern has been replicated on many faux products but will never be surpassed by the quality and durability of crocodilian leather. But with these characteristics comes a price tag that expects perfection. To achieve this, a thorough understanding of crocodilian skin histology, what occurs during the tanning process as well as potential defects and ways to avoid them is essential. The deepest layer of the crocodilian skin are the dermal layers, consisting of the deep dermis overlaid by the superficial dermis. The dermis is constructed primarily of collagen, laid in a cross-hatched pattern and supported by ground substance, which acts like mortar between the collagen bundles. Overlaying the dermis are the epidermal layers. Immediately connecting the dermis and epidermis is the basement membrane (or *stratum basale*), where new epidermal cells are generated. As the cells mature, they move up through the *stratum spinosum* and *stratum granulosum* layers, becoming more flattened and keratinised until they reach the *stratum corneum*, commonly called the 'scale'. The significance of this is that during the tanning process, the entire epidermis is removed leaving only the dermal layers. Also during tanning, the ground substance that supports the collagen is removed. If during the production process, any defect (injury or pathogen) occurs within the dermal layers, the collagen is restructured disrupting the collagen density and causing a change in contour. Additionally, restructured collagen fibres do not have the same diameter which affects the uptake of the dyes resulting in differing colour intensities. An overview of the consequence of some different pathogens are discussed as well as diagnostic tools available to assess prevalence and avoidance strategies. To find out more, enrol in the mini-course of the same name at www.crocodilianacademy.com.

Characterisation and Applications of Collagen Peptides Extracted from Australian Farmed Saltwater Crocodiles, *Crocodylus porosus*

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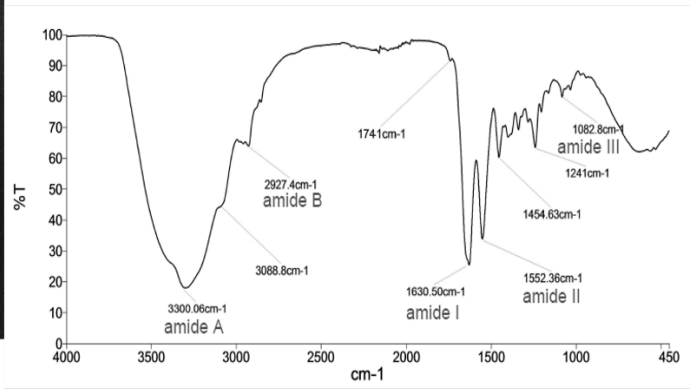
Abstract

Collagen peptides from marine organisms have gained interests in their use as nutriceuticals, cosmeceuticals and in tissue bioengineering. In this study, the isolation and characterisation of collagen from the Australian Saltwater crocodile (*Crocodylus porosus*) is described using a scalable extraction procedure with a comprehensive analysis of biophysical properties, anti-oxidant activity and cytocompatibility. Collagen was extracted from cartilaginous regions using acidic and enzymatic treatment then freeze dried. Fourier Transform Infrared spectroscopy (FT-IR) and Differential Scanning Calorimetry (DSC) were used to demonstrate the secondary protein and peptide structures, and thermal stability of crocodile collagen, respectively. Anti-oxidant activities were determined using Ferric Reducing Anti-oxidant Power (FRAP) and Cupric Reducing Anti-oxidant Capacity (CUPRAC) assays. Proteomics analysis by mass spectrometry included protein identification and sequencing. *In vitro* bioassays including cell-compatibility and wound healing experiments were performed using a human skin cell line (HaCaT). A crocodile collagen peptide lotion was developed and analysed for stability and

rheological properties. The FT-IR spectra of *C. porosus* collagen showed five characteristic peaks. The amide A, amide B, amide I, amide II, and amide III bands showed vibrations at 3300 cm^{-1}, 2927 cm^{-1}, 1630 cm^{-1}, 1552 cm^{-1} and 1241 cm^{-1}, respectively. The amide III peak suggested an intact triple-helical structure. The DSC thermograms showed three peaks with a Tmax of 74.1°C and 71.4°C for crocodile and bovine collagen respectively. Mass spectrometry revealed over 50 peptides ranging from 8 to 30 amino acids with collagen type-1-alpha-2 being predominant. The anti-oxidant activities were 0.987 mg/g and 13.48 mg/g by FRAP and CUPRAC, respectively. Collagen peptides showed no cytotoxicity and *in vitro* wound healing experiments showed activity between 8-80 μg/ml. In summary the crocodile can be a source of collagen peptides with undiscovered properties adding further value to the carcass and a new revenue stream for the industry.

Rib cartilage from *Crocodylus porosus* *(left), extracted collagen (right)*

FT-IR spectra of *Crocodylus porosus* collagen



CrocPLAN: Assessing Farm Productivity and Selection of Superior Performing Crocodiles

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Abstract

Crocodilian farm profitability is a function of inputs, production efficiency and, ultimately, the resultant number and quality of skins produced. Over the last 20 years, significant gains have been made by improving management systems including optimising welfare, stocking densities, feed quality, environmental control and disease management. While these improvements will continue to be refined, any economic assessment of productivity cannot be fully realised without understanding the genetic basis upon which the performance is based. Crocodile production performance, such as reproductive output, juvenile growth and survival, in its simplest form is a function of genetics and environment, which includes the management system. Despite tightening on-farm management systems, producers still observe variation within individuals - these are predominantly genetic (and maternal-genetic) effects. CrocPLAN is a subscription-based, production assessment tool that incorporates a pedigree that can disentangle underlying genetic performance from management improvements. This can be applied to both ranching and captive breeding operations, but for those doing captive breeding, CrocPLAN also allows performance differentiation of the captive breeding herd, allowing replacement and selection decisions to be formulated. This is more important now than ever with old age encroaching on many of founder farm breeding stock. While all crocodilian farms are encouraged to subscribe to CrocPLAN to assess their annual management gains and, for those with captive breeders, to optimise their current and future genetic capability, captive breeding should never come at the expense of sustainable use conservation programs due to the corporate social responsibility and livelihood benefits that ensue from these programs.

Assessing Farm Profitability Using CrocPLAN: A Case Study

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Abstract

Hartley's Creek Crocodile Farm (HCCF) is located north of Cairns in Queensland, Australia. In Queensland, wild collection of eggs is currently very limited, and most farms rely primarily on their own captive breeding herd to obtain production stock. This is the ideal setting for conducting a feasibility study for CrocPLAN as a tool to assess and monitor farm productivity. The production traits of interest were reproductive output, growth rate and survival. In 2023, hatchlings were individually identified to relate them back to their clutch-of-origin. Some additional record keeping was required to record deaths against clutch as well as measuring head length during the annual movement from the hatchling to grower pens. Age-adjusted head length is a proxy for time to reach harvest age. This data was collated into a pedigree and analysed using standard animal breeding statistical models. For each production trait, a Crocodile Breeding Value (CBV) was derived for each breeding pair. These CBVs were then combined into a Crocodile Economic Selection Index ($CESI) using the economic weights presented by Hermesch and Isberg within these proceedings. The $CESI ranked the HCCF breeding pairs based on their offsprings' performance allowing informed decisions to be made. Offspring from superior performing animals can be selected and raised as replacement breeding stock while poor performing animals can be replaced. CrocPLAN is a subscription-based service for $US2/animal. There were 965 crocodiles in the pedigree, costing $US1930, with the additional cost of $US573 for supplementary data collection. The total cost of implementing CrocPLAN in 2023 at HCCF was $US2502. The current recommendations, after only one year of data collection, is to replace seven breeders with their replacements conservatively estimated to generate an additional $US22,791 based on the current herd average (1181% ROI). Therefore, the return on investment (ROI) from using CrocPLAN can make considerable production gains in very short periods of time. The collation of additional years of data will also allow management changes to be assessed for continual improvement.

Australian Saltwater Crocodile: Harnessing R&D Investment for Sustainable Industry Growth

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Abstract

AgriFutures Australia is a statutory authority, one of 15 rural Research and Development Corporations (RDCs), and the only one with a remit to invest in research and development of Australia's new and emerging industries. The AgriFutures Emerging Industries program helps grow up-and-coming animal and plant industries for which there is a clear interest in their products but whose pathway for growth is unchartered. We do this through research, development and extension that explores opportunities for growth and through skills development for industry leaders. Our goal is to sustainably grow developing rural industries and assist them reach new markets. One such industry under AgriFutures' purview is the Australian Saltwater crocodile, *Crocodylus porosus*, consisting of 21 operators across the Northern Territory, Queensland, and Western Australia. This industry assumes a pivotal role in the Australian economy, particularly in the northern regions. Renowned for its production of high-quality crocodile skins catering to the luxury fashion market, the industry also contributes meat and other by-products. AgriFutures has actively invested in this industry, supporting 13 projects since 2007 with a cumulative investment of $1,232,597. One of the recent key investments has involved the development of the Australian Crocodile Industry RD&E (Research, Development and Extension) Plan 2024-2029. This RD&E Plan illustrates the industry's collaborative capacity, highlighting five key themes crucial for maintaining its social license, enhancing efficiency, and ensuring profitability. The strategic approach underscores the industry's commitment to sustainability and success, focusing on environmental sustainability, social license, production efficiency, skin quality, value-added by-products and ensure resilience and capability. This overview captures AgriFutures' strategic involvement in supporting sustainable growth within the Australian crocodile industry. Further, it underscores the economic significance of the industry and the commitment to explore novel avenues for investment and development.

From Farm to Fashion: How ICFA is Supporting Crocodilian Farming with Animal Welfare Standards and Environmental Integrity

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Abstract

The International Crocodilian Farmers Association (ICFA) is a pivotal non-profit organization committed to fostering sustainable crocodilian farming, emphasizing ethical practices, wildlife conservation, and economic development in rural communities. With 49 member entities spanning various countries, the ICFA has been instrumental in setting new benchmarks for crocodilian farming through the introduction of ICFA Standard 1001:2019. These guidelines, shaped by expertise from diverse fields, adhere to both national and international frameworks like CITES, ensuring the welfare of crocodilians is paramount. This initiative has led to 42 out of 46 farm sites achieving a specialized animal welfare certification, marking a significant step towards ethical crocodilian farming. In a groundbreaking move, the ICFA established the first collaborative, independent third-party certification system focused on animal welfare in crocodilian farming. This system, which also considers fair labor practices and worker well-being, has garnered support from a wide spectrum of industry stakeholders, including luxury brands and farmers, showcasing a united front for sustainable farming practices. Furthermore, the ICFA actively engages with academic institutions, hosting seminars at fashion and luxury management schools to instill a consciousness regarding sustainable and ethical crocodilian usage among future industry leaders. This educational thrust complements the ICFA's strategic vision of perpetuating sustainable farming practices that align with environmental and ethical standards. The decline in crocodilian populations due to excessive hunting and loss of habitat has been significantly reversed thanks to regulated trade measures and initiatives like CITES, showcasing the vital role of sustainable farming in conservation success stories. ICFA's commitment to sustainable use, ethical practices, and environmental care aligns with the Crocodile Specialist Group's (CSG) long-term goals and vision, promoting a collaborative effort for the conservation and ethical management of crocodilian species. This summary showcases the ICFA's holistic strategy towards sustainable crocodilian farming, emphasizing its dedication to ethical standards, conservation efforts, and the economic development of rural communities. By focusing on sustainable farming, this approach is essential not only in environmental conservation but also in enhancing the well-being of those in rural areas.

LCAs for Crocodilians: An Opportunity or a Curse?

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Abstract

The fashion & leather goods sector relies heavily on LCAs (life-cycle analyses). There is no surprise therefore that the crocodilian sector follows the same path. An environmental LCA is an excellent tool to understand, locate and identify actions to reduce the environmental impact of a commercial product, process, or service. Providing a common base for assessments, it allows for a same language across industries and geographies, and for comparisons. But it is not a perfect tool. Based on assumptions and collected data, and approached as a linear metric, it risks portraying a non-representative picture of the crocodilian sector's footprint if not approached with real-life facts, and a critical eye. This presentation is an introduction to environmental LCAs. It explores its benefits for your operations, be it at farm, tannery or manufacturing level, its limitations, and improvement opportunities. Whether you are familiar or not with the concepts of *cradle-to-gate* or *emission factors*, come and join us for a deep-dive in the world of impact normalization and measuring!

The Economic Impact of the Alligator Farming Program in Louisiana, USA

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Abstract

Louisiana's alligator farming program started in the early 1970's. For the first few years, the Louisiana Department of Wildlife and Fisheries provided hatchlings to new farms that met and abided by the Department's regulations. Those early farms were required to develop a captive breeding stock and be self-sustaining within ten years. After years of research into captive breeding, the Department determined that collecting eggs from nests in the wild was much more effective and efficient. Louisiana alligator producers now obtain all their hatchlings from eggs collected in the wild. In 2023, farmers collected 453,784 eggs from nests in the wild. A percentage of the hatchlings are released back into the habitats where the eggs were collected to compensate the wild population. There are currently 56 licensed alligator farmers in Louisiana but only about 20 produce and ship hides for the commercial market. The remaining licensees are either for educational displays or landowners involved with egg collection. Hide production reached a high of 450,221 in 2018. The most recent year of production reported was 309,984 hides in 2022. A recent study of the economic impact of the farmed alligator industry to Louisiana's economy was approximately $235 million in 2019. The direct value of the skins was over $90 million. These values did not include the additional value of the alligator meat resource or tourism value. The main production expenses to produce farm alligators in Louisiana were egg/hatchling cost, feed, labor, other variable costs, and utilities.

Changes in Louisiana's Wild Alligator Harvest

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Abstract

The wild alligator resource has had a commercial harvest program for over 50 years. The number of alligators harvested increased to around 30,000 in the year 2000. Up until the last eight years, the harvest ranged between 30,000 and 38,000. Since 2017, the harvest has dropped to between 14,000 and 23,000 per annum. In 2019, it was estimated that the wild harvest program contributed almost $3.5 million to the Louisiana economy. In 2023, only 18,000 were harvested. The increased supply of high quality, and specific size farm alligator skins has been the primary reason for the declining demand for wild skins. The value of the hide has dropped to the point that the greatest value of the animal is for the meat. Over the years, the meat market has grown in the southeastern United States. An emerging sport hunting business has developed and is helping to maintain interest and participation in the wild harvest. An economic assessment showed that between 2016 and 2018, non-resident sport hunters in Louisiana spent approximately $4700 per trip hunting alligators and contributing to related sectors of the state economy during their hunting trips. In addition to the wild harvest season, the Louisiana Department of Wildlife and Fisheries has a program in place to handle nuisance alligator complaints. Licensed nuisance alligator hunters are paid to either relocate small alligators or dispatch the larger and more dangerous ones.

Crocodilian Cornerstone: The Vital Role of Exotic Leathers in Lucchese Bootmaker's Luxury Craftsmanship

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Abstract

Founded in 1883, Lucchese Bootmaker represents the pinnacle of luxury in western boot craftsmanship, meticulously handcrafting each pair in El Paso, Texas. With over 500 employees in the USA, Lucchese exemplifies traditional American luxury and distinguishes itself in a competitive footwear market flooded with cheaper, mass-produced alternatives. This presentation, spearheaded by Men's Designer Trey Gilmore, highlights the critical importance of crocodile and alligator leathers in reinforcing Lucchese's prestigious standing within the luxury segment. Lucchese Bootmaker incorporates a diverse range of premium crocodilian leather in their boot production, including *Caiman crocodylus yacare* (Yacare caiman), *Caiman crocodylus fuscus* (Brown caiman), *Crocodylus porosus* (Saltwater crocodile), *Crocodylus niloticus* (Nile crocodile), and *Alligator mississippiensis* (American alligator). Lucchese's commitment to quality and exclusivity is evidenced by its reliance on exotic leathers. The choice to use crocodile and alligator hides is a declaration of Lucchese's dedication to superior craftsmanship and premium materials, which are essential for justifying the brand's higher production costs in the United States. This strategic decision not only allows Lucchese to appeal to a discerning luxury market but also differentiates it from competitors. Moreover, the unique characteristics of crocodile and alligator leathers greatly enhance the bespoke nature of Lucchese boots, appealing to aficionados of luxury footwear. The presentation will delve into Lucchese's sustainable and ethical sourcing practices for these leathers, demonstrating the brand's commitment to environmental stewardship and ethical responsibility. The use of crocodile and alligator leathers is not merely a choice of material but a cornerstone of Lucchese's heritage, enabling the brand to uphold its esteemed reputation while adhering to principles of sustainability and conservation. With a strong workforce and a dedication to traditional craftsmanship, Lucchese continues to symbolize the zenith of luxury footwear, blending tradition with a commitment to ethical and environmental standards.

Government's Integral role in Ensuring Sustainability, Traceability and Verification in the American Alligator Supply Chain

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Abstract

This abstract explores the crucial role of Government entities in managing the supply chain sustainability, traceability, and verification of American alligators, with a focus on the Louisiana Department of Wildlife and Fisheries (LDWF). The LDWF has successfully implemented a sustained use program for the American alligator, positioning it as a global model for wildlife conservation. The legal framework guiding this initiative includes global oversight through the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), with the U.S. Fish and Wildlife Service (USFWS) administering CITES requirements at the federal level. The Louisiana State Legislature has granted the LDWF full authority to regulate the alligator season within the state. The conservation goals of the LDWF include managing and conserving Louisiana's alligators as integral components of the wetland ecosystem, providing benefits to associated wildlife, and continually improving monitoring efforts. To ensure the sustainability of alligator populations, the LDWF conducts annual population surveys, employing aerial surveys and scientific tools to validate findings before granting permits for egg collection and wild alligator harvests. The LDWF's involvement extends to licensing, regulating, and overseeing alligator farming operations, ensuring compliance with science-based animal welfare standards through annual inspections. The permitting process for egg collection involves a three-party contract between the Government, landowners, and farms, with meticulous validation and record-keeping to verify alligator inventory on farms. Additionally, the LDWF regulates and enforces wild alligator harvests, issuing trapping permissions based on land ownership and assessing habitat quantity and quality to determine sustainable harvest levels. This comprehensive approach includes enforcement of hunting seasons, catch methods, and commercial sales of alligator products. In summary, the Government's multifaceted involvement in the supply chain, from population surveys to regulation and enforcement, plays a pivotal role in ensuring the sustainability, traceability, and verification of American alligators, contributing to the success of Louisiana's conservation program and serving as a global exemplar for responsible wildlife management.

Investment Returns on Competency-based Training in the Crocodilian Industry

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Abstract

Professional development of crocodilian farm staff offers numerous benefits to every level of the global industry from the balance sheet, boots-on-the-ground staff, up to and including, the corporate board level. From a staffing standpoint, investing in professional development increases workplace performance, morale and staff retention. Empowering staff with formal training provides the background theoretical knowledge behind the development of standard operating procedures (SOPs) by training the "why" as well as the "how". In turn, this instils critical thinking to identify potential production gains which are then reflected within the balance sheet (eg more 1st grade skins, higher hatch, growth and survival rates, etc.). At the managerial level, competency-based training provides evidence that staff have been trained appropriately in respective skill sets, thereby minimising deviations from SOPs and reducing work, health and safety (WHS) incidents. Formal training can provide a legal safeguard as it provides independent evidence that WHS protocols have been delivered, understood and assessed which can be provided to insurers for proof of compliance. At the corporate board level, having certified trained staff reduces the exposure risk with regulators around WHS and crocodile welfare. It also increases staff retention, ensuring corporate knowledge is retained and reinvested within the business. Finally, being able to provide evidence that staff are formally trained in world's best practice for crocodilian welfare empowers the industry against attacks to their corporate social responsibility. In 2020, a review of the crocodile training units within the Australian Vocational Education and Training framework updated the "Certificate III in Working with Crocodiles" qualification. The Crocodilian Academy is currently developing these units and will be offering them as both online (www.crocodilianacademy.com) and face-to-face courses.

Improving Crocodile Farming Profitability Using Economic Weights

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Abstract

Productivity of farming Saltwater crocodiles depends on multiple traits, such as growth, survival and reproductive output. To understand the relative importance of each of these traits on farm profit, economic weights can be used to reflect the marginal change in profitability when a trait is changed by one unit keeping all other traits constant. Economic weights for traits affecting profitability of farming crocodiles have been developed. It is the aim of this study to demonstrate how these economic weights enable crocodile farmers to combine multiple traits into one economic index to identify animals or husbandry practices that maximise crocodile farming profitability. The economic value for number of hatchlings per clutch was based on the annual capital, feed and operating costs of breeding female crocodiles expressed per hatchling. The economic value for days to harvest of a crocodile for skin and meat represents the daily costs of keeping a growing crocodile on farm. Obviously, skins with a superior grade achieve a higher price. The economic value for skin grade quantifies changes in profitability resulting from an increase in the proportion of skins with a better grade. Traits and their economic values were either expressed per clutch (number of hatchlings per clutch) or per growing crocodile. Therefore, discounted genetic expressions were used to convert economic values to economic weights expressed per clutch to place traits on a common basis of expression. Economic weights were applied to existing estimates of genetic merit of Saltwater crocodiles to outline variation in profitability between animals that can be used to improve overall farm profitability. In addition, the use of economic weights to evaluate alternative husbandry practices for improved farm profitability was illustrated. This should be easily adaptable to other crocodilian farming models from different countries as well as different species.

Ensuring Genetic Purity in Siamese and Saltwater Crocodile Populations

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Abstract

Hybrids between the Critically Endangered Siamese crocodile (*Crocodylus siamensis*) and the IUCN-listed Least Concern Saltwater crocodile (*C. porosus*) in captive populations pose a significant challenge to conservation and reintroduction programs of *C. siamensis*. This study advocates the use of alternative DNA markers and a diverse range of populations to identify and avoid these hybrids for reintroduction. Thus, DArT sequencing was employed to identify genome-wide single nucleotide polymorphisms (SNPs) in both species, confirming the genetic scenario of the parental species and their hybrids. A population of Saltwater crocodiles from Australia was chosen to compare the distribution of species-diagnostic SNPs. Various analytical approaches were employed to diagnose the level of hybridization in the presence of admixture, particularly in cases where three individuals exhibited potential backcrossing. To validate the species-diagnostic SNP loci, a PCR-based approach was used, selecting 20 SNP loci for PCR primer design. Out of these, three loci successfully differentiated between actual species and various hybridization levels. Combining mitochondrial and nuclear genetic information, including microsatellite genotyping and species-diagnostic DNA markers, introduced a novel approach that addressedd the limitations of each individual method. This integrated approach facilitates conservation prioritization before releasing into the wild, ensuring sustainable genetic integrity for long-term species survival in reintroduction and management programs.

Unraveling the Mysteries of Indonesian Crocodylians

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Abstract

The evolution of southeast Asia's crocodylians is enigmatic and only recently elaborated in a few large-scale phylogenetic studies. For the potentially up to eight island-occurring species in the region, they are characterized by a complex biogeographic history that is not yet fully understood. Nowhere is this more typified than across the Indonesian Archipelago, which consists of more than 17,000 islands and bridges the Greater Sunda, Wallacea, and Australasian biogeogeographic regions. The archipelago is home to four currently recognized species, with two additional taxa previously described, and potential for significant cryptic diversity within at least one of these species. *Crocodylus halli* was described morphologically from museum specimens, but molecular data from specimens of known wild origin needed to better resolve the validity of the taxon are largely lacking for the island of New Guinea. *Crocodylus raninus* remains an enigmatic lineage, only described from a handful of skulls, but no live individuals have ever been documented and there are no known contemporary populations. And, in the Sunda Region, *Tomistoma schlegelii* is a freshwater species inhabiting the disparate geographies of Borneo, Sumatra, and peninsular Malaysia, but no thorough genetic study has been done across its range. A detailed molecular phylogeography is critical for the crocodylians of Indonesia to better understand these species' evolutionary trajectories and ecological niches to better plan for their conservation. Here we present a review of what is known to date about Indonesia's mysterious crocodylians and an ambitious plan for resolving the many mysteries that this island nation yet contains - including recent, reliable evidence that *C. raninus* may yet exist in Borneo's remote wetlands.

Taxonomic Revisions and Conservation Status Updates for the African Dwarf Crocodiles (*Osteolaemus* spp.)

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Abstract

Despite their ecological and economic importance to the ecosystems and peoples of West and Central Africa, dwarf crocodiles (*Osteolaemus* spp.) have become the global crocodylian community's forgotten species. Arguably, they are the least known crocodilians globally, with few dedicated studies on their status, ecology, and distribution. The harvest and commercial trade of dwarf crocodiles is in the order of 100s of thousands annually, making this the largest unmanaged harvest, and among the largest harvests overall, of any crocodylian in the world. Recent research has identified significant cryptic diversity corresponding to three distinct species - each with their own complicated taxonomic past and conservation status. *Osteolaemus* was last assessed as Vulnerable (VU) for the Red List in 1996, a status which appears no longer broadly applicable to the genus. Relatedly, the *Osteolaemus* Action Plan is well out of date. This neglected status, complete with outdated taxonomy and general lack of Assessment and Planning, is among the barriers to implementing effective and sustainable management for dwarf crocodiles. Here, we reintroduce the dwarf crocodile species complex to the CSG, including updates on taxonomy and the Assessment and Planning phases of the IUCN conservation cycle. To revise the taxonomy, we are complementing existing molecular data with cranial and scalation characters to support species differentiation. Through a stepwise process of character identification, description, and blind testing, we have identified several preliminarily diagnostic and/or identifying characters. On the basis of this total-evidence approach, we are redescribing the genus and its three species, including elevating the existing name *O. afzelii* for the West African taxon. Additionally, CSG regional leadership is working with a cadre of up-and-coming CSG members in West and Central Africa to assess *Osteolaemus* against Red List criteria, globally and regionally, and mentor this next generation of conservation scientists through the development of regionally-relevant action plans. Filling these gaps and plotting the path for dwarf crocodile management is timely in light of ongoing West and Central African initiatives for wildmeat and sustainable wildlife management, supporting local communities and indigenous peoples, and reducing wildlife trafficking.

Is *Ultrastenos* Stein, Hand and Archer (Crocodylia: Mekosuchinae) a Gavial Ecomorph?

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Abstract

Ultrastenos willisi from the Oligocene of the Riversleigh World Heritage Area, was described as a mekosuchine crocodylian with a gavial-like, longirostrine morphology. However, the rostrum is not preserved, and the reconstruction rests on a set of inferences that are based on the shape of a mandibular fragment and a cranial reconstruction that was assembled from non-joining fragments. Contrasting with the reconstruction are the proportionally small supratemporal fenestrae and the blunt, molariform posterior teeth, which are discordant with the slender longirostrine morphotype. The issue is resolved by the discovery that QM F31076, a posterior skull fragment ('White Hunter cranial form 1'), which has been referred to *U. willisi*, is likely to be the missing posterior end of the extremely brevirostrine holotype of *'Baru' huberi*. QM F31076 'White Hunter cranial form 1' can be further linked to the holotype of *'B'. huberi* via their matching size, preservation and dermal ornamentation. 'White Hunter cranial form 1', in turn, shares a combination of cranial apomorphies with *U. willisi* and belongs to the same species, indicating that *U. willisi* is a junior subjective synonym of *'B'. huberi*. However, phylogenetic analyses have found that *'Baru' huberi* is more closely related to other mekosuchine genera than it is to *Baru*. Consequently, *Ultrastenos* should be retained as a valid genus, resulting in the new combination *Ultrastenos huberi*. With the discovery that *Ultrastenos* is not a longirostrine taxon there are no longer any known longirostrine mekosuchines suggesting that the otherwise disparate Mekosuchinae failed to occupy this region of morphospace.

When does Crocodylia First Appear in the Fossil Records?

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Abstract

Though often considered an "ancient" group that persisted through the Age of Dinosaurs, Crocodylia is a comparatively young clade. The last common ancestor of living alligators, crocodiles, and Gharials post-dated the basal divergences among crown-group squamates, turtles, birds, and mammals. But when, exactly, did Crocodylia first appear? The oldest unambiguous crocodylians date back to the Campanian stage of the Late Cretaceous (83.6 to 72.1 million years ago [Ma]). The earliest are from the lower Allison Member of the Menefee Formation in New Mexico, which is dated to the base of the Campanian; and from the Mooverville Chalk in the southeastern US, which straddles the Campanian-Santonian boundary. This puts the first appearance datum (FAD) for Crocodylia at approximately 82 Ma. Two of these early Campanian occurrences – *Brachychampsa sealeyi* and gigantic (10 m) *Deinosuchus schwimmeri* - are alligatoroids. The presence of two alligatoroids in the early Campanian suggests unsampled diversity; the lineage including Crocodyloidea and Gavialoidea does not appear until the late Campanian or overlying Maastrichtian, but must have come into being at the same time as Alligatoroidea. Nevertheless, the origination time of Crocodylia can be constrained to the Late Cretaceous. The crocodyliform record between the end of the Early Cretaceous (100 Ma) to the beginning of the Campanian is comparatively sparse, but crocodyliforms are well-sampled in the later part of the Early Cretaceous, and nothing unambiguously within the crown has been found. Several recent fossil discoveries purport to extend the crocodylian FAD below the Campanian. The most prominent of these is *Portugalosuchus azenhae* from the Cenomanian of Portugal. If *P. azenhae* is within the crown, it would extend the FAD by as many as 20 million years. Based on our own examination of the material, we interpret some of the morphology differently. In particular, the external mandibular fenestra that would have linked *P. azenhae* to the crown is better interpreted as postmortem damage; it lies within a narrow groove following the dentary-angular suture, is unlike the slitlike fenestra including the surangular in several basal crocodylians and close crocodylian outgroups, and its margins are uneven. Phylogenetic analyses based on our reconstruction recovers *P. azenhae* as a eusuchian, but not as a crocodylian. This is consistent with arguments based on molecular divergence estimates that *Portugalosuchus* was too old to be a crown-group crocodylian.

Patterns of Crocodylian Extinction and Survival in Quaternary Southeastern Asia with Implications for Restoration

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Abstract

We review the past diversity of crocodylians from the last ca. 2.5 million years of Southeastern Asia in light of published paleontological, archeological, and genetic studies, as well as novel fossil data. These records of the past provide valuable insights into poorly explored extinction patterns and risks as well as species management. Species and population diversity during historical and Pleistocene times was considerably higher in the region than today. We find that Quaternary extinctions were asynchronous and selective. The extinct *Gavialis bengawanicus* was distributed in Thailand and Java during the Early Pleistocene sea level low stand but it subsequently disappeared during the Middle or Late Pleistocene. We hypothesize that during interglacials, elevated sea level and associated reduction of deep riverine habitats, a type of habitat the modern *G. gangeticus* particularly favors, caused the extinction of *G. bengawanicus*. In the present interglacial, there is probably only limited suitable habitat left for *Gavialis* in Southeast Asia. In contrast, the peat swamp forest-specialist *Tomistoma schlegelli* likely survived past sea level fluctuations, as suggested by published genetic studies of extant populations, and has suitable habitats outside its current distribution, for instance in southern Thailand. Another survivor and shallow water inhabitant, *Crocodylus siamensis* can be traced back at least to the Middle Pleistocene of Thailand. *Crocodylus porosus* has no published fossil record from the region but undescribed specimens from Thailand may well belong to this species. From the Quaternary of Thailand, we recently described an extinct alligator, *Alligator munensis*. This taxon is closely related to extant *Alligator sinensis* and the timing of its extinction can be constrained to the Late Pleistocene to Holocene. The extinction of this species is puzzling because alligators are opportunistic taxa. Given the timeframe alone, human-induced extinction cannot be excluded as has been otherwise proposed for extinct gavialines from south China. *Alligator munensis* highlights that *Alligator sinensis* introduction programs could potentially expand well beyond their extremely restricted focus area in the Yangtze delta.

Advancing Taxonomic Research with AGRF's Genomic Solutions

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Abstract

Taxonomic research necessitates precise genetic analyses for species delineation, hybrid identification, and comprehension of population dynamics. AGRF stands as a premier genomics research organization, specializing in cutting-edge genomic sequencing, technical support, and bioinformatic services. Our expertise spans diverse domains such as agriculture, aquaculture, environmental science, and biodiversity. In the taxonomic realm, our comprehensive suite of services, bolstered by dedicated teams, empowers researchers to achieve their objectives. In the microbial space, we now offer full-length 16S and ITS sequencing, alongside shotgun metagenomics on the PacBio Revio. Moreover, we provide an array of targeted SNP genotyping solutions, including targeted Mass Spectrometry, NGS microarrays, GBS, and low-pass whole genome sequencing, all tailored to address your research inquiries effectively.

SAFE: A New Direction for Supporting Cuban Crocodile Conservation

Lauren Augustine

Philadelphia Zoo; AZA SAFE Program Leader: Cuban Crocodile

Abstract

The Association of Zoo's and Aquariums (AZA) has long promoted conservation through cooperative breeding and the sustainability of populations through their membership. The AZA has been managing Cuban crocodile (*Crocodylus rhombifer*) populations in North America since 1993 through a Studbook and a Species Survival Plan (SSP). Cuban crocodiles were exported to the United States prior to the widespread hybridization of the species with American crocodiles (*Crocodylus acutus*) and a recent genetic analysis revealed that the samples submitted from the North American managed population (n= 45), all identified genetically as Cuban crocodiles. In addition to preserving the genetic integrity of potentially extirpated populations of Cuban crocodiles, the AZA population has also served as a mechanism to increase our knowledge about this unique crocodilian. In recent years, the AZA introduced a new initiative, Saving Animals From Extinction (SAFE), aimed at utilizing the expertise of AZA accredited zoos and aquariums in leveraging their massive potential for outreach to save species. In order to strengthen *in-situ* and *ex-situ* efforts for conserving this species, the Cuban crocodile was made into an AZA SAFE Program. A 3-year plan was developed through collaboration with multiple partners from AZA institutions, the CSG, and the Zapata Crocodile Farm in Cuba. With a rich history, devoted Cuban conservationists, and AZA support, the future of Cuban crocodile conservation is optimistic.

Regional Collection Plan for Crocodylians in Europe

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Abstract

Within the European Association of Zoos and Aquaria (EAZA), Taxon Advisory Group (TAGs) are responsible for selection for which animal species should be kept and which ones should be replaced by other species. Following these recommendations, breeding programmes are established or discontinued. The recommendations are summarised in a Regional Collection Plan (RCP). Factors being considered for selection as a breeding program are primarily the conservation status but also availability, situation of the species within EAZA and in other zoo associations, size and geographical origin. The EAZA Reptile TAG developed the most recent Crocodylian RCP in 2021. In this presentation, the process of an RCP is explained. Also, the results of the RCP for the Crocodylian species in Europe is presented. Furthermore, special concerns as natural parent-rearing, inclusion of non-EAZA members and surplus policies are discussed.

Orinoco Crocodile Conservation Program in Krokodille Zoo Denmark

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Rene Hedegaard, Director of Krokodille Zoo in Denmark, visited Venezuela for the first time in 2007, and attended the Workshop on the Conservation of the Orinoco Crocodile in Venezuela and Colombia. He later travelled to the Cojedes River, site of one of the most important *Crocodylus intermedius* populations, and spent a few days at Masaguaral Ranch, the first captive breeding center for the species. Thus began his desire to collaborate and be part of the National Conservation Program of the Orinoco Crocodile in Venezuela.

In 2013, Krokodille Zoo received 6 female *C. intermedius* that had been hatched at Dallas World Aquarium (USA), and began discussions with Fundación para el Desarrollo de las Ciencias Físicas, Matemáticas y Naturales (FUDECI), Masaguaral Ranch and the Venezuelan Crocodile Specialists Group (GECV), to obtain some male of *C. intermedius* and establish the first breeding centre of the species in Europe. Rene returned to Venezuela in 2015 and 2016, to participate in the reintroduction of captive-bred 1-year-old individuals to their natural habitat, and to formalize his relationship with FUDECI, which manages the Orinoco crocodile project at Masaguaral Ranch. Several years were spent establishing the necessary steps to be able to send 7 Orinoco crocodiles (a pair of adults and 5 juvenile males), including the signing of a cooperation agreement between Krokodille Zoo and the Venezuelan Ministry of People's Power for Ecosocialism (MINEC), and provision of support for captive breeding activities, which resulted in the issuance of CITES export permits for the crocodiles. However, due to the COVID-19 pandemic, the entire operation was put on hold.

In 2022, the process was restarted, involving: renewal of CITES permits; hiring of Taurel Customs Agency to support export procedures; Transportes Aereos Portugueses (TAP) being identified as airline to transport the crocodiles to Europe; construction of transport boxes; and, obtaining of Venezuelan Health Certificate and other permits required for transfer of crocodiles from Masaguaral Ranch to Simon Bolivar airport. In October 2022, TAP advised that it did not have a service in Europe that could take the cargo to Germany, so it was decided that the crocodiles would travel by air to Lisbon (Portugal), by land to Hamburg (Germany), and then a ferry across the Baltic Sea to Denmark. The trip was rescheduled to 10 January 2023.

Two days before commencement of the operation, the team was assembled, comprising Omar Hernandez, Ricardo Babarro, Arnaldo Ferrer, Odilo Enes, Roldan De Sola, Leonel Ovalles, Tomas Blomh and myself. They were accompanied by Mecsys Fuentes, Eneida Marin and Andrea Velasco who, with myself, took charge of taking videos and photographs. The team went to Masaguaral Ranch to collect the crocodiles, each of which was injecting with 5% dextrose solution, micro-chipped and measured, before being placed in their transport boxes. The animals were not fed a week prior to the trip. 6 boxes were used, 5 of them contained a single Orinoco crocodile, and 2 specimens were in one box.

The first sector consisted of approximately 400 km from Masaguaral Ranch to Simon Bolivar Airport, on 9 January. During the transfer we stopped at different checkpoints, where documentation to show the legality of the operation were checked. Once at TAP warehouses, the National Guard, the Anti-drug Command, the Venezuelan Health Institute and the tax regulator (although the cargo was exempt) certified the documentation. However, Anti-drug Command demanded to see the crocodiles, which was not feasible given that they were unrestrained in their boxes, and without their jaws tied - there was potential risk that they could escape their boxes. So, each box was carried out with its crocodile inside, and x-rayed, to confirm that there were no drugs within them. The full load, boxes and crocodiles, weighed around 700 kg.

On 10 January, the boxes were loaded onto the plane (cargo hold at 27°C) for the trip to Lisbon. The flight was commercial, the Orinoco crocodiles were in a special area for live animals and I was in the passenger sector. The trip took more than 8 hours. After I completed migration formalities, Rene picked me up and we made our way to the cargo area of the airport, arriving at around 0600 h (local time; 11 January). Documentation was handed over, and we received the boxes. Cargo staff were excited about this "unusual" shipment, and took photographs as we checked the condition of the crocodiles, observing them through the side holes of the boxes.

The boxes were loaded into a covered truck, and at 1100 h we started our road trip across Portugal and northern Spain, and at night we crossed the border with France. The cabin containing the boxes were ventilated from time to time a route. At the first stop in Portugal, we placed tape over the ventilation holes of the boxes, since the ambient temperature was around 5°C, and we did not want the animals to feel that low temperature when the cabin was being ventilated.

In France, on the first night, Rene contacted Sarah Carpentier, a friend who works in a zoo/park in French Normandy, to book a hotel with rooms near the parking area, so that we could run an electric lead out the window, to a heater placed in the cabin with the boxes. At 0800 h the next day (12 January), we continued the journey across France, and at night across Belgium and the Netherlands, and arrived in Hamburg and the port where we took the ferry across the Baltic Sea to Denmark - arriving at 0400 h on 13 January. From the ferry terminal, we continued towards Eskiltrup, where Krokodille Zoo is located, arriving at around 0600 h. The trip from Lisbon to the zoo took 20 hours, and covered about 4000 km and 7 countries, and crossing the Baltic Sea.

Krokodille Zoo staff, Victor Vest and Alexander List, were waiting for us on arrival at the zoo, and helped unload the boxes into the Masaguaral Scene the name of the Tropical Hall in honor of Blohm family, a facility built especially for Orinoco crocodiles. The crocodiles were checked, and they appeared to be in good condition. Later that day, they were released into their new pools. The adult pair (3.55 m male, 2.5 m female) was placed in one pool, and the 5 young males (around 2 m TL) in another pool. When the boxes were opened, all crocodiles appeared cautious about entering their new habitats, but over time they adapted and moved throughout the enclosure. The whole process was filmed by Danish television.

The adult crocodiles, Tomas and Cecilia, were named after Tomas and Cecilia Blohm, in recognition of their conservation work with the species at Masaguaral Ranch. The juvenile males were named Omar, Ricardo, John T, Kasper and Alvaro. The females acquired in 2013 were named Rosana, Phoebe, Sarah, Elvira and Jenny.

On 15 January, two days after release into the enclosures, the crocodiles were offered food, which consisted of unborn piglets. Cecilia took one of the piglets but did not eat it immediately, and two of the juvenile males did the same. However, by the next morning there was no food remaining. One week later, all the crocodiles ate without a problem, indicating that the entire process worked perfectly.

The Masaguaral Scene consists of 7 pools, each one with caves where crocodiles can hide, and sand areas with infrared lighting to provide heat. The total volume of water is 130,00 litres, which circulates all the time and passes through four purification filters, so the water in the pools is always clear and clean. The Hall was finally opened to the public in April, with all Orinoco crocodiles at Krokodille Zoo on display.

It is important to highlight the conservation work of zoos, including studies of behavior, feeding, reproduction and environmental education. All the hatchlings produced at Krokodille Zoo will be sent to Venezuela for reintroduction into their natural habitats and to reinforce the wild populations. The entire operation, from Masaguaral Ranch to Krokodille Zoo, was filmed and photographed, and our social media ally Rio Verde edited a documentary that can be seen on YouTube: https://www.youtube.com/watch?v=HpkPXpitXHg.

Rewilding of Orinoco Crocodiles from Denmark

Rene Hedegaard

Krokodille Zoo, Denmark

Abstract

Rene Hedegaard, the founder of Krokodille Zoo in southeast Denmark, initiated a groundbreaking project in 2013 that reached fruition in 2023 with the arrival of a breeding group of the captivating and critically endangered Orinoco crocodile (*Crocodylus intermedius*). Over the 10-year span, substantial investments were made to support the growth and sustainability of this unique crocodile species. Since 2013, annual donations to Venezuela have funded the breeding project at the Masaguaral farm over there, ensuring the provision of food for the young crocodiles during their crucial first year before being released into the wild. The Krokodille Zoo, supported by sponsors, donors, and public campaigns, invested significantly in the building of a massive tropical hall named Masaguaral since 2016, for housing a thriving group of breeding animals. One distinguishing aspect of the project is the commitment to returning the young Orinoco crocodiles (which will be bred in Denmark) to their natural habitat, a sentiment that resonates strongly with sponsors and visitors alike. The Masaguaral hall, a tribute to the Blohm family's breeding program, began construction in 2019. Visitors actively engage in the conservation effort by adopting and naming young crocodiles during their crucial first year, with a waiting list already in place. All funds generated from this initiative contribute to sustaining the project and aiding conservation efforts in Venezuela.

Crocodile Body Temperature and Behaviour is Affected by Long-term Changes in Climate

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Abstract

Anthropogenic climate change, resulting in rising temperatures and greater temperature extremes, is already impacting organisms worldwide. Tropical ectotherms are at particular risk, as they may have a limited ability to compensate for the deleterious effects of temperature on performance through either acclimation or thermoregulation. Understanding how wild organisms experience climate change, and the impacts it has on their natural behaviours, is essential. We monitored the body temperature (Tb) of 203 Estuarine crocodiles *Crocodylus porosus* from 2008 to 2023 using implanted acoustic receivers to observe long-term trends in Tb, and investigate the relationship between Tb and the performance of crocodiles dual-tagged with satellite transmitters. We found that Tb has increased alongside rising air temperatures since 2008, and reflects the large climatic shifts caused by El Niño-Southern Oscillation. Crocodiles experienced more days close to critical thermal limits through time, at which temperatures, their diving performance was reduced. There was also an increase in the prevalence of active cooling behaviour when Tb was high, and during the longer heatwave periods. These results suggest that Estuarine crocodiles are experiencing temperatures that influence their behaviour, and may continue to experience stressful temperatures as the pressure of climate change increases.

Movements and Territoriality in Male Estuarine Crocodiles

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Abstract

The spatial and social behaviours of organisms are influenced by their need to maximise access to resources and mating opportunities, while minimising the costs of sharing their environment with conspecifics. One such mechanism, territoriality, can play a large role in shaping these behaviours over time. Male Estuarine crocodiles (*Crocodylus porosus*) have been suggested to live within dominance hierarchies, with large, dominant males maintaining exclusive territories and controlling access to resources. Using implanted acoustic transmitters and a network of fixed acoustic receivers, we tracked the movements of 104 wild male Estuarine crocodiles to identify how the expression of territorial behaviour changed with ontogeny and time of year. We found that between May and December, tagged crocodiles [0.3-2.5 m snout-vent length (SVL)] gradually reduced the area of their home range and increased the proportion of range overlap with neighbouring individuals. During this time, larger mature males (>2.2 m SVL) maintained the smallest home range area, while smaller mature males (1.6-2.2 m SVL) held the largest home ranges. Movements of large mature males within their home ranges peaked in September indicative of increased patrolling behaviour, while smaller mature males reduced their rate of movements at this time and became more site philopatric. While larger mature males exhibited minimal overlap with other large conspecifics, they did have overlap with other males at both the home and core range suggesting that they did not display total territoriality. These findings add to our understanding of crocodilian mating systems, and suggest that rather than being intolerant and asocial, crocodile communities are instead dynamic with potentially complex spatial and social structure.

Acoustic Communication in Estuarine Crocodiles (*Crocodylus porosus*)

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Abstract

Acoustic signalling is widespread throughout the Animal kingdom and is used in a variety of behavioural contexts to attract mates, increase social cohesion, provide parental care, and mediate social interactions. Crocodilians are the most vocal reptile group and use acoustic signalling (both vocal and non-vocal acoustic communication) to structure social hierarchies, negotiate courtship and mating and indicate territoriality. Despite their close evolutionary relationship to birds, ecological importance, and high public interest, the repertoire of many crocodilian species remains undocumented. With over half of extant crocodilian species listed as threatened, acoustic monitoring may provide a cost-effective and non-invasive means to monitor wild populations, however first the repertoire must be described. Here, we describe acoustic signals in mature Estuarine crocodiles and identify behavioural, sex-based, and diel factors influencing acoustic signaling. We found a total of 10 acoustic signal types produced by Estuarine crocodiles in the post breeding season. Although some of these acoustic signals have been previously described in other crocodilians, we also include two new sounds not yet described in any crocodilian species to date. Growls were the most repeated acoustic signal, produced by both males and females, with the maximum frequency (Hz) of growls differing between sexes. When growling occurred, we found females exhibited behaviour related to appeasement or avoidance, while males exhibited behaviour related to aggression or courtship. These findings suggest a complex acoustic and behavioural communication system exists in Estuarine crocodiles. This provides a baseline for future study seeking to investigate seasonal and population-based differences in acoustic signaling of this species, and, to further assess the feasibility of passive acoustic monitoring of crocodilians as a cost-effective alternative to traditional tagging methods.

Gharial Acoustic Signaling: Underwater POPs are Temporally Based, Context-dependent, Male-specific, and Individually Distinct

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Abstract

Gharials produce a sudden, high amplitude, pulsatile, underwater sound, referred to as a POP. The Gharial POP has durations ranging from 4 to 72 milliseconds, and is clearly audible on land and in water at ~200-500 m distances. POPs were performed only underwater by adult males possessing a sex-specific, cartilaginous narial excrescence, the ghara. Adult males produce single, double, or triple POPs. We recorded 531 POP events for 9 wild adult males resident in a 115-km stretch of the Chambal River during 2017-2019, using hydrophones and aerial mics. Here we present the acoustic features of the Gharial POP signal. These include its incorporation as the initial component in a complex breathing display, its reliance on temporal rather than spectral elements, its dependence on a specific social context, its consistency within an individual, and its individually distinctive patterning specific to a particular male. The breathing display consisted of sub audible vibrations (SAV) preceding each underwater POP, then a stereotyped exhalation-inhalation-exhalation sequence, concluding typically with bubbling & submergence. Each POP signal was performed in a specific social setting. Four contexts were identified: ALERT, PATROL, MALE-MALE, MALE-FEMALE. In each context, male identities were examined using Discriminant Function Analysis (DFA) and Random Forest (RF) models. Within each context, all of the males exhibited individually distinctive POP patterns which were context-specific, as well as context-dependent. Two dominant males each showed 11 POP patterns, each one male-specific and context-specific. In our study, 96% of the total variation in POP signal parameters was explained by POP signal timings (92%) and number of POPs (4%), and only 2% was related to frequency (spectral) differences. POP signal features were stable for individual males, from one year to the next; extensive POP recordings (n= 403) of a single male over 3 breeding seasons were consistent and nearly identical within contexts.

Showing Some Salty Secrets

David White

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Abstract

For 26 years (21 as an owner/operator), I've been taking small groups to view free-ranging crocodiles and other wildlife on a 6 km stretch of the Daintree River (120 km north of Cairns in Far North Queensland) in a 24 passenger, solar-electric powered boat. I am on the river from 0930-1730 h most days and about once a week at night. I recognise and have names for all the resident adult crocs (a stable population of about 15), as well as hatchlings and yearlings. The crocs know me, and their behaviour shows that they know each other too. They are habituated to the boat. We can park conveniently close, typically 5-15 m, whereas when private boats approach, they hide. It provides a wonderful opportunity to see and record crocodile behaviour. I have seen one little hatchling being carried down to the river by its mother grow up to become a mother itself, 15 years later. It's possible to follow a 'couple' from pairing up, after a female's creche responsibilities end, to note their behaviour together, courtship, mating, nesting, and on to the next creching. Observations go into a logbook, and much is recorded in hundreds of videos which also include many feeding strategies and targeted food, creching behaviour including riverside wallows, SAVs, behaviour of paired up 'couples', fighting and the diversity of vocalisations with accompanying context. Since 2016, observations have been logged to a circular chart displaying the seasonal cycle of each one, and that will provide some structure to my presentation. It is sometimes hard to avoid anthropomorphism. Hopefully these observations will one day lead to a better understanding of crocodilians and help to keep both humans and crocodilians safe.

Chemo-signaling in Gharial: Glandular Chemistry of Representative Wild *Gavialis gangeticus* in the National Chambal Sanctuary, India

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Abstract

Living crocodylians possess acute sensory capabilities, eg vision, audition, olfaction, gustation, and tactile sensation. In many species, multi-modal communication is common, particularly in intra-specific social interactions. To date, chemical signaling studies have been rudimentary and exploratory, and confined to sampling isolated captives, typically in zoos. We studied the chemical composition of gular (chin) and paracloacal (cloaca vent) glands, using secretory samples (flash frozen, liquid nitrogen) from 97 Gharial, representing differing sizes-ages and sexes, and residing in upstream and downstream stretches (~348 km total) of National Chambal Sanctuary, India. Using gas chromotography mass spectrometry (GCMS), we identified 182 glandular compounds (gular and paracloacal). Using multi-variant analyses (Partial least-squares Discriminant Analyses= PLS-DA), we focused on 47 of 182 compounds based on presence/absence. Significant differences were detected in size-age, sex, and river residence cohorts. Of these compounds, 21 were previously identified as putative pheromones, and 26 are phytochemicals. We observed clusters in PLS-DA analyses that clearly separated adult females vs. males on the bases of gular as well as paracloacal secretions; unique male-specific chemicals predominated in sex comparisons. This result suggests that sex-specific glandular products may facilitate communication amongst reproductively active Gharial. In addition, within groups of adult males and females, upstream vs. downstream residence was a significant factor in discriminating between adult females as well as between adult males in the paracloacal secretions. Habitat-specific features in two regions sampled may account for observed within-sex differences due to location. In brief, this study provides an initial, comprehensive inventory of Gharial chemo-signals, and suggests that these compounds may have functional roles as significant discriminatory elements in multi-modal communications. Management implications include both attractant as well as repellent possibilities, and also potential ways to enhance reproduction in rare, endangered populations/species. Future studies will likely reveal that chemo-signals are an understudied, but important component of crocodylian communication.

Display of Parental Care in Crocodylians in Zoos

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Abstract

Although it is well-known in Crocodylian species that mothers guard their nests and freshly hatched juveniles, in most zoos, eggs are taken for artificial incubation and consequently reared separately from the parents. Only a few zoos have shown natural incubation and rearing of the juveniles in the same enclosures as the mother or even parents. One of the first zoos to do so was ZOOMAT in Tuxtla Gutierrez in Mexico in the 1960s with spectacled caimans (*Caiman crocodilus*), followed by Atlanta Zoo with Morelet's crocodiles (*Crocodylus moreleti*) in the 1970s. In Europe, Zurich was a pioneer in 1990s with Siamese crocodiles (*Crocodylus siamensis*). Since then, several other zoos have followed and raised juvenile Crocodylians with their parents. The lecture gives several examples of zoos and species in which parental care has taken place on display. Also, the limits of these methods such as cannibalism and aggression between adult animals are discussed. In general, it is believed that this method has benefits for the behavior of parents as well as juveniles, but also increases the interest of zoo visitors for the reproductive biology of crocodylians.

POSTERS

Conquering the Crush: A Novel Crocodilian Jaw Prop

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Abstract

Crocodilians have diverse snout shapes ranging from the long, narrow snouts of the Indian Gharial (*Gavialis gangeticus*) to the broad snout of the American alligator (*Alligator mississippiensis*). Crocodilians possess the strongest bite force of all extant animals, with recorded values for adult alligators exceeding 9000 Newtons. This jaw closing pressure poses a challenge and safety risk for people working with crocodilians as veterinarians, wildlife managers, and researchers who must safely access the oral cavity to perform veterinary procedures, health assessments, foreign object removals, and sample or data collection. Conventionally, polyvinyl chloride (PVC) or metal tubes (pipes) placed longitudinally into the mouth are used to hold crocodilian jaws open for such operations. These short sections of opaque pipe can cause oral irritation, obscure the palate and tongue, and restrict access to the oral cavity and palatal valve.

In conjunction with a project investigating the diet of alligators, we identified a need to create an efficient tool to allow safe and direct access to the alligator oral cavity. We built two versions of a novel device for holding alligator jaws open that are adjustable to accommodate different gape sizes. The device allows for safe positioning within the mouth, includes safety considerations for device failure, and is adaptable to both widen and collapse the gape of the mouth. We successfully deployed and recovered the device on 76 wild alligators ranging in total length from 120 to 329 cm. We also performed mechanical tests in the laboratory to assess the maximum force the devices and associated materials can safely withstand, as well as the conditions under which the devices fail. Our medium-duty and heavy-duty device designs withstood forces up to 6 kN and 18 kN, respectively. We observed no material fracture in the devices at peak loads, but significant deformations did occur during laboratory testing. Overall, this device serves as a cheap and effective tool for veterinarians, wildlife researchers, and managers who need to safely hold open the jaws of crocodilians.

Crocodile Chronicles in Mexico: Nurturing Conservation Through Multidisciplinary Endeavors

Asela Marisol Buenfil-Rojas[1,5], José António L. Barão-Nóbrega[2,5], Mauricio González-Jáuregui[3,5], Sergio E. Padilla-Paz[3,5], Frederico Barroso[4,5] and Alberto Castillo[3,5]

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Abstract

It is common belief that crocodiles are dangerous animals and not uncommon to hear people saying they pose threats to humans and their surroundings. Although crocodiles are indeed predators in their habitat, they also regulate trophic networks and are highly relevant to the ecosystems they inhabit. During the 1970s in Mexico, crocodile populations were under serious threat (largely due to hunting for leather) but thanks to national and international legislations being implemented around that time, their numbers have since recovered. The concept of sustainable use and management has since been increasingly expanded upon and has generated significant economic benefits and source of income in Mexico, and better understanding sustainable management of crocodiles has been a key component towards the conservation of natural populations. Crocodile Research and Management for Conservation (CRMC) is a multidisciplinary research group originated through a shared passion for these fantastic beasts by people dedicated to generating and sharing knowledge that contributes to sustainable management of crocodylian species, and thus their conservation. Currently, our ongoing projects across different fields of study are generating information in the fields of ecotoxicology, ecophysiology, telemetry, thermography, geometric morphometrics, blood cell morphology and human-crocodile interactions. So far, we managed to obtain interesting information, recruited new students, and expanded upon via collaborative work. Through these efforts, we aim to contribute to the conservation of crocodylians in Mexico, highlight their potential as non-model organisms in many fields of study (not just ecology), and pushing the boundaries of research and management for conservation. Hence, we will introduce the progress in our ongoing projects and the future perspectives for the sites we have been monitoring.

Primary Productivity Correlates with the Growth of the Northern Territory Estuarine Crocodile Population

Tayhlia C. Casey, Mariana A. Campbell, Cameron J. Baker and Hamish A. Campbell

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Abstract

Large carnivores are crucial for maintaining the health and balance of ecosystems through various top-down and bottom-up processes. Large carnivores have been extirpated from much of the globe despite their ecological importance, leading to large-scale environmental changes. In northern Australia, the Estuarine crocodile (*Crocodylus porosus*) was driven to the brink of extinction during the mid-20th century. Since their protection in 1971, the population has increased from a few thousand to over 100,000 non-hatchling individuals. Over this period, Estuarine crocodiles in the Northern Territory (NT) have shifted from a primarily marine-based diet to more terrestrial-based and, therefore, may be supplying larger volumes of nutrients from terrestrial to aquatic and riparian ecosystems. Throughout this period, the Estuarine crocodile population recovery has been closely documented in the NT, providing a unique opportunity to investigate their environmental impacts. This study used a combination of population surveys and satellite imagery to assess the impact of Estuarine crocodiles on instream primary productivity and riparian vegetation vigour along the Mary River (NT). We found that areas with higher crocodile biomass displayed greater primary productivity. In contrast, there was no correlation between the distribution of crocodile biomass and vegetation vigour. However, when analysed over time, crocodile biomass was significantly correlated with the increase in riparian vegetation vigour and not primary productivity. We argue that by redistributing nutrients and suppressing large terrestrial herbivores, Estuarine crocodiles have increased primary productivity spatially and enriched riparian vegetation vigour temporally. These findings highlight the role of Estuarine crocodiles in nutrient translocation and ecosystem linkages in the short- and long-term. Understanding these processes can aid in ecosystem-based management and raise awareness of the need for continued conservation of Estuarine crocodiles.

Bite force of *Melanosuchus niger* (Alligatoroidea, Caimaninae) Estimated by Finite Element Analysis

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Abstract

Finite element analysis (FEA) is an increasingly employed tool for biomechanical analyses like bite force estimations. In this study, we apply FEA for the first time to estimate the bite force of the caiman *Melanosuchus niger* of South America. One osteological specimen, comprised of complete skull and mandibles (Museu Nacional-1034), was CT-scanned. The scans were segmented in the Amira software to create a computational model with distinction between different elements (skull, mandible, upper teeth and lower teeth). The model was transferred to the software Hypermesh, in which adductor chamber muscles involved in bite movements were modelled: m. pterygoideus ventralis, m. pterygoideus dorsalis, m. pseudotemporalis profundus, m. pseudotemporalis superficialis, m. adductor mandibulae externus medialis, m. adductor mandibulae externus profundus, m. adductor mandibulae externus superficialis and m. adductor mandibulae posterior. Both the areas of origin and insertion of the muscles were measured through photographs of the specimen with the software ImageJ. The value of the forces (in Newtons) was measured through the sum of the origin and insertion areas of the muscles divided by two and multiplied by 0.5, as per previous studies. Constraints were placed on the tip of the fourth mandibular tooth of both mandibles, creating a bilateral force estimation scenario. The model was analyzed in the software Abaqus. The total bite force of *M. niger* measured was 674 N, being 360 in the left mandible and 314 in the right mandible. The estimated bite force is lower than previous studies with direct measurements of living individuals (1911 N), a discrepancy that may be due to differences in estimated muscle size, although it has to be considered that this is the first FEA bite force estimation in a caimanine. Future analyses will address this issue and compare these results with those on fossil South American crocodylians.

Effects of the Sustainable Use Program Proyecto Yacaré

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Abstract

It is assumed that the sustainable use programs on crocodilians, generating economic incentive for its conservation, imply an improvement on the population where they are carried out. However, there is little information on the effect of released animals on natural populations and their potential for reintegration into nature. Some authors stated that releasing hatchlings into the wild was a useless procedure, due to the very low or non-existent recapture rate of released and marked individuals in the field. In Santa Fe Province, where "Proyecto Yacaré" operates, the presence in nature of released individuals of *Caiman latirostris* that had reached adult size and reproduced has been verified regularly. However, it was unknown if there was an influence of the initial confinement period in farms on the animals because different variables of released animals in sizes prior to adulthood (Class II) were ignored. For this reason, we considered whether *C. latirostris* specimens collected in nature through ranching, incubated and raised under controlled conditions and subsequently reintroduced to their place of origin presented attributes similar to wild ones. Therefore, released *C. latirostris* individuals were compared to wild ones in different parameters such as growth rate, sex ratio and maximum movement distance. After the analysis, it was concluded that the period of confinement to which the animals of "Proyecto Yacaré" use program are exposed does not alter their ability to reintegrate into nature.

Resumen

La presencia de los programas de uso sustentable presupone una mejora en las poblaciones de cocodrilianos sobre las que interfieren. Sin embargo, existe poca información del efecto de los animales liberados, sobre las poblaciones naturales y el potencial de reinserción de los mismos en la naturaleza. Algunos autores afirmaban que liberar crías en la naturaleza era un procedimiento inútil, debido a la muy baja o nula tasa de recaptura de individuos reinsertados y marcados en el lugar de trabajo. En la Provincia de Santa Fe, donde funciona "Proyecto Yacaré", se ha comprobado la existencia en la naturaleza de individuos reintroducidos de *Caiman latirostris* que habían llegado a tamaño adulto y se reproducían. Sin embargo, se desconocía si existía alguna influencia del período de confinamiento en granjas sobre los animales, debido a que diferentes variables de los animales liberados en tamaños previos a la adultez (Clase II), eran ignorados. Es por ello, que se planteó si los ejemplares de *C. latirostris* colectados en la naturaleza mediante ranching, incubados y criados en condiciones controladas y posteriormente reintroducidos en su lugar de origen; presentaban atributos similares a los silvestres. Por lo tanto, se compararon individuos de *C. latirostris* reintroducidos con respecto a los silvestres en diferentes parámetros como tasa de crecimiento, proporción sexual y distancia máxima de movimiento. Luego del análisis, se llegó a la conclusión de que el período de confinamiento al que se ven expuestos los animales del programa de uso "Proyecto Yacaré", no altera su capacidad de reinsertarse a la naturaleza. Además, se encontró evidencia de que el programa de uso sustentable resultó exitoso, mostrando una recuperación de la población de *C. latirostris* a lo largo de los años en los que viene funcionando.

Caiman Growth Rates in the Peruvian Amazon

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Abstract

There are three species of caiman in the Tambopata River of the Peruvian Amazon: Spectacled caimans (*Caiman crocodilus*), Black caimans (*Melanosuchus niger*) and Dwarf caimans (*Paleosuchus trigonatus*). Growth rates in Spectacled caimans (*Ca. crocodilus*) and Black caimans (*M. niger*) have been researched in comparison to weather and feeding patterns (Herron 1991) but no research has been done on Dwarf caimans (*P. trigonatus*) or in the Peruvian Amazon. Morphometric and PIT tag data collection started with consistency in 2020 by Fauna Forever, an NGO with a research station situated along the Tambopata River in the Madre de Dios Region of Peru. With these data, we are analyzing growth rates of the three species present. This will give us a better understanding of the populations present in the Tambopata River.

Conservation Insights into the Future of the Critically Endangered Indian Gharial Using Species Distribution Modelling

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Abstract

Conservation efforts in a dynamic global climate demand an understanding of the intricate relationship between organisms and environmental factors to formulate successful management and reintroduction strategies. This study employs Species Distribution Modelling (SDM) to project the future habitat suitability for the Critically Endangered Indian Gharial (*Gavialis gangeticus*), a species endemic to the river systems of the Indian subcontinent. By amalgamating contemporary and historical occurrence data, our methodology aims to assess the influence of environmental variables on Gharial habitat suitability across temporal scales. Utilizing the tidySDM R package, we meticulously modelled habitat preferences by drawing upon historical occurrence data sourced from museum collections, travel logs and literature records. This comprehensive approach enables us to illuminate insights into the species' historical distribution patterns and habitat preferences, thereby establishing a robust baseline for comparison with present-day conditions. Preliminary results from our SDM analysis reveal a discernible westward shift in suitable Gharial habitat, suggesting potential expansion into regions currently inhabited by the species and prospective extension to the eastern edge along the Irrawaddy River by the year 2090. By identifying range-limiting barriers, for instance the Thar Desert, we determine the significance of considering climatic drivers and barriers that shape the distribution dynamics of the species. These findings hold profound implications for informing conservation planning and management strategies, ensuring the sustained survival of the Indian Gharial amidst the multifaceted challenges posed by climate change and anthropogenic disturbances. Through the integration of SDM techniques, our research endeavours to provide a methodologically robust framework for navigating the complexities of preserving the species' habitat.

The Role of the Municipal Government of San Mariano in Philippine Crocodile Conservation

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Abstract

The Philippine crocodile (*Crocodylus mindorensis*) is a Critically Endangered, endemic freshwater crocodilian now restricted in its natural distribution to Southwest Mindanao and Northeast Luzon. The municipality of San Mariano in Isabela Province in Northeast Luzon hosts most of the remaining wild Philippine crocodiles in the country. Balancing the development needs of its rural population, and the obligation to conserve one of the worlds rarest animals, the Municipal Government has enacted several local laws to protect the Philippine crocodile and its habitat. The Philippine crocodile was declared the flagship species of the municipality. Eight local sanctuaries were declared and established in the municipality, protecting key habitats of the crocodiles. Philippine crocodiles are too small to be man-eaters, but there are conflicts with farmers over livestock predation. Farmers living near crocodile sanctuaries are supported in restoring crocodile sanctuary buffer zones with native tree species and fruit trees that will support their livelihood. At the same time, these buffer-zones will provide habitat for natural prey species and a biological fence between farm animals and crocodiles. Women's groups are supported to plant bananas in crocodile sanctuary buffer zones, produce banana products and use banana fibres for banana leather products. A crocodile-centred eco-tourism program is being developed. These crocodile and people friendly nature-based solutions are meant to increase local support and incentives for crocodile conservation and co-habitation with crocodiles. San Mariano is proud of its crocodiles and promotes the municipality to visitors and the public at large using the presence of the Philippine crocodile as a unique defining characteristic.

Home Range Selection Patterns of American Crocodiles (*Crocodylus acutus*) in Lago Enriquillo, Dominican Republic

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Abstract

The American crocodile (*Crocodylus acutus*) is a large crocodile that occurs in a wide range of habitat types throughout the neotropics. In many parts of its range, such as the Dominican Republic (DR), it has experienced declines and is vulnerable to local extirpation due to rapid habitat loss and overhunting. Currently in DR, it is limited to Lago Enriquillo, a landlocked hypersaline lake. The natural history of this species remains poorly studied in many parts of its range, including Lago Enriquillo. In particular, habitat selection of this population has not been studied and can provide critical information for managing this declining population. The objective of our study is to examine how different environmental and anthropogenic factors influence habitat selection in American crocodiles to make more informed conservation and management decisions. We quantified *C. acutus* habitat selection of the overall population, and by size-class, from 17 transects in Lago Enriquillo within an intensity of use framework. Our preliminary results suggest that *C. acutus* in Lago Enriquillo select home ranges based on moderate to low salinities and low wave action, with a moderate amount of submerged forest coverage and shorelines, mostly composed of sandy or coral fragmented beach. However, our preliminary results suggest that size-classes select home range based on different factors. Different habitat preferences between size-classes are important for wildlife managers to consider when creating and implementing management plans for crocodiles and their habitat. These different habitat preferences will be especially important with the Lago Enriquillo population when stakeholders choose which areas around the lake to prioritize increased monitoring and protection.

Yacaré Smile: Contribution to the Understanding of the Jaw Shape and Tooth Function in *Caiman latirostris*

Bruno Holubicki Fernández Campon, Alba Imhof and Alejandro Larriera

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Abstract

Crocodilians are known around the world as top predators on the food chain, consuming large prey in their adult stage. However, during their juvenile stage, they consume smaller, softer and easier to swallow prey. The shape of the bite and the shape of teeth considered key in juveniles *Caiman latirostris* are described here. For the description of the shape of the bite in the upper jaw and description of the teeth, we used 126 juvenile skulls from the Yacaré Project. To take samples, both jaws were separated, photos were taken using a 64-megapixel camera, from different planes, with a millimetre reference. The most prominent teeth of the mandible were selected as teeth of interest to position the landmarks with Tpsdig software and graphs were made with MorphoJ. For the shape of the teeth, a total of 14 landmarks were placed on the edge (crown) of the teeth to establish their shape. A PCA (Principal Component Analysis) was then performed for both studies. The results show a posterior widening of the jaw, with small and blunt teeth, wider than long, the middle region is narrower, has teeth that are longer than wide and larger than the posterior ones, while the anterior region has longer and thinner teeth. Knowing these aspects of the morphology of these animals allows an adequate management of the species and the possibility of offering food according to their biology and capacity on projects aimed to the releasing into the wild.

Management of Problem Crocodiles in the Northern Territory

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Abstract

Saltwater crocodiles live in the Top End of Northern Australia. Any body of water in the Top End has the potential to contain large and dangerous Saltwater crocodiles. The Parks and Wildlife Commission of the Northern Territory (Parks and Wildlife) provides a program of crocodile management and public education that is designed to reduce the risk of human/crocodile interactions that have the potential to result in serious injury or fatality of humans and domestic animals. The program applies three different approaches according to risk based strategic management goals: 1. Active Removal Zone: The objective is to significantly reduce the number of crocodiles in close proximity to large urban areas. In this zone, crocodiles are targeted for removal regardless of size or behaviour; 2. General Management Zone: The objective is to reduce the likelihood of a crocodile attack. In this zone, only animals defined as 'problem' crocodiles are removed; and, 3. Barrier and Removal Zone: The objective is to make the area free of Saltwater crocodiles so people can be in or near the water with a very low likelihood of a crocodile attack. In this zone, crocodiles are immediately removed when identified. Parks and Wildlife use a range of management actions to reduce the risk of crocodile attack. Some actions are more resource intensive than others and it can take time to deploy trained staff to more remote locations. Efforts to reduce the risk posed by crocodiles include both proactive and reactive management actions. These include a 24-hour crocodile sighting response service, crocodile surveys, harpoon capture and removal, permanently placed traps, mobile trapping and occasionally humane destruction by shooting.

Human-Crocodile Conflict Management in Bhainsroadgarh Wildlife Sanctuary, Kota, Rajasthan, India

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Abstract

Human/Wildlife conflict is one of the main issues confronting wildlife conservation worldwide due to the rapid increase in human population and depletion of natural resources. In this context, the conflict between humans and crocodiles has become a problem in wetlands and river systems of the world in which crocodilian species are found. This study occurred from 2011 to 2023 around Bhainsroadgarh Wildlife Sanctuary located in Chittorgarh District in the state of Rajasthan, India which has the Marsh/Mugger crocodile (*Crocodylus palustris*). To minimise the human/crocodile conflict the Forest Department of Rajasthan 'rescues' the crocodiles that move out of the river. During this study, most of the crocodiles were rescued from Rawatbhata township, which is a highly populated area. The majority of the rescue cases occur during the monsoon season (July to September). At this time, the water level of the river rises and the flow becomes violent; the crocodiles are able to move around into flooded areas and stay away from the turbulent flow of the river. This is where they come into conflict with the human population living on the riverbanks. During the study, two crocodile attacks resulted in a person seriously injured in 2014 and a fatality in 2023. The main reason for the crocodile attacks that occurred is excessive human interference in the river ecosystem. Although the Forest Department tries its best to mitigate the human-crocodile conflict, this task becomes riskier due to lack of necessary equipment and safety measures. To assist in managing the human-crocodile conflict there needs to be an awareness/education program in the District.

The Sustainable Harvest of Wild Saltwater Crocodile (*Crocodylus porosus*) Eggs Along the Middle Sepik River

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Abstract

In the early 1970s, after many years of unregulated commercial hunting of the wild crocodile populations for their skins, the Papua New Guinea (PNG) Department of Environment Conservation introduced the concept of a sustainable use management program in PNG. This unique scheme links the biodiversity conservation of the natural habitats through the sustainable harvest of its renewable resources with the direct involvement, and for the enhanced financial benefits, of the local landowners. Since the early 1960s, the commercial exploitation of wild crocodiles in PNG has evolved from mostly exporting wild skins, to harvesting juvenile animals for ranching (both in "village type" and commercial farms) and most recently to the large-scale harvest of eggs in the Middle Sepik River. This case study investigates how the collaboration between Sepik Management Initiative - a local Interest Group (IG) promoting the conservation of the wetland biodiversity in the Sepik River, the local landowners communities living along the river and Mainland Holdings Ltd Crocodile Farm - a private company - mutually contributes to the sustainable crocodile management program and the economic development of rural communities in PNG.

Phylogenetic Relationships of a New Small Neosuchian Crocodyliform from the Early Cretaceous Cloverly Formation of Montana

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Abstract

Eusuchian crocodyliforms - the group including Crocodylia and its closest extinct relatives - are traditionally diagnosed by procoelous vertebrae and an internal choana fully enclosed within the pterygoids, but recent phylogenetic analyses have recovered taxa lacking some of these diagnostic features, particularly the pterygoid-bound choana, within Eusuchia. To help resolve this inconsistency, we report a new crocodyliform from the Early Cretaceous Cloverly Formation of Montana. It is represented by a nearly complete diminutive skull and other referable fragmentary material. This skull bears a striking similarity to both *Theriosuchus pusillus* and *Wannchampsus kirpachi*, and is approximately 62 mm long. This specimen features several unique traits not seen in modern taxa, including a secondary choana bound anteriorly by the palatines; a compound palpebral comprised of a large anterior and a small posterior element; and heterodont dentition with conical anterior teeth and labiolingually compressed posterior teeth. The skull is likely from a near-adult individual whose length would have likely been around 1 m. Additional cranial material was found associated with procoelous vertebrae.

A maximum parsimony analysis recovers this crocodyliform as closely related to *W. kirpachi* basal within Paralligatoridae. This new taxon can be diagnosed by the following autapomorphies: anteriorly diverging nasals, and transversely expanded prefrontal pillars. This form emphasizes the disassociation of procoelous vertebrae and pterygoidal choanae at the root of Eusuchia. Moreover, it reinforces the concept that early eusuchians were small and outwardly resembled modern smooth-fronted caimans (*Paleosuchus*) and dwarf crocodiles (*Osteolaemus*), suggesting that the semiaquatic ambush predators that dominate modern crocodylian diversity arose from small, short-snouted, less-aquatic ancestors.

Immunotoxicity and Genetic Damage in *Caiman latirostris* Yearlings Exposed *In Vivo* to Commercial Pesticides

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Abstract

Crocodilians are endangered by habitat loss and perturbation as a result of anthropogenic activities. Natural populations of *Caiman latirostris* in Argentina and other countries in South America are potentially exposed to contaminants, particularly in areas with intense use of pesticides for agricultural purposes. Caimans can be exposed in all life stages to pesticides through direct contact with contaminated habitats. Consequently, changes in physiological processes such as reproductive success and breeding efforts could threaten animal survival and ecological function. For this reason, it is necessary to determine the effect of pesticides in the short-term as a relevant factor for the conservation risk crocodilians currently face. We evaluated immunotoxicity and genetic damage of four commercial formulations of glyphosate (GLY), 2,4-Dichlorophenoxyacetic acid (2,4-D), imidacloprid (IMI), chlorantraniliprole (CAP) and three mixture combinations on yearlings under controlled conditions. This study was carried out in Proyecto Yacaré and LEMA facilities. Animals were maintained in plastic pens and were exposed to seven different treatments for 60 days at pesticide concentrations recommended for their application in agriculture. A negative control group was also housed under the same conditions for comparison. After the 60 days, blood samples were obtained and growth parameters, total and differential white blood cells (lymphocytes, heterophils, eosinophils, basophils, and monocytes as immune parameters), as well as the frequency of micronucleus (FMN) and nuclear abnormalities (FNA: buds, notched, eccentric, lobulated nuclei, binuclear and total nuclear abnormalities) as genotoxicity biomarkers, were determined in erythrocytes. Results indicated a significant increase in the FMN in all the treatments compared to the control ($p<0.05$). Some treatments were observed to have changes on their leukocytes profiles and growth parameters. No significant differences were observed in the FNA among groups. These results warn about the importance of understanding the effects of pesticides on the genetic integrity and immune responses in the wild populations of crocodilians.

Caiman latirostris Eggshells as Biomarkers for Environmental Heavy Metals Contamination

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Abstract

Various anthropogenic sources produce waste that includes metals and metalloids. While copper and zinc are essential for embryo development but high concentrations may be toxic. In contrast, lead, mercury and cadmium may be toxic even at low concentrations. Caiman latirostris is an ideal bioindicator candidate for heavy metals contamination due to its features: habitat, longevity, and superior position in the food chain. Female *Caiman latirostris* may transfer bioaccumulated pollutants from their tissues to the eggs during vitellogenesis. The interaction of the eggs with the contaminated environment, such as nest material during the incubation period, may represent another source of exposure. Thus, depending on the source of contamination, heavy metals could accumulate in various parts of the eggshell (on the inner side, on the outer side, or associated with calcium deposits). The aim of this study was to evaluate the presence and location of heavy metals in the *Ca. latirostris* eggshell through micrographs obtained by Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy. Additionally, we used Atomic Absorption Spectrometry (AAS) to quantify copper, lead, chromium and zinc with the objective of comparing both methods. Due to the relatively low concentration of heavy metals in the eggshell, we were unable to detect their presence through the micrographs. However, we were able to quantify copper (1.45 μg/g), lead (0.85 μg/g), chromium (0.45 μg/g) and zinc (<0.0045 mg/g) through Atomic Absorption Spectrometry. Further investigation is needed in another crocodilian species inhabiting environments with higher exposure to heavy metals. This could help determine the location and concentration of heavy metals on the egg, allowing us to establish whether pollution is originated via maternal transmission or environmental interaction.

Challenge 60 Days: Diets to Strengthen the Immune System of *Caiman latirostris* Offspring

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Abstract

Breeding caimans is a challenging sector and strengthening the immune system may be one of the keys to greater productivity. Nutrition is crucial for animal health, impacting ingestion, nutrient absorption, and overall well-being. Health, in turn, is primarily regulated by the proper functioning and balance of the immune system. Thus, the relationship between adequate nutrition and immunity is clearly important and the extent to which this influences the overall performance mechanisms of the animal organism. In this regard, omega-3 supplementation in breeding animal diets is crucial for strengthening the immune system and modulating its response. The objective was to evaluate the immune response of caiman offspring subjected to an immunological challenge, previously fed for 60 days with diets enriched with n-3 sources: 1- control diet (C): chicken and balanced feed, 2- C + algae, 3- C + flaxseed oil, and 4- C + yellow anaconda oil. We exposed offspring caimans to *Escherichia coli* in a phosphate-buffered saline (PBS) solution. We took blood samples before and after 48 h of bacteria exposure to evaluate their immune response leukocyte count, leukocyte profile, and heterophils/lymphocytes ratio. The diets enrichment with flaxseed oil and yellow anaconda oil were beneficial for the animals that consumed them. The lymphocyte/mm^3 populations revealed lower values in the animals fed with these enriched diets regarding the control group. As has been suggested in previous studies by this and other working groups, these omega-3 rich diets could produce changes in the production of important mediators and regulators of inflammation, resulting in immune responses toward an anti-inflammatory profile. The above could beneficially affect animal health through a more effective immune response of caimans to bacteria usually occurring in their natural environment.

Interspecifics Relationships between *Caiman latirostris* and Freshwater Turtles: Friends or Enemies?

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Abstract

Changes in land use, including the expansion of agricultural frontiers and the emergence of peri-urban or rural artificial wetlands, influence the coexistence of different animal species in increasingly restricted areas. Crocodiles in general are perceived as relentless predators. However, both in nature and in artificial lagoons, they are observed coexisting with several species of turtles. We conducted a survey of interspecific behaviors between *Caiman latirostris*, *Phrynops hilarii*, and *Trachemys dorbignyi* at the Experimental Zoological Station in the city of Santa Fe. The enclosure is of artificial origin and corresponds to a wooded area surrounding a 500 m^2 lagoon. The enclosure houses approximately 200 reptiles: 50 specimens of *C. latirostris*, 95 of *P. hilarii*, and 45 of *T. dorbignyi*. These populations encompass both adult and juvenile individuals and can be considered a situation of low-density semi-captivity, where the animal load resembles natural situations. Annual egg laying is recorded for all three species, but the eggs are removed from the enclosure for artificial incubation. Direct observations were made at different times of the year to describe behaviors, along with digital photographs and recordings using a VideoMan digital camera model VM3000 S, which captured footage 24 hours a day. Interactions between organisms of different species were classified based on whether they were beneficial for one or both species involved, or if they were detrimental to any of them. The observed interspecific events included: swimming together, basking together on land, basking together in water, transportation of *T. dorbignyi* on *C. latirostris*, predation of *C. latirostris* on *P. hilarii*, simultaneous feeding, use of *C. latirostris* nests by *P. hilarii*, and territorial behavior during the reproductive season of *C. latirostris* with respect to *P. hilarii*.

The Vulnerable West African Dwarf Crocodile is Worth Conserving in Urban Ecosystems: Evidence from Ghana

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Abstract

This study explores the population structure and encounter rates of the West African dwarf crocodile in urban environments of Kumasi, Ghana, challenging the notion that such landscapes lack biodiversity. The study additionally investigated the trade dynamics of crocodiles in three major cities of Ghana. The study was conducted in six purposively selected urban centers of Kumasi, Ghana, where surveys were conducted using interviews, literature review, and standard diurnal crocodile survey methods. The study found no significant difference ($H= 6.88$, $df= 4$, $P= 0.143$) in encounter when compared with the findings of similar studies conducted on the species in its non-urban ranges, with the mean encounter rates varying significantly ($H= 18.95$, $df= 5$, $p= 0.002$) across the different freshwater habitats, ranging from 2.000 ± 0.540/km in KNUST campus to 0.063 ± 0.125/km in the Uaddara Barracks site. The population structure composed of all the three major size classes dominated by adults and hatchlings (41.176% [n= 28]; and 39.706% [n= 27]) followed by juveniles (19.118% [n= 13]) although did not vary significantly among sites, as well as when compared with similar studies on the species. Factors that influence the distribution of the species included opened canopy, closed canopy, dredged sites, agriculture land, settlement, and grassland, with closed canopy recording the highest abundance. In a survey of three markets in Kumasi, Tamale, and Accra, 100 interviews revealed the trade of crocodile parts, predominantly skin, feet, and bile from dwarf crocodiles, by specific vendors. No crocodile meat was found in meat markets; parts are sourced from hunters and farmers and sold in traditional medicinal markets, with Kumasi reporting the highest sales. The study underscores the significance of conserving habitats with forest fragments in urban areas for West African dwarf crocodile management programs, offering essential baseline data for policymakers to develop sustainable urban management strategies that prioritize biodiversity and support inclusive urban development.

A Reassessment of *Asiatosuchus grangeri* Mook, 1940 and Implications on the Origin of Modern Crocodiles

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Abstract

The genus *Asiatosuchus* has historically been used as a wastebasket taxon for any basal crocodile from the Paleogene. These species represent some of the closest extinct relatives to all modern crocodiles, possessing a combination of ancestral and derived traits of the crocodile lineage. Many of these species are represented by only fragmentary remains and are poorly described in the literature, leading to a lack of resolution in the phylogenetic relationships of these species. Here we sought to reassess the type species for the genus *Asiatosuchus*, *Asiatosuchus grangeri* Mook, 1940, a crocodile from the early to middle Eocene of China, around 50 Ma. All known fossil specimens of this species were reexamined to create as complete a description as possible. From this, a morphology-based phylogenetic analysis was conducted to determine the evolutionary relationships of modern and extinct groups of Crocodylia, with a focus on Crocodyloidea. Compared to previous analyses, *A. grangeri* was found to be somewhat more derived than previously thought and unrelated to other species that have previously been referred to the genus. The topologies of the generated trees demonstrate a phylogenetic grade of character changes that reflects the transition of ancestral crocodilian to the modern crocodile. The results of this analysis may also point towards an Asian lineage of early crocodile which persisted from the Late Cretaceous up to the Eocene, with *Asiatosuchus nanlingensis* Young, 1964 being returned as sister to *A. grangeri*. Further studies are required among basal crocodyloids to both resolve the remaining degree of uncertainty in their phylogenetic relationships and incorporate these findings with molecular data of extant species.

Responding to Crocodile Attacks in the Northern Territory

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Abstract

Saltwater crocodiles live in the Top End of Northern Australia. Any body of water in the Top End has the potential to contain large and dangerous Saltwater crocodiles. The Parks and Wildlife Commission of the Northern Territory (Parks and Wildlife) provides a program of crocodile management and public education that is designed to reduce the risk of human/crocodile interactions that have the potential to result in serious injury or fatality of humans and domestic animals. When a fatal attack on a human occurs, Parks and Wildlife work closely with other first response agencies, including NT Police, in order to remove or destroy the offending animals and to retrieve the body to help deliver closure and answers for the family of the victim. Under the direction of the Police, Parks and Wildlife offer invaluable expertise and experience in how to undertake searches efficiently and safely as well as interpreting signs such as tracks and bite marks to determine the size of the crocodile responsible for the incident and liaising with local people in order to understand the specifics of the search area. The actions undertaken by responders in the first 24 hours is crucial to the success of the retrieval of the victim and removing the offending animal. Parks and Wildlife crocodile management actions includes a 24/7 response service which ensures Rangers can be on scene as quickly as possible to deliver expert assistance and advice without delay.

Phylogenetic Tree Mandala for "Crocodylia"

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Abstract

"Phylogenetic tree mandala" is a circular phylogeny with photos or drawings of species. This is one of the ways for illustrating the Tree of Life developed by Dr. Masami Hasegawa (2017; Mol. Phylogenet. Evol. 117: 168-178), and is suitable to show visually how the biodiversity on Earth has developed from a common ancestor in the course of evolution. The latest version of the "Phylogenetic tree mandala" series is "Crocodylia". This "Crocodylia" poster was created in collaboration with an illustrator, Takashi Oda, and crocodilian researchers around the world, especially Professor Grahame Webb, Dr. Yusuke Fukuda and Dr. Masaya Iijima. The branch lengths of the central phylogenetic tree were created by an infographics expert, Tohru Sakano. These branch lengths represents the time of evolution with our best knowledge. We present this poster for the purpose of scientific education.

Human-Crocodile Interaction in Campeche, México: Capacity Building through Interinstitutional Collaboration

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Abstract

Human-crocodile interactions have become more frequent in Mexico, increasing the interest in addressing them by different government authorities and wildlife specialists. In 2016, the Commission of Natural Protected Areas, published the Protocol for the Attention of Human-Crocodile Interactions (PACH-H). In Mexico, various efforts have been made to implement this protocol and define the activities to be applied in the event of a crocodile contingency. In most parts of Mexico, this protocol is handled at the municipal level and is called "SOS Crocodile Patrol", where municipal authorities work to respond to crocodile incidents in coordination with the fire department and the civil protection department. In the State of Campeche, there is no government wildlife management service so we consolidated this protocol at the state level through collaboration between academic institutions, government agencies, firefighters and civil protection. This has added another link to the chain of communication, but it was more effective, since municipal authorities respond more quickly to calls made through the state government than to those made by municipal or academic institutions. Therefore, we undertook the task of identifying potential areas of crocodile-human interaction, in order to conduct workshops with local communities to prevent these incidents and, at the same time, train first responders in the application of the PACH-H protocol, as well

as in how to safely capture and handle crocodiles. Under this work scheme, since July 2023 when we started this work, we have conducted three training workshops on the safe capture and handling of crocodiles and we have responded to eight crocodile-human interactions, mostly being only observations and rescue of the crocodiles involved. We believe that the collaborative work between academic institutions and governmental agencies has resulted in better communication with society to prevent and, if necessary, effectively address the interactions that have occurred in Campeche Mexico.

Conversations with Community: the Development of a Northern Australian Crocodile Public Safety Campaign

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Abstract

Living with crocodiles is a way of life in northern Australia. Public safety and education programs have been promoted as essential for reducing Human-Crocodile Conflict (HCC) around the world, and northern Australia's approach exemplifies how similar programs tailored for local conditions can be successful. Australia's three northernmost jurisdictions Queensland, Northern Territory and Western Australia are within the range of the Estuarine crocodile (*Crocodylus porosus*). Estuarine crocodiles pose benefits and risks to a range of stakeholders. Crocodiles are also culturally significant to many Aboriginal and Torres Strait Islander peoples who have a diversity of relationships with them, including totemic and ancestral connections. The three respective Governments all deliver a 'Be Crocwise' program to complement and support crocodile management activities. Each jurisdiction has had a different journey and focusses on local issues and contexts. Early iterations of 'Be Crocwise' focused on youth engagement, signage, and brochures. This low-cost approach was politically attractive and resulted in strong brand recognition, however there was limited evidence that it influenced behaviour change. Each program experienced similar challenges, including complacency, available funding, and diverse cultural contexts. The modern approach is iterative, incorporating feedback from stakeholders, experts, coronial enquiries, behavioural psychology, and by targeting key audiences and considering local contexts. Recently the programs have worked closely together, creating efficiencies in developing collaborative programs by sharing knowledge and learnings. 'Be Crocwise' in northern Australia combines decades of experience and learnings, allowing continuous improvement and helping shape future crocodilian safety programs around the world.

Not all Interactions are Negative: Bird Assemblages in the Broad-snouted Caiman Nests

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Abstract

Predation on crocodilian nests is extensively studied due to its adverse effects on broods, yet benefical interactions also occur without negative impacts. In this study, we evaluated the bird community visiting caiman nests in Santa Fe, Argentina. At the beginning of the nesting season (December) and during four consecutive seasons (2018-2022), we searched for nests of *Caiman latirostris* in nesting areas (forest, floating vegetation, savannas, and river and lagoon banks). We installed a camera trap focusing on each nest (n= 62), which remained active during the nesting period (December-April), taking a photograph every five minutes. We selected the photographs showing bird presence and identified the species using identification guides. Independent species records and visit durations were used to calculate the Interaction Strength Index (ISI) to depict nesting area usage patterns. Monitoring efforts totaled 9,062 trap-days, detecting 109 vertebrate species: 80 birds (73%), 23 mammals (21%), and 6 reptiles (6%). Bird species richness was highest in forest and floating vegetation nests, with 46 species each, followed by savannas (32) and river and lagoon banks (19). Only *Caracara plancus* was observed preying on a nest; the others displayed commensalism with caiman nests. Birds associated with ground access, such as omnivorous species (*Turdus amaurochalinus*, *Taraba major*, *Paroaria coronata*, *Pitangus sulphuratus*, and *Turdus rufiventris*) were prominent interactors (ISI 0.1-0.64). *Troglodytes aedon* and *Dendrocygna viduata* exhibited significant interactions in forest and floating vegetation nests, respectively (*T. aedon* ISI: 0.46; *D. viduata* ISI: 0.1). Caimans modify canopy cover during nest construction, potentially benefiting ground-access birds. Future studies should evaluate the spatial contribution of nesting areas - comparing nesting areas versus areas with similar characteristics but without nests - and their relationship to ground access. Despite characterizing interactions as commensalism, insectivorous birds may indirectly benefit caiman broods by reducing harmful insect populations, such as ants, an aspect to consider in future research.

A Comprehensive Investigation on the Underlying Cause of Double Scale in Farmed Alligators

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Abstract

Double scale is a skin defect that shows grossly as a dent within affected crocodilian scales. The course of the dent is approximately symmetrical to the border of the scale. Double scale becomes more central in the scale as the animal grows, unless the defect resolves where it is no longer visible to the naked eye. The skin in affected areas also showed flaking and had a pitted appearance. Double scale has a negative effect on the economic viability of crocodilian farms. In response to the widespread finding of double scale on the flanks and bellies of alligators in a Texas-based farm, a thorough investigation was undertaken to understand the underlying causes of the condition. The investigation focused on analysis of the alligators feed, water supply, and clinical and histopathological examination of affected alligators. The key findings from this investigation showed very high levels of vitamin A and iron in the feed as compared to literature. In addition, vitamin A, palmate and iron were very high in liver tissue of affected animals. Serum glutamate dehydrogenase (GLDH) was also high in these alligators. Histopathology of the double scale skin defect showed abnormal collagen bundles in the dermis of affected alligators as well as thickened corneal layer in the epidermis. All animals with double scale also had liver fibrosis at histopathological examination. Animals fed with lower concentration of vitamin A and iron in the feed presented a skin free of double scale defect. Further, liver vitamin A, palmate and iron showed significantly lower levels in these animals compared with alligators with double scale, and livers were normal on histopathological examination. In these animals, serum GLDH levels were significantly lower compared to alligators with double scale and liver fibrosis.

A Goniopholidid Crocodyliform from the Cretaceous of Arkansas and its Implications for Neosuchian Phylogeny

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Abstract

Department of Earth and Environmental Sciences, University of Iowa, Iowa City, Iowa, United States. Goniopholididae is a clade of Jurassic and Cretaceous crocodyliforms found throughout the Northern Hemisphere. These were the largest semiaquatic continental predators for much of the Mesozoic. Goniopholidids were the first crocodyliforms to outwardly resemble living alligators and crocodiles but may have evolved their overall configuration independently. They will thus help us understand the ecological context that helped drive the repeated appearance of flat-snouted semiaquatic ambush predators among crocodyliforms. Unfortunately, the taxonomy of these crocodyliforms is poorly understood. European goniopholidids have been the subject of considerable work, but their North American relatives have been all but ignored. Here we present a new crocodyliform, based on a nearly complete skull, from the middle Cretaceous (Albian-Aptian) Holly Creek Formation of southwest Arkansas. Its overall morphology is similar to that of the putative goniopholidid *Denazinosuchus kirtlandicus* from the Late Cretaceous (Campanian) Kirtland Formation of New Mexico, though unlike *D. kirtlandicus*, the new form bears an anteromedially directed premaxilla-maxilla suture in palatal view. It shares certain features typically associated with goniopholidids, such as a transverse interorbital crest and perinarial crest. However, it also shares anterior and posterior rami of jugal comparable in depth, rod shaped jugal bar, and a frontal separated medially from orbit margin with paluxysuchids such as *Paluxysuchus* and *Deltasuchus*. This new specimen also bears an elongate anterolateral process of the postorbital. Phylogenetic analysis recovers the new taxon as sister to *D. kirtlandicus*, and the two forms fall out as derived goniopholidids. Intriguingly, paluxysuchids are also recovered in a derived position within Goniopholididae. This novel tree topology challenges long-held assumptions about the status and distribution of Goniopholididae, which may have a more expansive distribution in the Cretaceous of North America than previously believed. These results also bear on understanding morphological and ecophenotypic evolution on the line giving rise to extant crocodylians.

Fauna Associated with American Alligator (*Alligator mississippiensis*) Nests in Coastal South Carolina, USA

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Abstract

Wildlife conservation often involves identifying and highlighting the ecological role(s) of a species in an ecosystem. Crocodilians are considered "ecosystem engineers" because their modification of habitats provides opportunities for feeding, drinking, breeding, and other vital life activities to a wide variety of other animals. One such habitat modification is the construction of nest mounds during the breeding season by most crocodilian species, including American alligators (*Alligator mississippiensis*). While many reports exist describing wildlife associated with alligator nests, no studies have quantified faunal associates and their corresponding behaviors while visiting nests. From 2016 to 2021, we used automated game cameras to monitor and quantify wildlife and their behaviors at alligator nests during the egg incubation period (June-September) in coastal South Carolina, USA. We documented a total of 81 species (79 vertebrates, 2 invertebrates) at 78 alligator nests representing six taxonomic groups, including 48 birds (59.2%), 9 mammals (11.1%), 19 reptiles (23.4%), 3 amphibians (3.7%), 1 malacostracan (1.2%), and 1 insect (1.2%). Collectively, faunal associates primarily used alligator nests for feeding/foraging (51.8%), traveling (29.3%), and loafing (19.9%) and to a much lesser extent basking, burrowing/shelter, breeding, and nesting. However, trends in alligator nest use varied among faunal associate groups (birds, mammals, reptiles, amphibians, etc.), subgroups (eg passerines, raptors, wading birds, and waterfowl), and species. The results of this study indicate that a diverse assemblage of vertebrates (and some invertebrates) use alligator nest sites in coastal South Carolina for a variety of life activities during the egg incubation period, and the proportion of the behaviors exhibited varies among animal groups and species. This study provides a first step for investigations regarding the net impacts of alligator nest-faunal associate interactions and ultimately the greater ecological role of alligators and other crocodilians.

Acoustic and Satellite Telemetry: Preliminary Results of Monitoring of Post-release Siamese Crocodile (*Crocodylus siamensis*) Dispersal in Cambodia

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Abstract

Extant populations of Critically Endangered Siamese crocodile (*Crocodylus siamensis*) in southwest Cambodia are heavily fragmented and have low successful reproductive rates. Conservation actions in the form of captive breeding and release of genetically-pure *C. siamensis* stock are maintaining these populations with a long-term goal of creating robust and naturally increasing populations. Many of these target populations are situated adjacent to communities, and understanding of post-release dispersal is valuable to plan future release sites. In 2022, the Cambodian Crocodile Conservation Programme released a total of 35 juvenile and subadult *C. siamensis* into a river system in the Cardamom Mountains of southwest Cambodia across two releases, February and December. All 35 were tagged with acoustic tags produced by Innovasea, and five of these were also tagged with satellite tags produced by Wildlife Computers. We have monitored their first year post-release, a novel utilization of either of these technologies in the conservation of *C. siamensis*. The maximum dispersal recorded of this release cohort was 15.91 km from the release site, with a mean recorded dispersal of 4.43 km. Additional data collection is ongoing, and further analysis will be conducted in mid-2024. We anticipate these results providing insights to inform future release sites and release candidates, and may be applied to other much-needed *C. siamensis* releases or reintroductions in Cambodia or in the wider region.

Crocodylian Fauna of the Eocene Site of Bolca: History and Re-evaluation of Two Specimens at the Natural Sciences Museum of Turin (Italy)

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Abstract

Fossil crocodylians from the Eocene site of Bolca have been collected since the second half of the 19th century. Most of the 12 recovered specimens, most of which are poorly-preserved skeletons, are held at four museum collections in Italy and the USA, except two specimens that are currently lost. Most, though not all, have been published. Three taxa can be recognized, all previously referred to *Crocodylus*, but currently assigned to three different genera: the basal crocodyloid/stem longirostrine *Asiatosuchus*, the alligatorid *Hassiacosuchus*, and the planocraniid *Boverisuchus*. However, these identifications are mostly based on old studies, and no proper redescription or systematic assessments have been completed in recent years. A redescription of two specimens in the Museum of Natural Sciences of Turin - MGPT PU 17328 and MGPT PU 17329 is currently underway. The skull of MGPT PU 17328 preserves an elongated rostrum, large supratemporal fenestrae, two large posterior dentary teeth, and elliptical external naris, but cranial sutures are hardly detectable. The specimen preserves some vertebrae, scattered ribs and forelimbs and partially-complete rear limbs. Teeth are labiolingually compressed, which is consistent with a planocraniid referral, but whether the teeth were also serrated (which would be diagnostic of *Boverisuchus*) is unclear. MGPT PU 17329 has similar preservation, but the skull preserves small supratemporal fenestrae, nasals tips slightly projecting into the external naris, long premaxillary processes, a circular and non-ridged external naris, a wide frontal excluded from the supratemporal fenestrae, orbits flush with the skull table, and squared and keeled osteoderms. In addition, some original photos suggest a longer lacrimal than the prefrontal. Phylogenetic analysis places MGPT PU 17329 as the sister taxon of *Hassiacosuchus haupti*.

Increasing Crocodile Attacks on Sulawesi

Brandon Sideleau

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Abstract

Sulawesi, also known as Celebes, is a part of the Great Sunda Islands region in Indonesia. The island consists of six provinces - North Sulawesi, Gorontalo, Central Sulawesi, West Sulawesi, South Sulawesi, and Southeast Sulawesi. Only one species of crocodilian is confirmed to be present in Sulawesi - the Saltwater crocodile (*Crocodylus porosus*). Over the past decade, reports of attacks on humans by Saltwater crocodiles have increased dramatically in Sulawesi. Since 2014, a total of 123 attacks have been reported resulting in 62 deaths. Frequency increased from only four attacks (resulting in one death) in 2014 to 26 attacks (resulting in 15 deaths) in 2023. Attacks were recorded in all of Sulawesi's provinces. The highest numbers of attacks were reported from Southeast Sulawesi (46 attacks, 23 fatal), particularly on the islands of Buton and Muna and Central Sulawesi (35 attacks, 20 fatal), particularly around Palu Bay and in Toli-Toli Regency. The lowest numbers occurred in Gorontalo (two attacks, both non-fatal). Oddly enough, attacks have even been reported from waterways within heavily populated urban areas, such as Makassar and Palu cities. Attacks were also reported from far inland areas, such as along tributaries of the Konaweha River in Ladongi sub-district of Southeast Sulawesi.

Conservation of Siamese Crocodile (*Crocodylus siamensis*) in Cambodia

Pablo Sinovas and Ollie Roberts

Fauna & Flora, Cambodia Programme, Phnom Penh

Abstract

The Siamese crocodile (*Crocodylus siamensis*) has been extirpated from 99% of its historical range in Southeast Asia, and only a few hundred adults remain in the wild. This species is categorized as Critically Endangered and it faces the very real risk of extinction. The total wild population of *C. siamensis* in Cambodia is likely 250-500 individuals and could comprise fewer than 150 mature adults. Fauna & Flora together with government partners in Cambodia founded the Cambodia Crocodile Conservation Project in 2001 to prioritize the protection and recovery of this species. Over the past two decades, we have continued to monitor known extant populations of *C. siamensis* annually in the Cardamom Mountains (Southwest Cambodia), with populations appearing stable. Five sites (O'Som/Veal Veng Marsh, Areng, Chhay Reap/Upper Sre Ambel, Tatai Leu, Steung Kiew) are patrolled by community wardens to prevent threats to the extant populations, and Fauna & Flora have conducted crocodile releases of captive-bred individuals into these sites since 2013. Annual surveys at five sites have indicated that nesting levels are low, with one instance of successful wild breeding detected in O'Som in 2021. One nest has been detected annually between 2021-2023, but no eggs survived to term. Key sites are largely isolated with limited connectivity. Around 150 crocodiles have been released into these sites by Fauna & Flora to date. Due to depleted wild stocks and high levels of hybridization in farmed stock in the region, the continued *ex situ* conservation of genetically-pure *C. siamensis* is much needed. A stock of 264 captive pure *C. siamensis* is maintained at Fauna & Flora's Phnom Tamao conservation breeding facility in Cambodia, including the successful 2023 hatchling cohort of 87 crocodiles.

The Future of Science and Conservation: Integrating and Leveraging Diversity

Marisa Tellez

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Abstract

Diversity within science and conservation has been identified as an important factor to further scientific progress and accomplish goals at a higher quality and value. Yet, despite research illustrating the positive outcome of diversity given people have different strengths, backgrounds and knowledge, much of science continues to exclude rural and indigenous knowledge, as well as the expertise of scientists from the Global South. This presentation is to highlight the importance of inclusion and equality in the sciences and discuss solutions in which people of all backgrounds can come to the table as equals to move forward in a positive direction in shared common goals - species conservation, and stewardship of nature by communities.

Human Dimensions on the Reintroduction of Siamese Crocodiles in Kaeng Krachan National Park, Phetchaburi Province

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Abstract

Siamese Crocodiles (*Crocodylus siamensis*) are critically endangered both internationally and nationally. There are only four countries in the world where its population can survive threats that require immediate population restoration including Thailand. Despite existing know-how for reintroducing purebred Siamese crocodiles to their original habitats, the humans who share habitats with them have become a major hindrance to reintroduction. We recruited local people sharing a habitat with Siamese crocodiles in Kaeng Krachan National Park (KKNP) in our questionnaire survey to understand the human dimensions of the conservation of Siamese crocodiles. A total of 208 respondents, representing 6.66 percent of the population, were surveyed in five villages in three subdistricts. According to the findings, despite the positive attitudes toward Siamese crocodile and its conservation, and the high proportion of respondents orientating the value of Siamese crocodiles as mutualists with humans, the major obstacle to reintroduction and coexistence is fear of attacks on humans. The only acceptable reintroduction method was artificial incubation of wild-collected crocodile eggs from KKNP, as opposed to the hard or soft release of farm-bred ones. A greater risk was perceived by respondents of farm-bred crocodiles attacking humans than non-farm crocodiles in attacking humans. Siamese Crocodile reintroduction methods were deemed acceptable based on attitudes, risk perception, and acceptable conservation measures. We recommend that wild-collected crocodile eggs be artificially incubated and used for reintroduction initiatives in KKNP. To enhance understanding and balance conservation needs with human fear of Siamese crocodiles, the reintroduction process should be explained to relevant civil societies and stakeholders. The Department of National Parks, Wildlife, and Plant Conservation of Thailand should adopt this inclusive approach to restoring remaining Siamese crocodile populations in Thai protected areas.

The Influence of Human Disturbance on Frequency of Raccoon (*Procyon lotor*) Predation of American Alligator (*Alligator mississippiensis*) Nests

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Abstract

Raccoons (*Procyon lotor*) are dominant predators of American alligator (*Alligator mississippiensis*) nests in the southeastern United States, using a combination of olfactory, visual, and tactile cues to identify location of nests. Studies on alligator nesting ecology typically require researchers to create paths through marsh habitat, potentially introducing visual and olfactory cues that may be used by raccoons to locate nests/eggs. The purpose of this study was to evaluate the effect of human visitation to alligator nests on frequency of raccoon nest predation at two sites in coastal South Carolina, USA: Tom Yawkey Wildlife Center (TYWC) and Santee Coastal Reserve (SCR). We hypothesized that human foot traffic associated with nest monitoring increases the frequency of nest predation by raccoons. Results revealed a non-significant trend toward higher predation frequency of foot-visited nests compared to aerially and non-visited nests independent of study site (Mehta and Patel, p= 0.261). This trend was similar at both study sites (Mehta and Patel, TYWC p= 0.106, SCR p= 1). When comparing predation by access type (ie boat, drone, foot, no-access), there was an overall non-significant trend towards higher predation frequency of foot-visited nests independent of study site (Mehta and Patel, p= 0.255). TYWC experienced higher predation frequency of foot-accessed nests (Mehta and Patel, p= 0.031), while SCR experienced lower predation frequency of foot-accessed nests (Mehta and Patel, p= 1). Results suggest that at sites of long-term nesting research (eg TYWC), alternative access methods may be useful in mitigating olfactory or visual cues left by researchers. Post-hoc power analyses, however, indicate low statistical power for our comparisons (Nest Predation by treatment group: 33.15%, vs Nest Predation by access method: 29.62%). Overall, results of this study suggest raccoons may use human cues to locate alligator nests; however, replication of the study across multiple seasons to increase sample size would help to further test this hypothesis.

Dietary Enrichment with Essential Fatty Acid-rich Oils in *Caiman latirostris* Hatchlings

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Abstract

Enrichment of diets with essential fatty acids (EFA) is of great importance for the nutrition of breeding animals. In production systems, the feeding of hatchlings in their first months of life is essential to improve their growth and welfare. Supplementation of the diet with essential oils can have significant effects on growth, health and even the quality of the by-products obtained from them. The aim of this study was to evaluate dietary enrichment with EFA-containing oils and their effect on the quality of muscle tissue and fat in *Caiman latirostris* hatchlings. For 60 days, we fed 36 caiman hatchlings 3 times per week with four diets: a control diet (CD), an algae-enriched oil diet (AED), a flaxseed-enriched oil diet (LED) and a yellow anaconda-enriched oil diet (YED). Each enriched diet was supplemented with 2% of the corresponding oil. In muscle tissue, the YED group was characterized by a higher content of saturated fatty acids (SFA= 49.23%) and atherogenic (AI= 0.38) and thrombogenic (TI= 1.36) indices compared to the other diets. In terms of fat, the AED and LED groups had higher percentages of polyunsaturated fatty acids (PUFA) n-3 (4.34 and 5.36%, respectively) and lower n-3/n-6 ratio (5.88 and 4.35, respectively) compared to the other diets. There were no differences in weight or growth between individuals fed the different diets. The dietary treatments affected the FA profile of the meat and fat of the caimans. However, in the fat tissue of animals fed AED and LED, we observed an increase in the percentage of healthy PUFA such as PUFA n-3, which have important functions in the body and are favourable for animal health and welfare.

Effect of Maternal Hormonal Investment on the Production of Female *Caiman latirostris* Offspring

Florencia E. Valli[1,2,4], Micaela R. Mazaratti[1,2,4], Melina S. Simoncini[1,2,3], Gustavo M. Somoza[5,6], Alba Imhof[2], Marcela A. González[4] and Carlos I. Piña[1,2,3]

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Abstract

Caiman latirostris exhibits temperature-dependent sex determination (TSD). At constant incubation temperatures, between 29°C and 31°C, 100% females are produced with 100% males being produced between 33°C and 34°C. However, at a constant 32°C, offspring of both sexes are produced, with the male:female ratio varying between nests, indicating that sex determination may be influenced by steroid hormones deposited by the female in the egg yolk. The aim of our study was to evaluate the maternal hormonal reversal of estradiol (E2) and its influence on the sex ratio of *Caiman latirostris* nests in different seasons and during the thermosensitive period (TSP). We collected a total of 15 nests, both from the wild and in semi-captivity corresponding to three breeding seasons. In the yolk of these eggs, we measured the E2 content in the egg yolk at the initial stage (oviposition less than 5 days) and during the beginning (day 20), middle (day 30) and end of the TSP (day 40). In the early stage we observed differences between nests in relation to the amount of E2 detected, ranging from 2.56 ± 1.25 ng/g to 12.09 ± 2.87, but we found no differences between eggs from the same nest. Additionally, we registered no differences between seasons or between natural and semi-captive nests. However, we did find that E2 concentration decreased between the beginning and the middle of the TSP. Finally, we found that nests containing higher and lower concentrations of E2 were characterised by a higher percentage of female offspring than those with intermediate concentrations where the percentage of females was lower. This would indicate that females may be influencing brood TSD, although further seasonal analysis and assessment of testosterone hormone load would be necessary to establish a trend.

Prenatal Exposure to Corticosterone Does Not Affect the Morphometric Variables of Embryos and Neonates of *Caiman latirostris*

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Abstract

In species with temperature-dependent sex determination (TSD), the manipulation of certain hormones can affect the course of development. In previous studies, it was observed that corticosterone (a glucocorticoid hormone released in response to stress) can influence the TSD in *Caiman latirostris*. High concentrations of corticosterone bias the sex of the offspring towards males at 32°C (temperatures at which both males and females are produced) and reduce the duration of the incubation period (IP). The objective of this study was to evaluate whether morphometric variables of embryos and neonates are affected by supraphysiological concentrations of corticosterone. To achieve this, we measured the weight, total length, snout-vent length, and dorsal-cranial length in both embryos and neonates of *C. latirostris*. We incubated five nests (n= 133) at 32°C and distributed eggs into two experimental groups: a control group and another in which eggs were topically treated with a concentration of 1.4 mg/l of corticosterone during stage 20 of the thermosensitive period (TSP). To determine the morphometric variables of the embryos, we selected 16 eggs (corresponding to two nests, 8 embryos from each group) at stage 22 of the TSP and the remaining eggs were incubated until hatching, where we took the corresponding measurements of the neonates. We did not observe effects of corticosterone on morphometric variables, both during embryonic development and in neonates. This suggests that, despite corticosterone accelerating the IP, it wouldn't be doing so at the expense of the weight or size of the offspring. In light of these results, considering that the survival of *C. latirostris* offspring is dependent on their size, the hypothesis arises that females could influence the IP (reducing it) in adverse or stressful scenarios, hastening their hatching without altering the future survival of their offspring.

Length and Weight of Farmed Young Crocodiles (*Crocodylus moreletii*) as Predictors of Their Future Size

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Abstract

The aim of the study was to determine the earliest time at which the future size (length and weight) of farmed Morelet's crocodiles (*Crocodylus moreletii*) can be accurately predicted, to establish selection criteria in these individuals. A total of 8040 crocodiles (7394 males and 646 females) hatched from artificially incubated eggs were included. In each crocodile, the total length and weight were measured on days 1, 132, 248, 364, 500, 616, 750, and 878 of age. On day 878, crocodiles were classified into five size groups: runt (RT), small (SL), medium (MM), large (LG), and extra-large (EL). The association between evaluations for length and weight, the correlation between length and weight in each measurement, and the differences in length and weight between assessments and sex were determined. Analysis from day 132 through day 878 included both sexes together. There was no difference among groups ($P>0.05$) between length on day one and size on day 878. Difference was found between length on day 132 and size on day 878 in RT ($P<0.05$), and between length on days 248, 364, 616, and 750 and size on day 878 in all the groups ($P<0.05$). Difference was found between weight on day one and size on day 878 only in SL ($P<0.05$), and between weight on days 132, 248, 364, 616, and 750 and size on day 878 in all the groups ($P<0.05$). The size farmed Morelet's crocodiles will have at 878 days can be predicted with weight at 132 and length at 248 days. Use of the ranges of the size groups as selection criteria for growth will allow selecting the future smallest and largest individuals early in the production cycle and to enhance sustainable management of this species.

THEMATIC GROUP REPORTS

Red List Meeting (16 April 2024)

The outcomes of the meeting were:

- Current assessments are underway for *Melanosuchus niger*, *Mecistops cataphractus*, *Mecistops leptorhynchus* and *Crocodylus palustris*.

- The next assessments will be *C. mindorensis* and *C. siamensis*. Assessment teams will be assembled in due course but certain participants expressed interest in being involved.

- Action Plans (APs) have been used as the base for Red List assessments for some time with discussions held within the Executive Committee that perhaps APs are no longer relevant given the alignment of these documents. Participants of the meeting noted that for many grants, one of the criteria is that current APs are available for the species they are submitting the grant for. Thus, maintaining both of these documents, should be maintained.

- IUCN Green List of Species - it is unclear at this stage how the Green List of Species will be incorporated within the Specialist Groups. There has been discussion that RLAs will also be required to manage the Green List assessments but no official word has yet been communicated.

Prepared by: Sally Isberg (CSG Red List Authority)

Veterinary Science Group Meeting (18 April 2024)

Meeting opened at 1020 h

Attendance: Colette Adams, Emmanuel Amoah, Sergio Balaguera-Reina, Joshua Barwick, Hannah Beard, Amelia Benn, Paul Beri, John Bingham, Damien Brabrook, Kristy Brain, Gregory Brewil, Emily Moyes, John Burke, Manuel Cabrall, Connor Campbell, Otto Campion, Bel Carlson, Ben Chesneau, Bruce Clarke, Tony Colbert, Dot Corrie, Terry Cullen, Stephen Cutter, John Dalton, Rexy Djarrkadama, Peter Djiggir, Kris Dregalla, Josh Dregalla, Eilis Evans, Aramish Fatima, Mark Flint, Tyson Francis, Angela Freeman, Csaba Geczy, Gordon Grigg, Jessica Grills, Gervais Habarugira, Kristen Hay, Max Hemesch, Susanne Hemesch, Tanya Hollamby, Enam Hoque, Gareth Hunter, Sally Isberg, Barbara Isberg, Michelle Jeffrey, Cathelijne Klomp, Prem Kunmar, Eric Langelet, Alice Langelet, Charlotte Leyshon, Gary Lindner, Charlie Manolis, Paolo Martelli, Lonnie McCaskill, Robby McLeod, Craig Moore, Jasmin Moran, Irene Muere, Danielle Mulhall, Calvin Murakami, Charmaine Mutswiri, Clement Naabeh, Desiree Nadji, Matthew Neave, Annabelle Olsson, Steven Platt, Matt Plummer, Payton Prosser, Georgia Rankine, Cathy Shilton, Mark Shirley, Diedre Slawski, Padraig Strappe, Francois Taverne, Jarred Tenikoff, Yuhung Ting, Helen Truscott, Ashley Underhill, Kent Vliet, Rebecca Webster, David Williams, Madeine Winans, Rina Wong

1. Meeting chaired by Paolo Martelli and Cathy Shilton. Far more attendees (see above) than usual since meeting was held in main hall between regular sessions.

2. Workshop

    - Feedback was very positive. Unanimous opinion that the Veterinary Science group should continue.
    - Comments from group with regards to future workshops. Some repetition is OK as the attendees are not always the same.
    - Emphasis on lots of time and interaction for each topic at workshops, ability to discuss during the presentation.
    - Luis Bassetti to share also thoughts from the Mexico meeting.
        - Increase exposure to various technologies, such as endoscopy, to be considered both as a diagnostic tool for zoo animals and an ecology research tool (ovarian).
        - CSG vet representation in each jurisdiction is important (regional contacts.
        - Finding other ways to communicate with next generation of CSG veterinarians.

3. Website resources

    - Pending additions: this year's workshop presentations (completed)
    - Suggestions solicited for other useful resources?

- More sophisticated material on the website

4. Mailing list

    - How to archive topics sent.
    - Other methods of communication to decrease the sluggishness of e-mail mail-outs? Eg Vet Sci Group membership only chat group?
    - Possible ability to form a chat group using eg Facebook, or What's App Vet Group participants only. A suggestion of Telegram, Discord, Slack that might be more appropriate for chatting among the group than social media.
    - Suggestion after session from Angela Freeman of Hartley's Creek Crocodile Farm of using a subscription based program like Constant Contact to maintain contact lists of the various CSG SubGroups (form the trunk of a network of CSG contacts). This would facilitate adding people and also removing people, based on bounced e-mails. These contact lists could then be selected from to initiate conversations through other sites such as Linked-In Pro, send newsletters (which can be made within the Constant Contact program). Angela offered eg a week worth of time of her admin assistant that is experienced with Constant Contact to organize the CSG database based on Excel sheets of contacts.

5. Question about positions of co-chairs. Succession planning

    - Gradual replacement or *en bloc*
    - Criteria: vet with proven contribution to crocodilian veterinary science, interest to serve as co-chair, multiple languages
    - Nominations
    - Suggested also to establish regional chapters to facilitate discussions and identify options for succession

6. Other business

    - Other work/activities/meetings the CSG Veterinary Science Group could be monitoring/capturing
    - A way to share tricks of the trade.
    - Standard practices for collecting samples from wild harvested animals. If people from various countries have some standards in this regard, it would be appreciated if they could share them with us.
    - Interest from Federico, a Venezualan veterinarian working at Crocosaurus Cove to help create such a database of tissues. Issues of how to get samples from wild crocodilians (eg problem crocs), how to ensure archive is maintained, where maintained (BVL?), would need support from NTG for storage space.
    - Also seek input from NTG Biodiversity Conservation colleagues as to the types of samples that may be of interest to them
    - Follow-up on this post-meeting from CS is that Sally Isberg and I met with Federico and discussed the possibility of his designing a project, with fixed start and end date, aimed at health assessment of crocodiles in Darwin Harbour. We suggested he also liaise with the Croc Management Team, and crocodile scientists, such as Yusuke Fukuda. Could possibly solicit funding from Croc Farmers Association of the NT if toxicology was built into the project proposal. CS and SI would assist if Federico came up with a draft project plan, and CS provided numerous references for other helath assessment type of work on wild crocodilians from the literature for ideas. CS advised the concept of initializing a tissue bank for NT crocodiles is a large undertaking (creating an institution) and not something that is currently planned.

7. Prior to the meeting, Czaba Geczy suggested we have as an Open discussion on the rationale or the need or the benefits of systematically administering tranquillizers/anxiolytics/anesthestics/paralyzing agents of electro-stunning when handling crocodilians. Making abstraction of human safety and team experience but in relation to benefits to the patient: stress/muscle lesions/recovery time : return to water-acidosis-resume feeding, etc.

    - Opinion that chemical immobilization is not necessary for the majority of handling/moving crocodilians.
    - Opinion that we need a standard, agreed guideline for this issue, rather than debating publicly. Industry should guide this, rather than animal welfare groups.
    - This suggested discussion on sedative/anaesthesia administration did not get addressed at the meeting (perhaps a subject for next CSG).

Meeting closed at 1100 h

Prepared by: Paolo Martelli and Cathy Shilton (Co-Chairs, Veterinary Science Group)

Zoos Thematic Group

The following are a few brief notes on topics discussed at the Zoos Thematic Group meeting. Colette Adams (Deputy Director and COO of Gladys Porter Zoo, Brownsville, Texas USA) and I are co-Vice Chairs of the Zoos Group.

Role of the CSG Zoos Group

As I always do in these meetings, for those who are new to the group, I started by explaining our purpose in the CSG. Our role is to offer advice pertaining to all aspects of zoos, and crocodilians under human care, to the CSG Executive Committee, membership, or to those who ask the CSG for assistance. So, our position here is not "What can the CSG do for me" but the reverse. That said, I've also frequently emphasized to the CSG membership how important zoos, aquaria, and other living institutions, can be to crocodilian conservation, especially in terms of how much money, material, expertise, and in-kind service, zoos direct to *in-situ* conservation projects.

Animal Care Manual

Colin Stevenson (Crocs of the World) and I were communicating recently, and he suggested that this group might work toward producing an animal care manual (ACM) for crocodilians. This is an excellent idea. Such a manual would prove useful, not just for zookeepers and managers, but for many in the CSG. The CSG has been approached in the past for such a document by individuals outside of the CSG as well. Several members within the audience at the meeting volunteered to assist with the writing of an ACM. We will form an ACM committee and hold a virtual meeting within the next few weeks to discuss the content, generate an outline, and make assignments of who should champion each chapter. If others, not in attendance at the Zoos discussion session are interested in assisting with this, please let me know.

Communication within the Zoos Group

As has been discussed in the last few Zoos meetings, I again brought up the topic of communication within this group. From the start, we created a Google group that we use as a listserv. In discussions during the Chetumal meeting, Shawn Heflick (sheflick@aol.com) and Iri Gill (Chester Zoo, i.gill@chesterzoo.org) suggested we switch this over to a private Facebook group. They created one while still in Chetumal but left it to me to carry forward which, in hindsight, was their mistake. It was not clear to me how best to add people to this group. It seems it is easiest for us, the Group Admins (Shawn, Iri and me) to add you to the group if you are a Facebook friend with one of us. This allows us to quickly find you on Facebook and send you an invitation to the group. If you are not already a Facebook friend, you must send one of us a request. If you send it to me, if I recognize you are part of the zoo industry, I'll put you in. But, I have pretty limited memory for names and faces so you might want to send me a note as well. I think this is probably best for Shawn and Iri too.

There was a discussion about some of the potential problems with using Facebook as our primary means of communicating, including (1) not everyone wants to join Facebook, (2) some zoos do not allow Facebook on zoo computers, and (3) some employers may not allow employees to access Facebook on work time. Other means of communicating were discussed, such as using a WhatsApp group, or creating a listserv on the CSG's system. The CSG Executive does not currently know who members of this group are, so we need a means of getting that information to the CSG. We asked Sally Isberg if we can send out an invitation to the entire CSG membership. She said that is possible, but also suggested that the CSG will soon be sending out notices for CSG membership renewal, and we could put a checkbox at the bottom of the notice for members to express their interest in being part of this group, or other CSG Thematic Groups. So, this question of how best to communicate within this group is, obviously, as yet unresolved. I will try to continue this discussion within the group, by both the Google and the Facebook Groups.

One last note about membership in the Zoos group. Being a member of this group does not imply membership in the CSG. By the same token, we don't worry about whether you are a CSG member when we add you to the Zoos Thematic group. If you wish to be a part of the group, send me a note.

Sustainable Utilization of Crocodilians

One thing I've never been able to achieve, in my role as Chair of the Crocodilian Advisory Group within the Association of Zoos and Aquariums, that is of paramount importance to the CSG is to include the story of Sustainable Utilization as a successful conservation strategy as part of zoos' education programs or signage. This is an on-going struggle. If you are associate with a zoo and able to convince your own institution to develop an education program or display related to SU and the conservation of crocodilians, please do so. We'd be happy to help.

The Place of Zoos within the CSG

At the close of the Zoos Group meeting, Colette Adams pointed out that most non-zoo CSG members had exited the room before the discussion began. In a plea to the CSG membership at-large, she requested zoos be respected as the CSG allies they have proven themselves to be. For example, in just over 10 years, nearly $US1M in crocodilian research and conservation funding has been distributed via CrocFest, with a large portion of that funding contributed by zoos. She further pointed out that zoos are important, telling millions of visitors each year the conservation stories that will help ensure future support for CSG initiatives. Zoos have been, and continue to be, good public relations representatives for crocodilians.

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