CROCODILE SPECIALIST GROUP NEWSLETTER

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CROCODILE

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NEWSLETTER

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COVER PHOTOGRAPH: Selection of recent CSG Student Research Assistance Scheme (SRAS) applicants.

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

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The CSG Newsletter provides information on the conservation, status, news and current events concerning crocodilians, and on the activities of the CSG. The Newsletter is distributed to CSG members and to other interested individuals and organizations. All Newsletter recipients are asked to contribute news and other materials.

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Marco Schultz, Germany.

Editorial

The passing of Dr. Winston Kay, Australia, last February was sad news indeed, and our sincere condolences go out to his wife and children. Winston worked for the Western Australian Department of Parks and Wildlife, but his PhD thesis on "Population Ecology of *Crocodylus porosus* (Schneider 1801) in the Kimberley Region of Western Australia", completed through the University of Queensland, broke much new ground, especially in tracking adults. It is also with sadness that we report on the passing of a former CSG member, Walter Herd, who passed away on 16 November 2015, at 95 years of age. Walter had been the agent for TCIM tannery in France for more than 40 years. Although he retired from the business around 15 years ago, he maintained relationships with many ex-colleagues and business partners. He travelled many times to Africa and knew many crocodile farmers and traders in South Africa and Zimbabwe.

I wrote to Dr. Simon Stuart, Chairman of the Species Survival Commission, and the Colombian Government (Vice-Minister Pablo Viera Samper, Ministerio de Ambiente y Desarrollo Sostenible) regarding caiman farming in Colombia. According to national laws, production of *Caiman crocodilus fuscus* should be restricted to close-cycle captive breeding. Yet ranching and wild harvesting are commonplace. This means Colombia is in breach of CITES, by using wild animals in contravention of Colombian laws, and by exporting the skins with "captive breeding" source codes on the CITES Export Permits. The EU made a decision to suspend trade in December 2015, pending an attempt to resolve the problem at the CITES Standing Committee meeting in January 2016. Hank Jenkins and I submitted an information paper from the CSG about the situation as we understand it. It is our understanding that Colombia and the EU have reached agreement on a series of actions that Colombia needs to take to rectify the situation.

Resolving the problems with *Caiman crocodilus fuscus* management in Colombia will be important for establishing the confidence of the Parties to CITES in Colombia's new proposal: "To transfer from Appendix I to Appendix II the population of *Crocodylus acutus* (Cuvier, 1807) of the Regional District of Integrate Management of Mangroves of Cispata Bay and nearby sectors of the Estuarine Delta of Sinú River, located in the Department of Cordoba, Republic of Colombia, in accordance with Conf. Resolution. 11.16 (Rev. CoP 15) on Ranching and trade in ranched specimens of species transferred from Appendix I to Appendix II." The proposed *C. acutus* ranching program will be restricted to an egg-harvest strategy, within this one part of Colombia, where the program is operated by local people for local people. The draft proposal has been reviewed by a number of CSG members, with comments sent back to the Colombian authorities.

I also wrote to the President of Honduras and to his Minister of Energy, Natural Resources, Environment and Mines, concerning a situation which developed with *C. acutus* at Cocodrilo Continental farm. The farm had apparently run into financial hardship, and it was alleged in the media that the crocodiles were not being adequately fed or cared for. I strongly recommended that the problem be investigated by Honduran authorities, and that all necessary actions be taken to ensure that an animal welfare problem does not develop.

Following decisions made at the CSG Steering Committee Meetings in Cambodia (May 2015) and Louisiana (May 2014), a set of draft best management practice (BMP) guideline for crocodilian farming were prepared, largely by Charlie Manolis and WMI. This draft has now been circulated to a large number of CSG members with appropriate expertise to review, and their comments are now being integrated in a next draft, which will be circulated to all CSG members before finalization.

Together with CSG Steering Committee members Matthew Shirley, Samuel Martin, Christine Lippai and Perran Ross, I attended the 3rd West and Central Africa Regional Meeting of the Crocodile Specialist Group at the University of Nangui Abrogoua, Abidjan, Cote d'Ivoire, on 8-10 December 2015. A detailed summary of the meeting will be provided in the next issue of the newsletter (Jan-Mar 2016). It was particularly nice to meet so many people, from 16 regional countries, all trying to find ways of improving the conservation and management of crocodiles. Holding these meetings regularly, and using them to share insights and technologies within the region, should remain a priority for the CSG.

With the assistance of Perran Ross and Curt Harbsmeier, we have established a not-for-profit NGO in the USA, the "International Association of Crocodile Specialists-USA, Inc.", under section 501(c)(3) of the USA Internal Revenue Code. Contributions by US donors to this NGO may be tax deductible.

The 24th Working Meeting of the Crocodile Specialist Group will be hosted by SANParks at Nombolo Mdhluli Conference Centre, Skukuza Rest Camp, Kruger National Park, South Africa, on 23-26 May 2016. The theme of the working meeting is "Crocodiles, Communities and Livelihoods". There will be a veterinary workshop on 21 May, and a meeting of the CSG Steering Committee on 22 May. Details are now available on the meeting website (www.csg2016southafrica.org). I urge all CSG members and others interested in crocodilian conservation, management, research and trade to consider participation in the meeting.

Professor Grahame Webb, *CSG Chairman*.

Obituary

Louis J. Guillette, Jr. (1954-2015)

Louis J. Guillette, Jr. (Lou), one of the world's most influential research scientists in the field of environmental health, died on 6 August 2015 at the age of 60, from complications (bacterial pneumonia) associated with non-Hodgkin lymphoma. Though Lou had been fighting the disease for almost a decade, his passing was sudden and came as a shock to everyone who knew him. Over the past few months, many colleagues and friends have published their own knowledge and interpretation of Lou, and shared their personal stories and feelings about him. These well-written pieces provide a thorough overview of Lou's life and accomplishments, and the incredible person he was. In this piece for the CSG Newsletter, we build on these previously published writings and include additional information on Lou's life, his work with crocodilians, and our relationships with this great mentor and friend.

Lou was an extremely energetic man with a passion for science, people, and the natural environment. He worked at the frontiers of integrative science, connecting genetic, physiological, chemical, and environmental data to make new discoveries that linked environmental conditions to the reproductive health of wildlife and people (Edwards *et al*. 2015). He helped usher environmental research into a new era and is most recognized for identifying endocrine disruption in American alligators and linking this ground-breaking research to consequences on human health (Helbing *et al*. 2015). This work was instrumental in instigating a paradigm shift in the field of ecotoxicology; the recognition that a change in hormone signaling during critical windows of development caused by low dose exposure to environmental contaminants can lead to deleterious health effects, including cancer (Helbing *et al*. 2015).

Among his many accomplishments, Lou published nearly 300 scientific papers, 43 book chapters, and 5 books (Edwards *et al*. 2015). He mentored 36 PhD students, 14 postdoctoral fellows, 17 Master's students, and over 100 undergraduates (Edwards *et al*. 2015). He was a master teacher and researcher, and his reach extended worldwide through productive and ongoing collaborations with colleagues in Africa, Asia, Australia, Canada, Europe, Japan and Central and South America (Edwards *et al*. 2015; Iguchi 2015; MUSC 2015; Tyler 2015). Most importantly, he was a loving and devoted husband and father. Lou is loved, remembered, and celebrated by his family, students, postdocs, colleagues and friends. He lived a full life of generosity, creativity and adventure (Edwards *et al*. 2015).

Lou was born on 29 August 1954 at Sheppard Air Force Base in Wichita Falls, Texas, the oldest of four children. Typical of the transient life of a military family, Lou moved relatively often during his childhood. He spent his pre-school years in Spain, and upon returning home some years later, he was tested for placement back into the US school system. Because of a heavy exposure to the Spanish language as a toddler, young Lou did not perform well on the exam (in English). Unaware of the language issue, the teachers reviewing his test scores informed Lou's parents he "might have a future as a truck driver". Years later, the family was transferred to Goose Bay, Newfoundland (Canada), where in high school Lou excelled academically and as a track and field athlete, particularly in the hurdles. During this time, he was also very active in the scouts program where he became an Eagle Scout and eventual troop leader. When his family moved again to the state of New Hampshire, Lou became an avid mountain climber, one of his lifelong passions. Soon after, Lou enrolled in college at New Mexico Highlands University. However, during the summers he would return to New Hampshire where he worked as an Outward Bound instructor at a YMCA camp. Here, he eventually met, fell in love with, and married Elizabeth ("Buzzy") Arnold who was on the faculty at the University of New Hampshire at the time and worked during the summer as the YMCA camp nurse. Lou and Buzzy went on to raise four children and remained happily married for 39 years until his death.

After completing his BSc degree at New Mexico Highlands, Lou and Buzzy moved to the mountains of Colorado, west of Boulder. Interested in graduate school, Lou soon approached

Dick Jones at the University of Colorado about joining his lab (Helbing *et al*. 2015). Dr. Jones recalls being impressed with Lou's "excellent undergraduate training and academic record in biology, remarkable and natural ability to form preliminary research questions" as well as, "his unusual amount of excitement and enthusiasm to do the detective work of creative research in biology, and his likable, friendly personality" (Helbing *et al*. 2015). Lou certainly did not disappoint, completing both his MA and PhD in five years with 10 publications. Much of his dissertation research occurred in the mountains of south-central Mexico where he examined reproductive strategies and the evolution of viviparity in *Sceloporus aeneus* lizards. Lou's graduate school experience sparked one of his lifelong research passions - the evolution of the reproductive system, particularly sex determination, viviparity, and placentation, and set the groundwork for what was to become an exemplary career in research and teaching (Helbing *et al*. 2015). During his years as a graduate student in Colorado, Lou also volunteered as a paramedic and fireman, where his climbing skills were often critical when rescuing lost and injured mountain climbers.

Following a brief stint as Assistant Professor at Wichita State University, in 1985 Lou was recruited to the University of Florida (UF), Gainesville, where he set up his own laboratory of comparative endocrinology (Helbing *et al*. 2015). He was soon approached by scientists at the Florida Fish and Wildlife Conservation Commission (particularly Allan "Woody" Woodward and Franklin Percival) to help solve the mystery of unusually low hatching rates observed in some alligator populations in the north-central portion of the state (Edwards *et al*. 2015). Thus began Lou's research on the reproduction and ecotoxicology of the American alligator for which he became world renowned. In 2006, Lou expanded his research program by initiating a collaborative project with the National Aeronautics and Space Administration (NASA) to examine the ecology and ecotoxicology of alligators living in habitats on the Kennedy Space Center. Collectively, Lou's research at UF augmented basic knowledge of alligator biology while creating an in-depth model for understanding the effects of contaminants in wildlife (Edwards *et al*. 2015).

Lou recognized the connection between elevated contaminant exposure in alligators, altered endocrine function, and reproductive abnormalities. He further recognized that these effects could translate to reproductive problems in humans (Edwards *et al*. 2015). Indeed, Lou showed that alligators may act as sentinels for studying the effects of long-term environmental contaminant exposure on wildlife health, with many parallels to human development and postnatal life. He taught, "If the environment is not healthy for alligators, then it's probably not healthy for us." The alligator research led by Lou became one of the most comprehensive and convincing programs in the world demonstrating that some reproductive problems in wildlife were caused by endocrine disrupting chemicals, and this fundamentally contributed to the founding, vision, and growth of environmental endocrine disruption as a scientific field (Edwards *et al*. 2015; Helbing *et al*. 2015). In addition, there is little doubt that Lou's work on sublethal levels of environmental contaminants in alligators heightened research into human reproductive problems as well (Helbing *et al*. 2015). Lou's work was not without its critics; however, he always held to the mantra of "let the science do the talking" (Helbing *et al*. 2015).

Academically, Lou was elected as a fellow of the American Association for the Advancement of Science in 1997, selected as the UF Teacher/Scholar of the Year in 1998, and promoted to Distinguished Professor in 2001. From 2001 through 2015, Lou was recognized as an ISI Highly Cited Research Scientist in Ecology and Environmental Biology (Edwards *et al*. 2015). In 2003, he was appointed as Extraordinary Professor of Toxicology and Pharmacology at the Faculty of Veterinary Science, University of Pretoria, South Africa. In 2006, he was named an HHMI Professor by the Howard Hughes Medical Institute and harnessed this prestigious award to create and build the UF Group Advantaged Training of Research (GATOR) program to give high school and undergraduate students an opportunity to work alongside faculty and graduate student mentors to learn how science is conducted and about the importance of academic honesty and research ethics (Edwards *et al*. 2015; Helbing *et al*. 2015). The GATOR program was ground-breaking in that it emphasized equally the skills of mentoring, communication, scientific philosophy, and research in the education of young scientists (Edwards *et al*. 2015).

Largely due to his expertise in reproductive biology and unique ability to examine and elucidate the influence of environmental contaminants on the health of both wildlife and humans, in 2010 Lou was recruited as the CoEE Endowed Chair in Marine Genomics at the Medical University of South Carolina (MUSC) and Hollings Marine Laboratory in Charleston. This was a "dream position" for Lou, where he could more effectively tackle how to prevent and treat health problems caused by environmental factors (Helbing *et al*. 2015). At MUSC, Lou was Professor of Obstetrics and Gynecology, Professor of Public Health Sciences, Director of the Center for Marine Biomedicine and Environmental Science, and Director of the SmartState Center for Marine Genomics. This move characterized Lou's tirelessness and love for taking on new challenges in advancing the field of environmental health. In Charleston, Lou established a large and interdisciplinary team consisting of graduate and medical students, postdoctoral fellows, medical fellows, basic scientists, physicians, wildlife biologists, and analytical chemists, all focused on understanding the direct connections between the health of women and children and the health of their environment. In recognition of Lou's tremendous accomplishments as a scientist, mentor, and teacher, in 2011 he received the Heinz Award for the Environment (Heinz Science Medal), recognized as the highest international award for work on environmental health (Edwards *et al*. 2015).

Lou's research on crocodilian biology and ecotoxicology steamrolled ahead during this time as well. Upon arriving in South Carolina, he quickly created a collaborative relationship with Phil Wilkinson who had been conducting field investigations on alligator ecology in the state's coastal plain since the mid-1970s. This alliance soon blossomed

into a much larger collaboration of scientists and students throughout the USA and abroad. However, although now residing in South Carolina, Lou was adamant about maintaining his long-term alligator projects in Florida, and his longstanding collaborations with colleagues at the Florida Fish and Wildlife Conservation Commission, the US Fish and Wildlife Service and NASA, and UF allowed these projects to continue flourishing. In 2012 Lou initiated a collaborative project with Kruger National Park and the Mpumalanga Tourism and Parks Agency in South Africa to further investigate the health of Nile crocodiles in the Olifants River system where large-scale crocodile mortalities had occurred a few years before. On the day he died, Lou was just five days from leaving the USA for the fourth year of field work on this project.

Although a brilliant scientist, much of Lou's success was related to his larger-than-life personality. As aptly described by Helbing *et al*. (2015), "Lou had a rare ability to transcend traditional disciplines and unite people for a common cause. His charismatic personality, conviction, and enthusiasm were infectious. He was a dynamic, passionate facilitator and advocate for science education. He felt equally at ease in front of scientists, physicians, students, the general public, and alligators. He inspired a sense of family among those who knew him. His optimism and humor always helped keep things in perspective. His flair for storytelling captivated the many audiences with whom he shared his research message. An avid photographer and aficionado of culture and the arts, his stories would unfold with wonderful images and a delivery that engaged as well as entertained. Lou's charisma made him highly sought after by the media. He was an advisor to the Science Communication Network and his research was featured on programs on Discovery Channel, CBC, PBS-Frontline, CNN, NHK and BBC. He was deeply concerned that there are populations of children and wildlife whose health will be compromised because of their exposure to environmental contaminants. With an exceptional ability to communicate and the gravitas of an internationally known researcher, Lou served as a science advisor to many US and foreign agencies regarding the impacts of environmental contamination on human and ecosystem health." In 1993, he famously testified before US Congress, telling lawmakers that "every man sitting in this room is half the man his grandfather was", in reference to reduced sperm counts in recent generations and the potential influence of synthetic chemicals in food, water, cosmetics and the environment on hormones vital to reproduction and early childhood development.

Despite all of Lou's personal successes, for him, science was about people - building relationships, fostering creativity, and providing opportunity (Heindel *et al*. 2015; Helbing *et al*. 2015; Iguchi 2015; Tyler 2015; MUSC 2015). He lived by the motto of a dear mentor, Howard A. Bern: "One's legacy to science is not the work that you do, but the people you leave behind" (Helbing *et al*. 2015). Lou was a role model and tireless advocate for mentoring young scientists, and he viewed this responsibility as his most important contribution to science (Helbing *et al*. 2015). He had exceptional skills as a mentor and a wonderful ability to communicate scientific ideas (Edwards *et al*. 2015). There is no doubt that Lou's global perspective and stories of adventure were a magnet for students and made his laboratory a lively and spirited place. To work with Lou was to be guided on a life-changing journey into the heart and soul of scientific research. His students became part of something larger than themselves, an academic family linked with laboratories all over the world, gathered in the common pursuit of comparative and field-based scientific inquiry. Lou's students and postdocs have gone on to careers in academics, government, industry, non-profit organizations, and medicine. They carry forward his influence and philosophy and continue to build on his legacy (Edwards *et al*. 2015).

If you asked Lou what it meant to be a scientist, he would say that it is the "four best jobs on Earth". The following is an excerpt, written by one of Lou's former graduate students, that reflects Lou's philosophy and his ability to inspire (Edwards *et al*. 2015).

"To be a scientist is to be an adventurer, a detective, an artist, and a storyteller. As an adventurer, you will break new ground, discover things no one else has discovered, and see things no one else has seen. As a detective, you will seek out the evidence and build your case. You will look in unlikely places and notice the small details that will matter later. As an artist, you will create new ways of seeing the world. You will find beauty you did not know existed and you will use your hands and mind to shape tomorrow's knowledge. As a storyteller, you will weave together the history, adventure, evidence, and innovation of your discoveries to teach and inspire others. With these wonderful opportunities comes great responsibility. Good research requires honesty, open-mindedness, and fairness. Good researchers continuously seek the truth while understanding that truth can change depending on experience and perspective. Success will depend on your ability to simultaneously believe in yourself and ask more from yourself. And, like all who venture into the unknown, there will come a time when you are tired, hungry, discouraged, or lost. At these times, understand that you have within yourself the will to move forward, the guidance of mentors to help you, and the friendship of colleagues gained along the way (Martinot 2015)."

Everyone that has ever worked with Lou has his or her own tales about swashbuckling adventures in the field, exciting discoveries in the laboratory, or simply the myriad ways he taught, inspired, or helped us. Over the years, Lou collaborated with numerous members of the CSG, and also served on the graduate committees of many, including the late John Thorbjarnarson. Personally, we (TRR, RHL, HB) worked with Lou for many years on a variety of crocodilian projects in the USA, Belize and South Africa. The stories and experiences from these interactions with Lou are far too many to recall here, but they provide a constant source of comfort in his absence. We are honored to have called Lou a mentor and friend, and like so many of his students and colleagues, are privileged to be members of his extended family.

Lou was an exceptional human being. His death creates a gaping hole in the lives of many and in the fields of environmental health, crocodilian reproductive biology, and ecotoxicology. His life, however, provides a wonderful legacy - the people he trained and the passion he instilled in them to continue his quest for harmonizing human activity with environmental, wildlife and human health (Helbing *et al*. 2015). Lou provided the example against which many of his students and colleagues continually compare their own professional endeavors, and he is the benchmark against which many of us gauge the quality, thoroughness, creativity and care we give to our jobs, research and own mentoring of the next generation of scientists (Edwards *et al*. 2015).

He will be deeply missed.

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"No More Endlings" - now available

"No More Endlings", a non-technical publication which documents the profiles of around 46 globally endangered species, is now available (Motivational Press, 2015; 429 pp.; visit www.allisonhegan.com for more detailed description). The book relates the conservation stories of the researchers and other personalities working on these species, including *Tomistoma schlegelii*.

The chapter by Mark Bezuijen (Tomistoma - In Pursuit of Living Fossils) draws on the work carried out by the CSG, Wildlife Management International, People, Resources and Conservation Foundation, and other agencies, in Indonesia since the 1990s.

Aimed at general readership to raise public awareness and funds for biodiversity conservation, 50% of royalties will be donated to conservation agencies, including the CSG. "No More Endlings" is available for purchase at www.amazon.com, www.amazon.co.uk and www.barnesandnoble.com.

World Tomistoma Day

5 August 2016 will see the celebration of the first World Tomistoma Day. Given the prevalence of 'Wildlife Awareness Days' that highlight endangered species, the CSG Tomistoma Task Force (CSG-TTF) feel it is time to establish a day that raises the profile of an endangered crocodilian species. The idea was initiated by, and continues to be developed by the CSG-TTF.

The date selected (5 August) is the birth date of the late Ralf Sommerlad - a founding member and former Chairman of the CSG-TTF [see CSG Newsletter 34(2): 4-5]. Ralf was one of the world's most passionate and energetic supporters of Tomistoma conservation. This date has since been checked within Tomistoma range states and a number of other countries so as to avoid important holidays.

In the coming months the CSG-TTF will be contacting zoological parks, aquaria and other centers around the world to encourage them to organise World Tomistoma Day events. Wildlife awareness days provide a great opportunity to promote public awareness for an endangered species and to generate international support for its conservation. We envision this day evolving into events that create the same levels of participation as those achieved by other wildlife awareness days, such as World Rhino Day.

As planning progresses, we will update information on the CSG website and Facebook page. For additional information about organising and/or participating in World Tomistoma Day events, please contact Colin Stevenson (coleosuchus@hotmail.com), Bekky Muscher-Hodges (muscherhodges@sazoo.org) or Aubrey Shwedick (ashwedick@gmail.com).

CSG Student Research Assistance Scheme

The CSG Student Research Assistance Scheme (SRAS; http://www.iucncsg.org/pages/General-Information.html) provided funding to 7 students in the October-December 2015 quarter, bringing the total approvals for the year to 15.

1. Fabio Muñiz (Brazil): Phylogeography and population genetics of Cuvier's Dwarf caiman (*Paleosuchus palpebrosus*) in the Amazon: next-generation sequencing approach.

2. Sebastian Brackhane (Germany): Implementation of a community-based monitoring system (CBMS) for *Crocodylus porosus* in Timor Leste.

3. Hernan Ciocan (Mexico): Population dynamics of wild and reintroduced *Caiman latirostris* and evaluation of their monitoring methods.

4. Liliana Berenice Garcia Reyes (Mexico): Determination and quantification of heavy metals in *Crocodylus acutus* and *Caiman crocodilus*, Tonala, Chiapas, Mexico.

5. Andrea Argumedo León (Mexico): Population status of *Caiman crocodilus* for its conservation: a genetic focus.

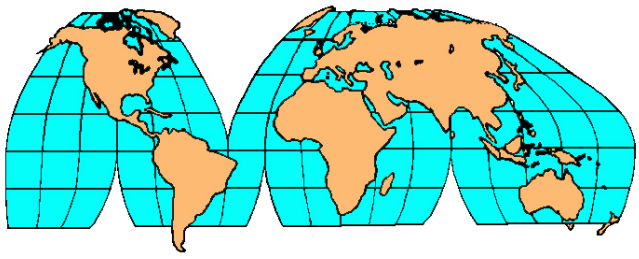
6. Maria Laura Romito (Argentina): Oxidative damage of DNA in *Caiman latirostris* exposed to pesticides under semi-natural conditions.

7. Miriam Boucher (USA): Investigating bioacoustics and behaviour of American crocodiles in Belize.

It is now 7 years since the CSG Student Research Assistance Scheme commenced in January 2009. During this period 94 applications have been approved from 29 countries. (Argentina 15, Australia 5, Benin 1, Bolivia 1, Brazil 11, Burkina Faso 1, Canada 1, China 1, Colombia 6, Costa Rica 3, Cuba 1, Ecuador 1, Ethiopia 1, Germany 3, India 1, Iran 1, Malaysia 1, Mexico 7, Nepal 1, Netherlands 1, Panama 1, Peru 1, Philippines 1, South Africa 7, Thailand 1, Uganda 2, United Kingdom 1, USA 14, Venezuela 3). To date reports have been received on 70 projects, with 24 still ongoing. Full details on all grant proposals can be found on the CSG website at: www.iucncsg.org (under Grants).

Tom Dacey, *CSG Executive Officer, <csg@wmi.com.au>*.

Regional Reports



Latin America and the Caribbean

Brazil

FIELD COURSE AND WORKSHOP "ECOLOGIA DE TRANSICAO CERRADO-FLORESTA AMAZONICA". On 27 July to 28 August 2015 a practical-theoretical course held by PROCAD (031/2013) and conducted by the Universidade de Brasilia (UNB), Universidade do Estado de Mato Grosso (UNEMAT) and Universidade Federal de Tocantins (UFT), in Nova Xavantina and Gaúcha do Norte (Mato Grosso, Brazil). The aims of the course were to increase the interaction between the three universities (UNB, UNEMAT, UFT), and develop studies for the conservation of this very important transitional ecosystem (Brazilian savannah/Amazon forest).

The activities were divided in: 2 weeks in Nova Xavantina, with theoretical and practical courses on statistics, reptile physiology and climatic change; and other 3 weeks in Gaúcha do Norte, with different courses about identification and characterization of plants, insects behaviour, fish morphology, turtles nesting, surveys and physiological studies of crocodilians and lizards. All students had the opportunity to participate during theoretical and practical sessions. The different elements of the course were conducted by: Dr. Rinaldi Colli, Dr. Leza, Dra. Malvasio, Dr. Brandao, Dr. Pellegrin, Dra. Simoncini. Invited professors were Dr. Donald Miles (USA) and Dr. Barry Sinervo (USA). The field course was directed to undergraduates, graduates and professionals from three universities of different areas, and was attended by approximately 70 people.

The field work on crocodilians was conducted with night surveys for species identification, capture, evaluation of health, and to collect important data for ecological and conservation studies. Also the students read publications of the Crocodile Specialist Group about conservation status of two species identified (*Caiman crocodilus* and *Paleosuchus palpebrosus*) and different aspects of crocodilian ecology. Then the students designed individual projects to evaluate the thermoregulatory behaviour of caiman, and the abundance and distribution in different habitats for the two species. Those activities were supervised by Dra. Malvasio and Dra. Simoncini. All the methodologies and results were discussed in the field course and the students are writing their manuscript for publication. Many of the students were interested to develop studies on this important transition ecosystem (Brazilian savannah/Amazon forest) with caimans and collaborating with CSG action plans.

Melina Simoncini, *Proyecto Yacaré-CICyTTP (CONICET), Argentina*.

NEW RECORDS ON OCCURRENCE OF *PALEOSUCHUS* IN THE BRANCO RIVER BASIN, RORAIMA STATE, BRAZIL. Most living crocodilians are endemic to a single zoogeographic region (Martin 2008). In general, the distribution of crocodilians can be explained by a succession

of paleogeographic events (Brochu 2003). Recent studies have demonstrated the importance of these events in the diversification of cryptic species of *Osteolaemus* (Eaton *et al*. 2009; Franke *et al*. 2013; Shirley *et al*. 2014a,b) and of *Paleosuchus palpebrosus* (Muniz 2012). Both these genera comprise small species that live in headwater streams in forest environments and are among the most terrestrial of living crocodilians (Eaton 2010; Magnusson and Campos 2010a,b). These and other shared traits appear to render these species more susceptible to diversification due to events of fragmentation and isolation of populations, probably associated with paleogeographic barriers.

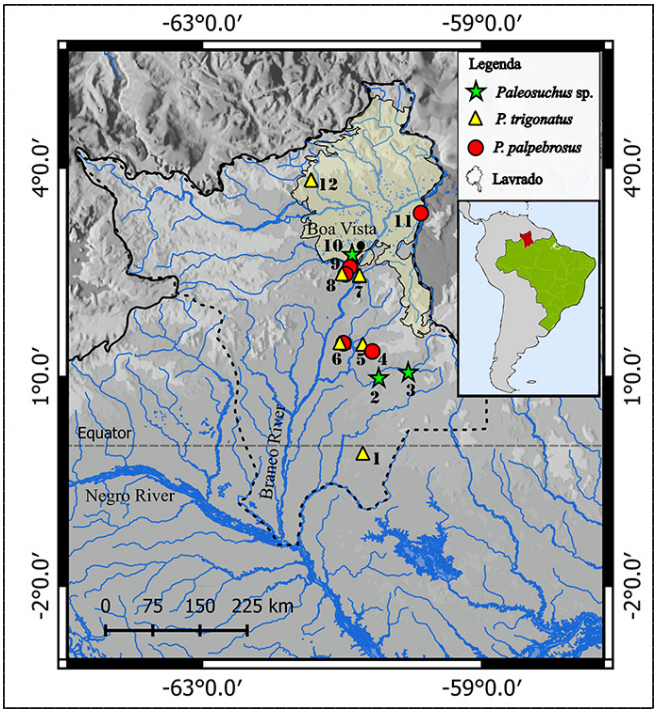


Figure 1. Locations where *Paleosuchus trigonatus* and *P. palpebrosus* specimens were recorded in the state of Roraima. Stars represents individuals not identified to species level. Locations are: (1) Branquinho River, Vila Jundiá; (2) Rorainópolis; (3) São Luiz do Anauá; (4) one *P. palpebrosus* specimen run over on Highway BR 174; (5) Itã River; (6) Viruá National Park; (7) Villa Serra Grande II; (8) buriti palm groves on the right bank of the Mucajaí River, "Igarapé da Muda" and "Igarapé Trairão" streams; (9) buriti palm groves of the left bank of the Mucajaí River, "Igarapé Tacacá" and "Igarapé Santa Rita" streams; (10) Água Boa River; (11) buriti palm grove along the "Igarapé da Vaca" stream; (12) Amajari River.

The history of the formation of the Branco River basin in Brazil is fairly well known. The headwaters of the Branco River flowed north towards the Atlantic, forming the proto-Berbice basin, up to the end of the Pleistocene (Schaefer and Dalrymple 1995; Lujan and Armbruster 2011). These headwaters were located in a mountain range called a "paleogeographic divide", which separated the proto-Berbice basin from the Amazon basin. This "paleogeographic divide" is believed to have been eroded during the Pleistocene, resulting in the redirection of the Branco River southwards. Today, the Branco River is part of the Amazon Basin, the main tributary of the Negro River, and is located on the Guiana Shield, a megadiverse region in which four to five areas of endemism are located (Cracraft 1985; Naka 2011; Naka *et al*.,2012).

Four species of crocodilians occur in the Branco River basin: *Caiman crocodilus* (Spectacled caiman), *Melanosuchus niger* (Black caiman), *P. palpebrosus* (Cuvier's Dwarf caiman) and *P. trigonatus* (Schneider's Smooth-fronted caiman). The two *Paleosuchus* species, both of which are small and shy, occur in low densities (Magnusson and Campos 2010a) and require survey methodologies different from those used for the other species (Magnusson and Lima 1991; Campos *et al*. 1995). Earlier studies reported the occurrence of *P. palpebrosus* in the Mucajaí River and its tributaries, of *P. trigonatus* in Viruá National Park, and of both species in the Maracá Ecological Station (Rebêlo *et al*. 1997; Gordo *et al*. 2009; Souza 2010).

The purpose of this note is to report new points of occurrence of *Paleosuchus* spp. to the north and south of the proto-Berbice/Amazon paleogeographic divide, in the Branco River basin, and to identify potential threats to the species in the state of Roraima, Brazil. Subsequent studies are planned to examine the effect of paleogeographic events in the Branco River basin on *Paleosuchus* using population genetic tools.

Nighttime surveys of *Paleosuchus* spp. were made by canoe and on foot in March, August and November 2015 along rivers, streams and buriti palm groves in areas of forests and savannas (known locally as "lavrado"). Caiman that were spotted were georeferenced and, when captured, their snout-vent length (SVL, in cm) was measured. A piece of caudal scale tissue was removed and stored in 95% alcohol and deposited in Animal Genetic Tissue Collection (CTGA) of the Federal University of Amazonas (UFAM). Tissue samples of *Paleosuchus* spp. will be used in population genetic analyses by Fabio Muniz in his doctoral studies and by Pedro Senna in his masters studies in the Graduate Program of Genetics, Conservation and Evolutionary Biology at the National Institute for Amazon Research (INPA).

We spotted 52 *Paleosuchus* spp. individuals at 12 locations in the state of Roraima, 22 of which were *P. trigonatus* and 26 were *P. palpebrosus* - four individuals were not identified to species level. Of these, 33 individuals were captured (16 *P. trigonatus* and 17 *P. palpebrosus*). The densities were calculated using only individuals with a SVL of >40 cm. *Paleosuchus trigonatus* were found in 6 locations at an average density of 0.66 ind./km and *P. palpebrosus* were found in 5 locations at an average density of 0.41 ind./km.

New records of *P. palpebrosus* in the state of Roraima were made in Viruá National Park and in a buriti palm grove of the "Igarapé da Vaca," a tributary of the Tacutu River. The species was also recorded in tributaries of the Mucajaí River, and in buriti palm groves along the "Igarapé da Muda," "Trairão," "Santa Rita" and "Tacacá" streams. New records of *P. trigonatus* were made in the Branquinho River near

Vila Jundiá, in the Itã River in Vila Serra Grande II, in the Amajari River, and in a buriti palm grove along the "Igarapé da Muda," a tributary of the Mucajaí River.

The species were found to co-exist in two creeks: one *P. trigonatus* hatchling (SVL= 22.0 cm) and three *P. palpebrosus* hatchlings (SVL= 22.0, 22.6 and 22.9 cm) in the "Igarapé da Muda," and one *P. trigonatus* (SVL= 95.0 cm) and one *P. palpebrosus* (SVL= 44 cm) in a stream near the entrance to Viruá National Park, all captured during the same night (Fig. 1).

In the state of Roraima, *P. trigonatus* was found in rivers with flowing waters and rocky substrate, such as the Branquinho, Itã and Amajari Rivers; in small montane forest streams, such as Serra Grande II; and, in a buriti palm grove located in a savanna and ombrophilous forest ecotone. *Paleosuchus palpebrosus* was typically found in buriti palm groves located in open areas of savanna and "campinarana" vegetation and in forested areas. The species was also recorded in large rivers such as the Apiaú, Mucajaí and Uraricoera, in points closest to headwater (Rebelo *et al*. 1997; Souza 2010).

Two new records were made in situations that indicate human impact, burned gallery forest and roadkill. In the first instance, a *P. palpebrosus* individual was found in a pool in the "Igarapé da Vaca" stream in burned buriti palm vegetation (03°19' N, 59 °51' W). Burning and deforestation of buriti palm groves are reportedly common practices in areas of savanna and can pose a direct threat to *P. palpebrosus*, mainly due to habitat loss. In the second instance, a dead *P. palpebrosus* was found run over on highway BR 174 (01°21' N, 60°36' W; Fig. 1), near a stream in a buriti palm forest. We also recorded a dead *Caiman crocodilus* run over on a stretch of highway BR 174 in November, close to where the *P. palpebrosus* was found (01°25' N, 60°43' W). Being run over has been reported as one of the threats to *Paleosuchus* in Brazil (Campos *et al*. 2012). The roads in the region of Roraima pose a threat to *Paleosuchus* particularly because they pass through a variety of aquatic environments as streams, ponds seasonal flood and areas of buriti palm groves. The individuals can move through the land and cross the highway in order to reach another water body, running the risk to be run over.

Both species are subject to poaching in the region as well. We documented the death of two *P. trigonatus* individuals caused by residents. According to reports, poaching is common both in Indian reserves and in communities along the roads. In general, the conservation status of *Paleosuchus* can be considered of "low concern" due to low human density and the fact that Roraima has one of the last preserved wetland forests in the world (Hammond 2005; Naka *et al*. 2012). However, we identified some areas where the species are more vulnerable, such as savannahs, known as "lavrado", and in urbanized areas close to Boa Vista and around Rorainópolis, where human occupation and deforestation grow apace (Diniz and Lacerda 2015).

Population genetic studies of these *Paleosuchus* spp. specimens are being conducted to investigate the influence of the historical processes that occurred in the state of Roraima on the genetic diversity of the species. Is there a genetic structure associated with the paleogeographic events that gave rise to the current Branco River? What is the genetic diversity of these populations? and is there a cause for concern in terms of conservation? These are the questions that underpin our future research.

Acknowledgments

We are indebted to Priscila Azarak, Beatriz Lisboa, Bruno de Souza Campos and the staff of Viruá National Park for their practical support, and INPA (National Institute for Amazon Research), UFAM (Federal University of Amazonas) and Embrapa Pantanal for their financial support. The master's and doctoral scholarships were granted by FAPEAM (Amazonas State Research Foundation) and the capture permit was issued by SISBIO/Brazil (no. 49641-2).

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Europe

United Kingdom

TOMISTOMA IN THE UK. There is renewed interest within UK zoos to display Tomistoma (*Tomistoma schlegelii*). For the past few years, Paignton Zoo has displayed the species within its Crocodile Swamp exhibit. These animals are from the successful breeding program established by Fuengirola Zoo in Spain. In August 2015 Chester Zoo unveiled its 'Sunda Gharial' exhibit within its expansive Islands section, with animals from La Ferme aux Crocodiles in France.

Crocodiles of the World (COTW), the UKs only crocodile zoo, located near Oxford, also has a pair of adult Tomistoma, which were imported from Johnson Jong's Crocodile Park in Sarawak, Malaysia, and were destined for the Rare Species Conservation Centre in Kent. Until a suitable enclosure could be prepared, the Tomistoma were being held at COTW. Earlier in 2015, the pair were officially transferred to COTW, where they will remain.

The Tomistoma arrived in the UK on 3 September 2014. The male, hatched in 1995, was 3.4 m long and weighed 132.9 kg. The female, hatched in 1999, was 2.3 m long and weighed 37.5 kg. As of now the Tomistoma are off-display at COTW, and have settled in nicely. These animals will allow COTW to begin raising awareness - and therefore funds - in order to support *in-situ* conservation projects for the species and the CSG Tomistoma Task Force. COTW will also be the focal zoo

for co-ordinating World Tomistoma Day events in Europe.

Crocodiles of the World, established by Shaun Foggett in 2011, has the largest collection of crocodilians in the UK, with 16 species held and 5 species breeding regularly.

Colin Stevenson, *CSG Tomistoma Task Force (coleosuchus@hotmail.com)*.

North America

USA

SUMMER CROCFEST 2015 RAISES $US23,000 FOR GHARIALS. Summer CrocFest 2015 took place on 27 June 2015, at the Everglades Alligator Farm in Homestead, Florida, USA, near the entrance to the world famous Everglades National Park. The event attracted 150 supporters and raised $US23,000 for Gharial (*Gavialis gangeticus*) research. Proceeds are being directed to the continued efforts of Dr. Jeff Lang, the Senior Scientific Advisor for the Madras Crocodile Bank Trust and the Gharial Conservation Alliance. Thanks to the generosity of private and corporate sponsors and zoos, over the last 6 years CrocFests have raised over $US140,000 for endangered crocodilians.

At CrocFest, organisors announced the creation of the Ralf Sommerlad Crocodile Conservation Award, in honor or Ralf Sommerlad, who passed away recently. See following article for details on the award.

A detailed summary of Summer CrocFest 2015 is available on the CSG website (see www.iucncsg.org homepage).

[Note: Peliminary numbers are in for Christmas CrocFest 2015, held at Crocodile Manor (Shawn Heflick's home) in Palm Bay, Florida, USA, on 5 December 2015. Some 150 attendees, as well as many other sponsors and supporters, helped raise over $US34,000 for the African slender-snouted crocodile, *Mecistops cataphractus* (conservation work conducted by Dr. Matt Shirley). A more detailed report will be forthcoming shortly, under separate cover].

RALF SOMMERLAD CROCODILE CONSERVATION AWARD ESTABLISHED BY CROCFEST. The organizers of CrocFest are pleased to formally announce the recipient of the inaugural Ralf Sommerlad Crocodile Conservation Award: Virginia Aquarium (Mark Swingle and Chip Harshaw). This prestigious award was created by CrocFest organizers following the untimely death of our friend and colleague, Ralf Sommerlad, in June this year. The award was presented at Christmas CrocFest 2015 (5 December 2015).

Ralf Sommerlad was a world renowned crocodilian expert. In European zoos, and was known as a "crocodile whisperer." He and Ludwig Trutnau co-authored "Crocodilians: Their Natural History and Captive Husbandry" (2006), which gained much critical acclaim. Ralf also published numerous articles in scientific journals and lectured worldwide on the biology, behavior and protection of crocodiles. He was a founding member and chairman of the CSG Tomistoma Task Force (CSG-TTF) and served on the IUCN-SSC Crocodile Specialist Group as a Regional Vice-chairman for Europe.

Ralf was among a small group which in 2009 first envisioned backyard BBQs as a fundraising tool for crocodilian conservation. From that idea CrocFest was born. He was our friend and we will miss him. Accordingly, it is with honor and respect that we created the Ralf Sommerlad Crocodile Conservation Award. This award will be presented annually to an individual or organization for outstanding commitment and contributions to crocodilian captive husbandry and conservation - both areas of great importance to Ralf and all of us.

The Virginia Aquarium & Marine Science Center, formerly known as the Virginia Marine Science Museum, opened to the public in 1986. It houses over 1100 specimens representing some 300 species of fauna. In the early 2000s Mark Swingle and Chip Harshaw began investigating the possibility of opening a crocodilian exhibit that would have real conservation value and expose the public to a crocodilian rarely displayed in US collections. After researching possible species and consulting with the AZA Crocodilian Advisory Group, they chose *Tomistoma schlegelii*. And so began a strong commitment to the species that continues to this day.

In 2005 they opened a temporary exhibit and displayed a young Tomistoma for the first time. By 2007 they identified

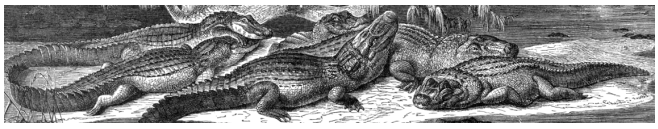
a pair of unrelated, captive adult Tomistoma (one in Florida, USA, and one in Toronto, Canada) that were available and in need of a facility for captive breeding efforts. In 2008 Chip attended a CSG-TTF conservation workshop in Thailand, establishing Virginia Aquarium's commitment to international conservation of this species. At that meeting, Chip first met Ralf Sommerlad, forging a friendship that would last until Ralf's death. That same year, construction began on a 1100 m^2 series of exhibits called "Restless Planet", which included the Malaysian Peat Swamp exhibit intended for the adult Tomistoma. The exhibit opened to the public in November 2009 to overwhelming success. In 2010, with Ralf's encouragement, Chip flew to East Kalimantan to work with Rob Stuebing and survey Tomistoma in Danau Mesangat, an area critical to Tomistoma conservation in Indonesia.

In 2014 Mark and Chip became members of the IUCN-SSC Crocodile Specialist Group. In 2015, Virginia Aquarium imported a new pair of juvenile Tomistoma from Kuching, Sarawak, Malaysia, the first legal importation of Tomistoma from a range state into the USA since 1974. In addition, over the last 10 years Virginia Aquarium has financially supported a number of *in-situ* crocodilian conservation projects benefiting the world's most endangered crocodilians.

Please join us in congratulating Virginia Aquarium, Mark and Chip, for their deep commitment to crocodilian captive husbandry and conservation.

Colette Adams, Curt Harbsmeier, Shawn Heflick and Flavio Morrissiey, *CrocFest organisors*.

Science



Recent Publications

Shine, R., Amiel, J., Munn, A.J., Stewart, M., Vyssotski, A.L. and Lesku, J.A. (2015). Is "cooling then freezing" a humane way to kill amphibians and reptiles? Biology Open 2015 4: 760-763 (doi: 10.1242/bio.012179).

Abstract: What is the most humane way to kill amphibians and small reptiles that are used in research? Historically, such animals were often killed by cooling followed by freezing, but this method was outlawed by ethics committees because of concerns that ice-crystals may form in peripheral tissues while the animal is still conscious, putatively causing intense pain. This argument relies on assumptions about the capacity of such animals to feel pain, the thermal thresholds for tissue freezing, the temperature-dependence of nerve-impulse transmission and brain activity, and the magnitude of thermal differentials within the bodies of rapidly-cooling animals. A review of published studies casts doubt on those assumptions, and our laboratory experiments on cane toads (*Rhinella marina*) show that brain activity declines smoothly during freezing, with no indication of pain perception. Thus, cooling followed by freezing can offer a humane method of killing cane toads, and may be widely applicable to other ectotherms (especially, small species that are rarely active at low body temperatures). More generally, many animal-ethics regulations have little empirical basis, and research on this topic is urgently required in order to reduce animal suffering.

Hekkala, E.R., Platt, S.G., Thorbjarnarson, J.B., Rainwater, T.R., Tessler, M., Cunningham, S.W., Twomey, C. and Amato, G. (2015). Integrating molecular, phenotypic and environmental data to elucidate patterns of crocodile hybridization in Belize. Royal Society Open Science 2: 150409.

Abstract: The genus *Crocodylus* comprises 12 currently recognized species, many of which can be difficult to differentiate phenotypically. Interspecific hybridization among crocodiles is known to occur in captivity and has been documented between some species in the wild. The identification of hybrid individuals is of importance for management and monitoring of crocodilians, many of which are Convention on International Trade in Endangered Species (CITES) listed. In this study, both mitochondrial and nuclear DNA markers were evaluated for their use in confirming a suspected hybrid zone between American crocodile (*Crocodylus acutus*) and Morelet's crocodile (*Crocodylus moreletii*) populations in southern Belize where individuals and nests exhibiting atypical phenotypic features had previously been observed. Patterns observed in both phenotypic and molecular data indicate possible behavioural and ecological characteristics associated with hybridization events. The results of the combined analyses found that the majority of suspected hybrid samples represent crosses between female *C. acutus* and male *C. moreletii*. Phenotypic data could statistically identify hybrids, although morphological overlap between hybrids and *C. moreletii* reduced reliability of identification based solely on field characters. Ecologically, *C. acutus* was exclusively found in saline waters, whereas hybrids and *C. moreletii* were largely absent in these conditions. A hypothesized correlation between unidirectional hybridization and destruction of *C. acutus* breeding habitats warrants additional research.

Sam H., Hor, L., Nhek, R., Sorn, P., Heng, S., Simpson, B., Starr, A., Brook, S., Frechette, J.L. and Daltry, J.C. (2015). Status, distribution and ecology of the Siamese crocodile *Crocodylus siamensis* in Cambodia. Cambodian Journal of Natural History 2015(2): 153-164.

Abstract: The Siamese crocodile is one of Southeast Asia's most endangered species, and Cambodia is believed to hold the largest remaining wild population. Between 2000 and 2014, interviews and field surveys were conducted on foot and by boat to document the species' distribution, ecology, status and threats. Crocodiles were confirmed in 35 locations in 11 provinces, each holding between one and 40 individuals. Over 75% of sites and 90% of individuals were found in Southwest Cambodia, with the largest groups located near settlements of

indigenous communities who traditionally revere crocodiles. We conservatively estimate the national wild population to number approximately 200-400 individuals (100-200 mature adults). Analysis of over 650 faeces revealed a wide variety of prey, with snakes and fish being the most frequently recorded. Crocodiles were found in freshwater lakes, swamps and slow-moving rivers, from near sea level to an elevation of 600 metres. Threats include accidental capture and drowning in fishing gear, poaching, habitat loss and degradation, and inbreeding and other risks associated with very small populations. No evidence was found of crocodiles attacking people in Cambodia. The crocodiles are not reproducing well, with fewer than 5 nests reported annually. Trial releases since 2012 indicate that captive-bred crocodiles could help repopulate and reinforce wild stocks, but they must be genetically tested to avoid releasing hybrids. Good progress has been made in enlisting the cooperation of local communities to protect key wetlands, but continued efforts from the government and NGOs are also required to enable this Critically Endangered species to recover

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Mannion, P.D., Benson, R.B.J., Carrano, M.T., Tennant, J.P., Judd, J. and Butler, R.J. (2015). Climate constrains the evolutionary history and biodiversity of crocodylians. Nature Communications 6: 8438. (doi:10.1038/ncomms9438).

Abstract: The fossil record of crocodylians and their relatives (pseudosuchians) reveals a rich evolutionary history, prompting questions about causes of long-term decline to their present-day low biodiversity. We analyse climatic drivers of subsampled pseudosuchian biodiversity over their 250 million year history, using a comprehensive new data set. Biodiversity and environmental changes correlate strongly, with long-term decline of terrestrial taxa driven by decreasing temperatures in northern temperate regions, and biodiversity decreases at lower latitudes matching patterns of increasing aridification. However, there is no relationship between temperature and biodiversity for marine pseudosuchians, with sea-level change and post-extinction opportunism demonstrated to be more important drivers. A 'modern-type' latitudinal biodiversity gradient might have existed throughout pseudosuchian history, and range expansion towards the poles occurred during warm intervals. Although their fossil record suggests that current global warming might promote long-term increases in crocodylian biodiversity and geographic range, the 'balancing forces' of anthropogenic environmental degradation complicate future predictions.

Klenner, S., Witzel, U., Paris, F. and Distler, C. (2015). Structure and function of the septum nasi and the underlying tension chord in crocodylians. Journal of Anatomy (doi: 10.1111/joa.12404).

Abstract: A long rostrum has distinct advantages for prey capture in an aquatic or semi-aquatic environment but at the same time poses severe problems concerning stability during biting. We here investigate the role of the septum nasi of brevirostrine crocodilians for load-absorption during mastication. Histologically, both the septum nasi and the septum interorbitale consist of hyaline cartilage and therefore mainly resist compression. However, we identified a strand of tissue extending longitudinally below the septum nasi that is characterized by a high content of collagenous and elastic fibers and could therefore resist tensile stresses. This strand of tissue is connected with the m. pterygoideus anterior. Two-dimensional finite element modeling shows that minimization of bending in the crocodilian skull can only be achieved if tensile stresses are counteracted by a strand of tissue. We propose that the newly identified strand of tissue acts as an active tension chord necessary for stabilizing the long rostrum of crocodilians during biting by transforming the high bending stress of the rostrum into moderate compressive stress.

Fermino, B.R., Paiva, F., Soares, P., Tavares, L.E.R., Viola, L.B., Ferreira, R.C., Botero-Arias, R., de-Paula, C.D., Campaner, M., Takata, C.S.A., Teixeira, M.M.G. and Camargo, E.P. (2015). Field and experimental evidence of a new caiman trypanosome species closely phylogenetically related to fish trypanosomes and transmitted by leeches. International Journal for Parasitology: Parasites and Wildlife (doi: 10.1016/j.ijppaw.2015.10.005).

Abstract: *Trypanosoma terena* and *Trypanosoma ralphi* are known species of the South American crocodilians *Caiman crocodilus*, *Caiman yacare* and *Melanosuchus niger* and are phylogenetically related to the tsetse-transmitted *T. grayi* of the African *Crocodylus niloticus*. These trypanosomes form the crocodilian clade of the terrestrial clade of the genus *Trypanosoma*. A PCR-survey for trypanosomes in caiman blood samples and in leeches taken from caimans revealed unknown trypanosome diversity and frequent mixed infections. Phylogenies based on SSU (small subunit) of rRNA and gGAPDH (glycosomal Glyceraldehyde Phosphate Dehydrogenase) gene sequences revealed a new trypanosome species clustering with *T. terena* and *T. ralphi* in the crocodilian clade and an additional new species nesting in the distant Aquatic clade of trypanosomes, which is herein named *Trypanosoma clandestinus* n. sp. This new species was found in *Ca. yacare*, *Ca. crocodilus* and *M. niger* from the Pantanal and Amazonian biomes in Brazil. Large numbers of dividing epimastigotes and unique thin and long trypomastigotes were found in the guts of leeches (*Haementeria* sp.) removed from the mouths of caimans. The trypanosomes recovered from the leeches had sequences identical to those of *T. clandestinus* of caiman blood samples. Experimental infestation of young caimans (*Ca. yacare*) with infected leeches resulted in long-lasting *T. clandestinus* infections that permitted us to delineate its life cycle. In contrast to *T. terena*, *T. ralphi* and *T. grayi*, which are detectable by hemoculturing, microscopy and standard PCR of caiman blood, *T. clandestinus* passes undetected by these methods due to very low parasitemia and could be detected solely by the more sensitive nested PCR method. *T. clandestinus* n. sp. is the first crocodilian trypanosome known to be transmitted by leeches and positioned in the aquatic clade closest to fish trypanosomes. Our data show that caimans can host trypanosomes of the aquatic or terrestrial clade, sometimes simultaneously.

Crump, M. (2015). Eye of Newt and Toe of Frog, Adder's Fork and Lizard's Leg: The Lore and Mythology of Amphibians and Reptiles. University of Chicago Press: Chicago.

Calverley, P.M. and Downs, C.T. (2015). Movement and home range of Nile Crocodiles in Ndumo Game Reserve, South Africa. Koedoe 57(1), Art. #1234, 13 pages.

Abstract: The study of movement patterns and home range is fundamental in understanding the spatial requirements of animals and is important in generating information for the conservation and management of threatened species. Ndumo Game Reserve, in north-eastern KwaZulu-Natal, bordering Mozambique, has the third largest Nile crocodile (*Crocodylus niloticus*) population in South Africa. Movement patterns of 50 Nile crocodiles with a total length of between 202 cm and 472 cm were followed over a period of 18 months, using mark-resight, radio and satellitetelemetry. The duration of radio transmitter attachment (131 ± 11.4 days) was significantly and negatively related to total length and reproductive status. Satellite transmitters failed after an average of 15 ± 12.5 days. Home range was calculated for individuals with 10 or more radio locations, spanning a period of at least 6 months. There was a significant relationship between home range size and total length, with sub-adults (1.5-2.5 m) occupying smaller, more localised home ranges than adults (>2.5 m). The largest home ranges were for adults (>2.5 m). Home ranges overlapped extensively, suggesting that territoriality, if present, does not result in spatially discrete home ranges of Nile crocodiles in Ndumo Game Reserve during the dry season. Larger crocodiles moved farther and more frequently than smaller crocodiles. The reserve acts as a winter refuge and spring breeding site for an estimated 846 crocodiles, which also inhabit the Rio Maputo during the summer months. Nile crocodile movement out of the reserve and into the Rio Maputo starts in November and crocodiles return to the reserve as water levels in the floodplain recede in May. Conservation implications: Movement patterns of Nile crocodiles show the important role the reserve plays in the conservation of Nile crocodile populations within the greater Ndumo Game Reserve-Rio Maputo area.

Molnar, J.L., Pierce, S.E., Bhullar, B.-A.S., Turner, A.H. and Hutchinson, J.R. (2015). Morphological and functional changes in the vertebral column with increasing aquatic adaptation in crocodylomorphs. R. Soc. open sci. 2: 150439.

Abstract: The lineage leading to modern Crocodylia has undergone dramatic evolutionary changes in morphology, ecology and locomotion over the past 200+ Myr. These functional innovations may be explained in part by morphological changes in the axial skeleton, which is an integral part of the vertebrate locomotor system. Our objective was to estimate changes in osteological range of motion (RoM) and intervertebral joint stiffness of thoracic and lumbar vertebrae with increasing aquatic adaptation in crocodylomorphs. Using three-dimensional virtual models and morphometrics, we compared the modern crocodile *Crocodylus* to five extinct crocodylomorphs: *Terrestrisuchus*, *Protosuchus*, *Pelagosaurus*, *Steneosaurus* and *Metriorhynchus*, which span the spectrum from terrestrial to fully aquatic. In *Crocodylus*, we also experimentally measured changes in trunk flexibility with sequential removal of osteoderms and soft tissues. Our results for the more aquatic species matched our predictions fairly well, but those for the more terrestrial early crocodylomorphs did not. A likely explanation for this lack of correspondence is the influence of other axial structures, particularly the rigid series of dorsal osteoderms in early crocodylomorphs. The most important structures for determining RoM and stiffness of the trunk in *Crocodylus* were different in dorsoventral versus mediolateral bending, suggesting that changes in osteoderm and rib morphology over crocodylomorph evolution would have affected movements in some directions more than others.

Shaker, N.A. and El-Bably, S.H. (2015). Morphological and radiological studies on the skull of the Nile crocodile (*Crocodylus niloticus*). Int. J. Adv. Res. Biol. Sci. 2(9): 149-162.

Abstract: The present study was conducted on six heads of the Nile crocodile (*Crocodylus niloticus*). The heads were removed from their bodies and prepared by hot water maceration technique. The bones of the skull were studied separately and identified by using a specific acrylic color for each bone. The cranium of the crocodile composed of the cranial bones and the facial bones. The crocodile had four paired paranasal sinuses; the antorbital, the vomerine bullar, the pterygopalatine bullar and the pterygoid sinuses. The mandible of crocodile formed from six fused bones (articular, angular, suprangular, coronoid, splenial and dentary). The X ray images were applied for identifying the paranasal sinuses which their contribution to the morphological organization of the head.

Strickland, B.A. (2015). Spatial ecology and population estimation of the American alligator (*Alligator mississippiensis*) in inland systems of Mississippi. MSc thesis, Mississippi State University, Mississippi, USA.

Abstract: Wildlife management and conservation frequently rely on understanding mechanisms that influence distribution and abundance of animals. I quantified space use for a population of inland riverine adult male alligators in Mississippi. Results indicated habitat selection is a scale-dependent process and aquatic vegetation, water depth, and water temperature may be important factors influencing alligator foraging and thermoregulation. Apparent habitat suitability and low alligator density did not manifest in an observed body size-based dominance hierarchy. I also analyzed long-term Mississippi alligator spotlight survey data for trends and effects of environmental covariates on counts. Model results indicated alligator counts have increased over time. This response likely reflects benefits accrued from decades of protection and wetland conservation. Distance sampling does not appear to be a feasible monitoring technique for riverine alligator populations. Nevertheless, it is important

that survey protocols and monitoring programs account for imperfect detection and model important covariates

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Kelly, M.L., Peters, R.A., Tisdale, R.K. and Lesku, J.A. (2015). Unihemispheric sleep in crocodilians? Journal of Experimental Biology 218: 3175-3178.

Abstract: Reduced vigilance is the conspicuous cost of sleep inmost animals. To mitigate against this cost, some birds and aquatic mammals have evolved the ability to sleep with one-half of their brain at a time, a phenomenon known as unihemispheric sleep. During unihemispheric sleep the eye neurologically connected to the 'awake' hemisphere remains open while the other eye is closed. Such unilateral eye closure (UEC) has been observed across avian and non-avian reptiles, but has received little attention in the latter. Here, we explored the use of UEC in juvenile saltwater crocodiles (1) under baseline conditions, and in the presence of (2) other young crocodiles and (3) a human. Crocodiles increased the amount of UEC in response to the human, and preferentially oriented their open eye towards both stimuli. These results are consistent with observations on unihemispherically sleeping cetaceans and birds, and could have implications for our understanding of the evolution of unihemispheric sleep.

Huang, Y., Dong, S. and Liu, Y. (2015). Effects of solvent polarity and acidity on the extraction efficiency and fatty acid compositions of oil from Nile crocodile. International Journal of Engineering and Advanced Research Technology 1(1):

Abstract: Crocodile oil extracted from the fatty tissues of crocodiles is rich in monounsaturated and polyunsaturated fats, which have high economic and medical values. The present study describes and compares the effects of polarity and acid of extraction solvents on the extraction efficiency and fatty acid compositions of crocodile oil extracted by six solvents extraction systems, which are the combinations of three polarity levels (75% CH_2Cl_2, 50% CH_2Cl_2 and 25% CH_2Cl_2) and two acidity levels (non-acidified and acidified). The oil extract was saponification with 0.5M KOH before re-suspected by n-hexane, and the fatty acid compositions of lipids was analyzed by gas chromatography-Mass Spectrometer (GC-MS). Analysis of variance (ANOVA) shows that solvent polarity not acidity of six extraction solvent systems has a significant effect on the oil yield. Different solvent systems could extract an obvious different type and amount of fatty acids compositions, which consisted of long carbon chains fatty acids. Among the six solvent systems examined, 50% CH_2Cl_2 + 46.7% methanol without acid was the best for extraction of oils from crocodile fat. DPPH antioxidation test indicated that crocodile oil extracted by solvent systems of 50% CH_2Cl_2 + 46.7% methanol without acid showed higher antioxidation activity (77.5%) than oil (56.0%) extracted by petroleum ether. The findings in this work are very helpful to screen the extraction solvent systems to extract the oil from crocodile organism.

Prasad, G.V.R., Sharma, A., Verma, O., Khosla, A., Singh, L.R. and Priyadarshini, R. (2015). Testudoid and crocodiloid eggshells from the Upper Cretaceous Deccan Intertrappean Beds of Central India. Comptes Rendus Palevol. 14(6-7): 513-526.

Abstract: Chelonian and crocodilian eggs and eggshells are relatively rare in the fossil record as compared to those of dinosaurs and avians. In India, prior to the present report, turtle eggshells have been reported from the supposed Late Cretaceous infratrappean beds of Duddukuru, Andhra Pradesh. Likewise, crocodilian eggshells were described from the intertrappean beds of Bombay whose assignment to Maastrichtian age is not based on any age diagnostic fossils. Here we report the first definitive Late Cretaceous turtle and crocodilian eggshells from the intertrappean beds of Kisalpuri, Dindori District, Madhya Pradesh (Central India). The testudoid eggshells from Kisalpuri, though broadly comparable to those of Duddukuru, particularly in radial structure, differ from each other in finer details such as external surface ornamentation and the organization of crystallites in the radial section. The crocodiloid eggshells from Central India are distinct from known fossil eggshells in having non-interlocking wedge-like crystallites and ringed craters on the basal plate groups. Keeping in view the limited fossil specimens available for the present study, the testudoid and crocodiloid eggshells from the Late Cretaceous of Central India are referred to the oofamilies Testudoolithidae and Krokolithidae, respectively.

Maijaroen, S., Anwised, P., Klaynongsruang, S., Daduang, S. and Boonmee, A. (2015). Comparison of recombinant α-hemoglobin from *Crocodylus siamensis* expressed in different cloning vectors and their biological properties. Protein Expression and Purification (doi:10.1016/j.pep.2015.09.028).

Abstract: Hemoglobin (Hb) is an important component in red blood cells of the vertebrate. It is a major respiratory protein with oxygen or carbon dioxide transport function. Hb has been reported to contain bioactive peptides which have antibacterial and antioxidant activities. In this study, the alpha hemoglobin chain (αHb) gene of *Crocodylus siamensis* was cloned into the three different expression vectors and expressed in *Escherichia coli* BL21 (DE3). The recombinant αHb proteins from all constructs could be expressed and purified. The result from UV-visible absorption spectra showed a similar pattern of all recombinant proteins to the oxy-hemoglobin form of intact hemoglobin. The different recombinant αHb could exhibit antioxidant activities. All recombinant proteins could inhibit the growth of *Bacillus* spp. Especially, most of the recombinant proteins could inhibit the growth of *B. amyloliquefaciens* TISTR 1045 better than intact one. The result obtained from this study can provide us further information about the possibility using of αHb as a supplementary food.

Jensen, B., Elfwing, M., Elsey, R.M., Wang, T. and Crossley, II, D.A. (2015). Coronary blood flow in the anesthetized American alligator (*Alligator mississippiensis*). Comparative

Biochemistry and Physiology Part A: Molecular & Integrative Physiology 191: 44-52.

Abstract: Coronary circulation of the heart evolved early within ectothermic vertebrates and became of vital importance to cardiac performance in some teleost fish, mammals and birds. In contrast, the role and function of the coronary circulation in ectothermic reptiles remains largely unknown. Here, we investigated the systemic and coronary arterial responses of five anesthetized juvenile American alligators (*Alligator mississippiensis*) to hypoxia, acetylcholine, adenosine, sodium nitroprusside, isoproterenol, and phenylephrine. We recorded electrocardiograms, monitored systemic blood pressure, blood flows in both aortae, and blood flow in a major coronary artery supplying most of the right ventricle. Coronary arterial blood flow was generally forward, but there was a brief retrograde flow during a ventricular contraction. Blood pressure was significantly changed in all conditions. Acetylcholine decreased coronary forward flow, but this response was confounded by the concomitant lowered work of the ventricles due to decreased heart rate and blood pressure. Coronary forward flow was poorly correlated with heart rate and mean arterial pressure across treatments. Overall changes in coronary forward flow, significant and not significant, were generally in the same direction as mean arterial pressure and ventricular power, approximated as the product of systemic cardiac output and mean arterial pressure.

Parlin A., Dinkelacker, S. and McCall, A. (2015). Do habitat characteristics influence American alligator occupancy of Barrier Islands in North Carolina? Southeastern Naturalist 14(1): 33-40.

Abstract: The geographic range of *Alligator mississippiensis* (American alligator) extends to North Carolina, where information on populations is limited. In North Carolina, American Alligators are found near the coast, but typically not on the extensive barrier-island chain known as the Outer Banks. The goal of our study was to determine if habitat varied among sites occupied by American alligators on island - the Outer Banks and Roanoke Island - and sites on the adjacent mainland. Water depth, variance in water depth, turbidity, salinity, conductance, and pH varied among sites on Roanoke Island from sites on the mainland (P= 0.008) and the Outer Banks (P= 0.001). However, sites on the mainland and the Outer Banks were similar (P= 0.536). Ultimately, American alligators may access the Outer Banks and find suitable habitat, but to date, little research has examined American alligator habitat use in this portion of its geographic range; long-term occupancy is probably limited by of the effects of human disturbance and major storm events.

Temple, B.L., Finger, Jr., J.W., Jones, C.A., Gabbard, J.D., Jelesijevic, T., Uhl, E.W., Hogan, R.J., Glenn, T.C. and Tompkins, S.M. (2015). In ovo and in vitro susceptibility of American alligators (*Alligator mississippiensis*) to avian influenza virus infection. Journal of Wildlife Diseases 51(1): 187-198.

Abstract: Avian influenza has emerged as one of the most ubiquitous viruses within our biosphere. Wild aquatic birds are believed to be the primary reservoir of all influenza viruses; however, the spillover of H5N1 highly pathogenic avian influenza (HPAI) and the recent swine-origin pandemic H1N1 viruses have sparked increased interest in identifying and understanding which and how many species can be infected. Moreover, novel influenza virus sequences were recently isolated from New World bats. Crocodilians have a slow rate of molecular evolution and are the sister group to birds; thus they are a logical reptilian group to explore susceptibility to influenza virus infection and they provide a link between birds and mammals. A primary American alligator (*Alligator mississippiensis*) cell line, and embryos, were infected with four, low pathogenic avian influenza (LPAI) strains to assess susceptibility to infection. Embryonated alligator eggs supported virus replication, as evidenced by the influenza virus M gene and infectious virus detected in allantoic fluid and by virus antigen staining in embryo tissues. Primary alligator cells were also inoculated with the LPAI viruses and showed susceptibility based upon antigen staining; however, the requirement for trypsin to support replication in cell culture limited replication. To assess influenza virus replication in culture, primary alligator cells were inoculated with H1N1 human influenza or H5N1 HPAI viruses that replicate independent of trypsin. Both viruses replicated efficiently in culture, even at the 30C temperature preferred by the alligator cells. This research demonstrates the ability of wild-type influenza viruses to infect and replicate within two crocodilian substrates and suggests the need for further research to assess crocodilians as a species potentially susceptible to influenza virus infection.

Abu-Zidan, F.M. (2015). Crossroad between camel bites and crocodile bites. African Health Sciences 15(2): i-iv.

Reber, S.A., Nishimura, T., Janisch, J., Robertson, M. and Fitch, W.T. (2015). A Chinese alligator in heliox: formant frequencies in a crocodilian. J. Exptal. Biol. 218: 2442-2447.

Abstract: Crocodilians are among the most vocal non-avian reptiles. Adults of both sexes produce loud vocalizations known as 'bellows' year round, with the highest rate during the mating season. Although the specific function of these vocalizations remains unclear, they may advertise the caller's body size, because relative size differences strongly affect courtship and territorial behaviour in crocodilians. In mammals and birds, a common mechanism for producing honest acoustic signals of body size is via formant frequencies (vocal tract resonances). To our knowledge, formants have to date never been documented in any non-avian reptile, and formants do not seem to play a role in the vocalizations of anurans. We tested for formants in crocodilian vocalizations by using playbacks to induce a female Chinese alligator (*Alligator sinensis*) to bellow in an airtight chamber. During vocalizations, the animal inhaled either normal air or a helium/oxygen mixture (heliox) in which the velocity of sound is increased. Although heliox allows normal respiration, it alters the formant distribution of the sound spectrum. An acoustic

analysis of the calls showed that the source signal components remained constant under both conditions, but an upward shift of high-energy frequency bands was observed in heliox. We conclude that these frequency bands represent formants. We suggest that crocodilian vocalizations could thus provide an acoustic indication of body size via formants. Because birds and crocodilians share a common ancestor with all dinosaurs, a better understanding of their vocal production systems may also provide insight into the communication of extinct Archosaurians.

Woodward, H.N., Freedman Fowler, E.A., Farlow, J.O. and Horner, J.R. (2015). Maiasaura, a model organism for extinct vertebrate population biology: a large sample statistical assessment of growth dynamics and survivorship. Paleobiology (http://dx.doi.org/10.1017/pab.2015.19).

Abstract: Fossil bone microanalyses reveal the ontogenetic histories of extinct tetrapods, but incomplete fossil records often result in small sample sets lacking statistical strength. In contrast, a histological sample of 50 tibiae of the hadrosaurid dinosaur *Maiasaura peeblesorum* allows predictions of annual growth and ecological interpretations based on more histologic data than any previous large sample study. Tibia length correlates well (R^2>0.9) with diaphyseal circumference, cortical area, and bone wall thickness, thereby allowing longitudinal predictions of annual body size increases based on growth mark circumference measurements. With an avian level apposition rate of 86.4 μm/day, *Maiasaura* achieved over half of asymptotic tibia diaphyseal circumference within its first year. Mortality rate for the first year was 89.9% but a 7-year period of peak performance followed, when survivorship (mean mortality rate=12.7%) was highest. During the third year of life, *Maiasaura* attained 36% (x= 1260 kg) of asymptotic body mass, growth rate was decelerating (18.2 μm/day), cortical vascular orientation changed, and mortality rate briefly increased. These transitions may indicate onset of sexual maturity and corresponding reallocation of resources to reproduction. Skeletal maturity and senescence occurred after 8 years, at which point the mean mortality rate increased to 44.4%. Compared with *Alligator*, an extant relative, *Maiasaura* exhibits rapid cortical increase early in ontogeny, while *Alligator* cortical growth is much lower and protracted throughout ontogeny. Our life history synthesis of *Maiasaura* utilizes the largest histological sample size for any extinct tetrapod species thus far, demonstrating how large sample microanalyses strengthen paleobiological interpretations.

Böhmer, C., Rauhut, O.W.M. and Wörheide, G. (2015). New insights into the vertebral Hox code of archosaurs. Evolution & Development 17(5): 258-269.

Abstract: Variation in axial formulae (ie, number and identity of vertebrae) is an important feature in the evolution of vertebrates. Vertebrae at different axial positions exhibit a region-specific morphology. Key determinants for the establishment of particular vertebral shapes are the highly conserved Hox genes. Here, we analyzed Hox gene expression in the presacral vertebral column in the Nile crocodile in order to complement and extend a previous examination in the alligator and thus establish a Hox code for the axial skeleton of crocodilians in general. The newly determined expression of HoxA-4, C-5, B-7, and B-8 all revealed a crocodilian-specific pattern. HoxA-4 and HoxC-5 characterize cervical morphologies and the latter furthermore is associated with the position of the forelimb relative to the axial skeleton. HoxB-7 and HoxB-8 map exclusively to the dorsal vertebral region. The resulting expression patterns of these two Hox genes is the first description of their exact expression in the archosaurian embryo. Our comparative analyses of the Hox code in several amniote taxa provide new evidence that evolutionary differences in the axial skeleton correspond to changes in Hox gene expression domains. We detect two general processes: (i) expansion of a Hox gene's expression domain as well as (ii) a shift of gene expression. We infer that the ancestral archosaur Hox code may have resembled that of the crocodile. In association with the evolution of morphological traits, it may have been modified to patterns that can be observed in birds.

Kanhere, E., Wang, N., Asadnia, M., Kottapalli, A.G.P. and Miao, J.M. (2015).Crocodile inspired Dome Pressure sensor for hydrodynamic sensing. Pp. 1199-1202 *in* 18th International Conference on Solid-State Sensors, Actuators and Microsystems (TRANSDUCERS). IEEE: Anchorage.

Abstract: This work is inspired by the 'Dome Pressure Receptors' (DPRs), which are scattered on the skin of crocodiles, assisting them to locate the origin of disturbance, both on water surface [1] and inside the water [2]; thereby enabling them to hunt preys even in dark environment and turbid waters. In this study, a dome structure embedded with piezoelectric pressure sensors is constructed, which carries out the mechano-receptive function of DPRs for direction detection. The experimental results demonstrate that the proposed dome structure could determine the direction of the origin of a disturbance.

Ukpong, E.E., Eniang, E.A., Owoh, P.W. and Ekpo, I.J. (2015). The requirements and prospects for commercial crocodile farming industry in Nigeria. Journal of Forestry, Environment and Sustainable Development 1(1): 80-85.

Abstract: Crocodiles are valued mostly for their skin products such as designer belts, shoes, boots, handbags, purses, wallets and briefcases. Skins are also manufactured into headbands, wristbands, guitar straps, trophy and other products. Crocodiles are farmed for their meat which is very low in cholesterol. Other body parts are primed for the tourist trade and these include heads, skulls, teeth, backscratchers, key tags or entire taxidermically prepared animals. This study was aimed at enlightening people on the need to go into crocodile farming since it has almost been hunted to extinction. The study addressed among other things the problems of lack of awareness by farmers on the potentials and benefits of crocodile farming and the large global market for crocodile products. The problems and prospects for crocodile farming in Southern Nigeria were highlighted. The requirements for

managing a commercial crocodile farm include construction of a pond to provide for 4 m^2 space for a single adult crocodile and 1 m^2 space for a young one. Water demand is not less than 25,000 l/year/skin. Young crocodiles in captivity require control environment until they are a year old to do well. Climate is very important because temperature and humidity determine its fertility. Temperature for its survival must be 30-35°C. Temperature at 32°C and 99% humidity produce crocodile's maximum fertility. In natural environment, crocodile fertility rate is 80% but in farm condition fertility rate is 60%. Young crocodiles require about half a kg of meat per month while adult ones require about half a kg of meat every day. The authorization for this farming is obtained from the Ministry of Environment, while a minimum size area of 6 ha and about 15 well trained staff members are required. To process and export crocodile skin, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) permits and tags must be obtained. China is the largest buyer of crocodile meat. Other major buyers of crocodile products are Australia, America, Europe and other developed countries, while 90% of world market is controlled by Australia and Papua New Guinea. America, South Africa and Zimbabwe are major sellers. The problems of this farming include: feeding habit as carnivore and long maturity period, low technical knowhow, low capital base, scarcity of large area of land and poor market profile awareness. The prospects for crocodile farming in Nigeria include a warm favourable climate in terms of temperature, high humidity and adequate water supply, available labour, ready market and social acceptability.

Thomadakis, C. (2015). The Mechanisms of Continuous Tooth Replacement in The Nile Crocodile (*Crocodylus niloticus*). PhD thesis, University of the Witwatersrand, Johannesburg, South Africa.

Abstract: It is recognised that tooth loss as a consequence of oral diseases affects quality of life in humans. This has directed studies towards biological tooth replacement in vivo. In humans and other mammals, tooth replacement occurs only once (diphyodonty) as opposed to non-mammalian vertebrates where tooth replacement continues throughout life (polyphyodonty). Detailed knowledge of tooth initiation, development and morphology amongst vertebrates and especially amniotes, is necessary to understand the tooth replacement process. Crocodilians provide an interesting model for tooth replacement studies as they also exhibit thecodonty. Regulation of polyphyodonty has not been genetically defined, and it is uncertain whether the molecular mechanisms of continuous tooth replacement are similar to those involved in the primary dentition. The aim of this study was therefore to analyse crocodilian odontogenesis in detail, with the aid of light microscopy and CT scans, in order to provide a structural framework for molecular processes regulating polyphyodonty. Crocodile probes to bmp4 and pitx2 were designed, generated and labelled for use in *in situ* hybridisation. The expression patterns of pitx2 and bmp4 in embryos and hatchlings of the polyphyodont Nile crocodile (*Crocodylus niloticus*) were examined at different stages of tooth development. Histologically crocodilian tooth development appears similar to mammals. Interesting variations include the initiation of odontogenesis in the ectomesenchyme, the presence of dental placodes, the 'null generation teeth', the two different bell-stage tooth germs and the tooth-family organisation. A direct 1:1 relationship between the status of the erupted tooth and the developmental phase of the replacement tooth was not seen. However in more mature teeth, the replacement tooth germs were at a more advanced developmental stage than those associated with less mature teeth. Molecular data revealed that pitx2 was expressed in the oral epithelium and the dental placode. Bmp4 expression was not evident in the dental placode, but was localised in the odontoblasts of early bell stage tooth germs.

Hastings, A.K. and Hellmund, M. (2015). Rare *in situ* preservation of adult crocodylian with eggs from the middle Eocene of Geiseltal, Germany. Palaios 30(6): 446-461.

Abstract: Parental care is found in all extant archosaurs (crocodylians and birds) and parsimony suggests this behavior is homologous. There are known 'parent atop eggs' fossils of nonavian theropod dinosaurs (ancestors to birds), but no equivalent fossil for crocodylians has been reported yet within this context. Here we present a remarkable fossil of an adult crocodylian (*Diplocynodon darwini*) preserved *in situ* with eggs from the middle Eocene of Geiseltal, Germany, providing the first-reported evidence for the antiquity of parental care in the crocodylian lineage. The degree of articulation, the unusual curled posture of the adult, the position of the eggs, and the surrounding sediment indicate the adult may have died atop its nest after oviposition. Size relationships between the adult and eggs are consistent with values from modern related taxa and no other crocodylian was found within 12 m of the eggs. Thorough documentation of fossil vertebrate skeletons collected near the fossil crocodylian does not indicate flow influenced its curled posture. Despite being sexually mature, the adult crocodylian did not exhibit full fusion of the neurocentral sutures, an indicator of immaturity in nonavian archosaurs. Even in a paratropic environment, temperatures may temporarily drop below cold tolerance for warm-adapted crocodylians, possibly explaining the death of the adult and the young inside the eggs. Although still indicating egg attendance, the fossil may alternatively indicate the mother died from dystocia (egg-binding) during oviposition, which would be to our knowledge the first published record of this rare phenomenon in a fossil archosaur.

Submitted Publications

LOLONG AND THE CARTILAGE RINGS IN CROCODILIAN WINDPIPES. Back in the early and middle 1800s there was considerable scholarship concerning the anatomy of the crocodilian windpipes system (especially regarding its bending or not). However, because the problem is a mixture of ontogenetic and taxonomic variations mixed variously together, there remains considerable room for new data and improved understanding regarding the bends and reversals and even a proper loop that can happen in

the trachea and syrinx and exposed bronchial tubes, and in some cases these deviations from straight and direct can be relatively absent.

The greatest weakness in our understanding of shape and course (path or route) variation in the windpipes of the living crocodilians is due to the numerical smallness of the taxonomic and comparative age samples available to the early French and then also early English and German comparative anatomists concerned with the reptilian and avian respiration system (Ross 2014). Further, some of the old data involved obscure synonyms and at least one prominent nomenclatural confusion at the genus level (Ross and Ross 2004).

One of the early anatomists concerned with the straightness versus bendy windpipes question, Heinrich Rathke, also investigated the number and development of the cartilage rings that are arranged mostly parallel to each other and at regular intervals all along the tracheal and bronchial tubes. These individual rings encircle the airway and serve the function of holding the windpipes open, and although the cartilages are purposefully stiff, the membrane spaces between them are very flexible. The general rule is that each of the tracheal and bronchial cartilage rings is discrete, meaning that one ring does not physically contact another, but occasional irregularities where two rings become connected can sometimes occur, and perhaps especially in the syrinx region.

The data from Rathke (1866) concerning the numbers of rings in the tracheal tube, and the results for the exposed left bronchus versus the exposed (outside of the lung) right bronchial tube, was the subject of Ross and Ross (2004), and the important thing is that taxonomic variation in both tracheal and bronchial rings numbers seems to perhaps (but if so then sometimes awkwardly) happen, but in many cases advanced embryos and very young hatchlings were being compared with dissections of various larger carcases, including some full grown adults. Unfortunately the taxonomic identities of Rathke's germane material is not necessarily trustworthy, because there was a tendency for anatomists to only receive permission to destructively take apart a crocodilian specimen when the animal in question was not of value for its normal external appearances, and often the reason for a specimen being of little value was its lack of proper provenance. It was often (and in many museums remains to this day) the accepted practice that specimens with faulty or deficient data were possibly okay for dissections, as were carcases missing their head and/or skin.

It is often difficult to identify an embryo in alcohol to species because the animal is so small and not yet fully formed. The appearance (certain aspects of head shape and dentition, and some details of the disposition of scales and bony scutes in the skin, and coloration) can differ significantly between the hatchling and its parents. Thus, for all of the above reasons, I today propose that people at crocodilian farms and abattoirs that have clearly taxonomically identified (known genetics) stock and that have all of the sizes of life available for study, should set aside Rathke (1866) and all of its reiterations (see Ross and Ross 2004) concerning the numbers and development of the cartilage rings in the exposed windpipes system in the living Crocodylia, and then start and begin and embark on a new modern study with significantly larger samples (statistically relevant this time) and more trustworthy and detailed taxonomic identifications.

The old German texts are often not easy to read, and there are some specialist's language problems, for example involving the difference between the part of the bronchial tube that is outside of the lung, compared with the part of the same tube that is inside the lung. Further, the syrinx is seldom detailed, and there are different degrees of completeness and discreetness in and among the cartilage rings that are easy to overlook or get confused about, especially when embryos, neonates, half-growns and adults are being discussed on the basis of often a sample of remarkably few individuals.

The Rathke (1866) study is today sufficient as a framework of questions that still deserve our attention. The Rathke (1866) results are in some cases and details untrustworthy, but he did establish that at least some taxa at some ages exhibit incomplete rings (approximately six of them) immediately adjacent to the larynx. These anteriormost six tracheal cartilages are each mostly present and are regularly spaced, but the circular or oval shape of the cartilage ring is missing its dorsal curved and connecting section. The dorsal gaps in the anterior-most six or so tracheal cartilages form a progressive series from broadest gap at the larynx end, and then regularly narrowing to nearly complete (nearly no gap) by the 6th ring away from the larynx. There is very little recorded about these incomplete cartilage rings, perhaps because the view in an animal when being skinned for its leather (or in classroom dissection) is the ventral view when the throat skin is removed. The incomplete rings look the same as the complete rings in ventral view.

Concerning the six or so tracheal rings (closest to the larynx) that have dorsal gaps in them, surely taxonomic variation deserves testing, and presuming that this zone of special incomplete cartilages at the anterior end of the trachea is an adult character, then the next theoretical question concerns whether or not this same special (limited to six or so rings) dorsal tracheal surface zone also occurs in all juveniles and all advanced embryos. Further, it raises the question of whether all very early embryos lack the cartilage rings throughout the whole (bronchi, syrinx, trachea) windpipes, but the advancing embryo develops them as time passes. It deserves knowing if there is any age (in any taxon) at which more than the anterior six (and theoretically including meaning all) tracheal cartilages are incompletely formed in the living Crocodylia, and if so it then becomes interesting to know at what age the complete rings (in contrast to the incomplete anterior half dozen or so, as applicable) become complete, and does the cartilage building process start happening at the posterior end, or is it initiated at the anterior end, or do all of these germane cartilages develop and grow evenly throughout the whole trachea? The same question applies to the bronchi, and even the syrinx.

At the posterior end of the trachea there should theoretically be a cartilage ring that is purely and properly tracheal and

its neighbour is a cartilage ring inside the structure called the syrinx, which is a continuation of the single tracheal windpipe that bifurcates inside the syrinx into two pipes that exit and leave from the syrinx. The syrinx is a Y-shaped junction in which one tracheal tube leaves at the direction toward the larynx, versus (and in the opposite direction) two bronchial tubes that leave and proceed on their paths that will terminate at the lungs. The distinction between the tracheal number versus the bronchial number in Rathke (1866) and his followers has generally ignored the syrinx, and there are relatively few (if any) details in the crocodile literature about exactly where the syrinx starts and stops. However, there is nothing preventing modern students from defining the windpipes as four external zones (larynx, trachea, syrinx, exposed bronchi), and a fifth zone (the internal and not exposed bronchial tubes) in the lungs. The crocodilian syrinx, to be comparable with that of birds, must have a length and have a tracheal end that is separated from its bronchial end.

The actual way that either one (or both) of the external bronchial tubes enters the lung (and becomes an internal ring number) is often confounding because the distinction is irregular, and thus the task of deciding which ring is the last at the posterior end of each external bronchial tube is not always satisfying. It might also sometimes be just a little tricky and even difficult to say precisely which ring is actually the last in the syrinx, versus individually the first in either of its two bronchial continuations.

The syrinx is the traditionally uncounted and overlooked part of the externally visible cartilage rings component in the crocodilian windpipes system from the larynx to the lungs. Remarkably little has been said about the distinction between the anterior end of the syrinx versus the posterior end of the trachea, but perhaps it is obvious when a person looks at this distinction line between the tracheal rings zone and the separate zone of the comparable cartilages of the syrinx. Alternatively one could ignore the syrinx and just count rings until the single (one) pipe series stops, and the double (two) pipes series begins. This is possibly what Rathke and his contemporaries did, and for pragmatic reasons I find myself (below) adopting the one pipe versus two pipes simplistic dichotomy, and thus accomplish the putting of the greatest unknowns (special predictable problems and added difficulties) at the end, as opposed to the beginning of each counting of windpipes rings.

Closest to the crocodilian's nose and mouth, the larynx is technically part of the windpipes system, but it lacks the cartilage rings phenomenon that characterizes the trachea and the bronchi most obviously, and to some degree the syrinx also has a series of regularly spaced structural cartilages that hold the air passage open. There is a fairly obvious distinction between the posterior end of the larynx versus the anterior end of the trachea, and thus the part of the windpipe that is purely tracheal is fairly well defined (when the syrinx is clearly seen and distinguished from it). In contrast, the Rathke (1866) data in Ross and Ross (2004) suggests variation between the left and right bronchi, as would be expected because of the ambiguity at the posterior end of each exposed (external) bronchus as it becomes enveloped by an overlapping development of expanded lung tissue.

Further recommending the tracheal rings counts, compared with alternatively bronchial rings counts, is the simple size and ease of accessibility factor. The trachea is easiest to count the rings on, and the trachea is the region in which the special sharp bendings and convolutions including a proper loop can occur. The syrinx and the bronchi tend to be more conservative with regard to their positions because they are closest to the lungs, but it deserves comment that the anterior end of the trachea (near where it joins with the larynx) is also conservative in its position within the body. The region where the greatest variation in the degree of convolutedness happens is closer to the syrinx than to the larynx (Ross 2014).

It is tempting to assume that convoluted tracheas are longer than relatively straight ones in animals that are the same size as each other, but that hypothesis remains untested, and the technical and philosophical problems involved with measuring tracheal length still need work, and in my opinion things are not yet clear enough for measurements of length to be reliably repeatable (but I encourage someone to tackle this basic question of neck length versus straightish tracheal length versus convoluted tracheal length). Is proportional neck length (versus whole animal length, or whatever) a variable in the living Crocodylia? Should we measure along the insides or outsides of bends? In an individual animal specimen, what is the difference between the shortest possible straight line, versus the actual strongly bent and even wildly transversely convoluted route sometimes present?

However, an easier hypothesis to test is that high numbers of tracheal rings correlate with high degrees of convolutedness (at least in the adult). In this case it is convolutedness that is the variable, because Rathke (1866) and his followers tell us that the number of tracheal rings (complete and incomplete combined as appropriate) does not change during the course of the crocodilian's (at least air breathing) life. This is yet another hypothesis to be tested today with improved samples.

It was classically understood that in any individual crocodilian trachea the diameter and thickness of the cartilage rings is overwhelmingly constant through its whole length (from the larynx to the syrinx), and that the spacing between the rings is also remarkably regular. However, it is obvious that the rings (those that are complete, and also the approximately six special incomplete rings when present) are smaller in smaller animals, versus larger in larger animals. The rings surely grow in size, but apparently not in number.

Recently the Toledo *et al*. (2009) dissection of an extra large crocodile revealed the intuitively understandable fact that when and where its (Lolong's) trachea made particularly sharp (hairpin or horseshoe) bends, there was an associated added thickening and strengthening of the already existing cartilage rings. This newly noticed phenomenon of differentially thickened tracheal cartilage rings distributed in small zones where sharp bends occur now creates a need for a numbering system from one end or the other. My suggestion is away from the larynx for the trachea and its associated single-tube part of the syrinx, and similarly away from the

syrinx on each bronchus going toward the lungs. There could be a total number of single-tube rings, and each of them has a name (its number counting from anterior to posterior). This method is purely pragmatic, and based on the clarity of the larynx versus trachea distinction, and similarly there is a certain amount of clarity about where the bifurcation (into the bronchi) has happened.

The exciting new development in the study of crocodilian respiratory systems, especially the trachea and syrinx and bronchial windpipes spanning the gap between the larynx and the lungs, is that every animal that accidentally dies at a crocodilian captive breeding or rearing program, and every commercial sized animal killed for its skin, and meat also, are all potential sources of data. It is no longer necessary to beg scraps at systematics collections where so often only inferior material is available for destructive dissection.

The count of single tube windpipe rings, and the average between the two exposed bronchi, and some notes and pictures about the syrinx (where does it start, where does it stop, and is it irregularly ringed), and similar detailed attention to regions of increased thickening associated with strong bending (the Lolong phenomenon) are needed, and today can be easily taken from a very large and taxonomically diverse sample, and at various ontogenetic ages as well.

Isolated tracheas that have been destructively cut out of the body for storage (in alcohol, formaldehyde, frozen or possibly salted) or immediate examination should have enough of the larynx to include at least part of the glottis, because the lengthwise glottal slit of the muscle adjusted connection (opening) between the pharynx and the larynx faces up and is visible only in dorsal view. It is important to remember that the glottis is on the side in which the six (or possibly five) incomplete rings are at least sometimes reported as present at the anterior end of the trachea. Similarly, the posterior end of the recovered isolated tracheal specimen should include the whole syrinx and beyond it as much of the external bronchi as is convenient to clearly record and show the angle of divergence at (and immediately posterior to) the posterior end of the syrinx. Sometimes the bronchi are close to parallel with each other (and may even physically gently touch each other for a while), while in other examples (taxa and or ages) the two bronchial tubes diverge immediately from each other, and are quickly widely spaced and headed in different directions.

In the end, the external bronchial rings, if they are to be counted and given identifying numbers (anterior to posterior for practical reasons), then some definitions are needed, such as perhaps the bronchial series starts with the first completely discreet ring posterior to the syrinx, and perhaps each of the two external bronchi stops at the last completely visible ring before the lung tissue conceals it, partly and irregularly at first. This is at least repeatable, and the number of external bronchial rings is apparently individually and taxonomically variable, but currently (based on old data) believed to be constant throughout life after hatching (and at least a while before, in the egg).

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EVEN *CROCODILUS* MERCK, 1785, DESERVES A TYPE SPECIES. Some of the various I-spelling genus-group names *Crocodilus* are based on the Nile crocodile of Egypt and are thus functionally equal to the Y-spelling genus *Crocodylus* Laurenti, 1768, which has *C. niloticus* Laurenti, 1768, as its type species. The two original syntypes of *Crocodylus niloticus* Laurenti, 1768, represented to him (in 1768) the copulatory male and female that had been famously written about by Martyr (1511) in his book about time spent, and about local stories (including one natural history misinformation about crocodiles having sex in the "missionary" position) that he heard while in Cairo and surrounding Egypt. We know the story from Peter Martyr's (1511) "Babylonian Legatien" book (in Latin) in the English translation and paraphrase on page 688 in Edward Topsell (1658).

Unfortunately the two illustrations that were listed as being *C. niloticus* by Laurenti (1768) are clearly not from Africa, and thus an awkwardness has existed for centuries in which everyone has known that the two germane figures (#3 and #4) in Seba's plate 105 (and today importantly their newly known actual specimens in European museums) are really *Paleosuchus* smooth fronted caimans from South America (we think that both are *P. trigonatus*). It is absolutely certain that Josephi Nicolae (Josephus Nicolaus) Laurenti's (1768) species-group name *C. niloticus* was not intended to have South America as its type locality (which the museum specimen in Berlin and the other in Paris both newly demand). Rather, the *Crocodylus niloticus* binomen currently on the CITES list is based on the Martyr (1511) misinformation (about the male and female during and immediately following sex) in a story heard by him concerning one boat of sailors and their encounter with a pair of copulating adult crocodiles

on a temporary sandy island in the Nile River (possibly somewhere near Luxor).

We hope that the ICZN soon decides to set aside the two *Paleosuchus* individuals and then immediately replaces them with a neotype of *Crocodylus niloticus* Laurenti, 1768, which we currently and actively recommend should (in the best interests of parsimony and the preservation of general and common sense) be the individual specimen (or in this case its famous published picture) that we and the germane part of history have taken to be the lectotype of *Crocodilus vulgaris* Cuvier, 1807. This would be a good thing (preserving the predominant assumption of established usage), because when and if *Crocodylus niloticus* (the type species of *Crocodylus* Laurenti) and *Crocodilus vulgaris* (the type species of *Crocodilus* Cuvier) are both based on the same picture from 1807, then the two genus-group names (as those two historically important combinations) will become absolute synonyms because they actually share the exact same individual type specimen (the *niloticus* neotype equals the *vulgaris* lectotype), and of course also its wild from the Nile River individual provenance, which is wild (at the time when Napoleon's army and scientists were there) near modern Luxor and ancient Thebes, Egypt.

Older than *Crocodilus* Cuvier, 1807, is *Crocodilus* Latreille, 1801, which also has the Nile crocodile of Egypt as its basis explicitly and individually and in total agreement with and following the now (since an ICZN action in 2005) suppressed *Crocodilus* Lacépède, 1788, whose historical precedence should deservedly be inherited by Latreille (1801). Thus, we think of Lacépède's (1788) or more technically correctly Cepède's (1788) today suppressed *Crocodilus* as functionally (the same basic idea) equaling the today still available *Crocodilus* Latreille, 1801, and further we simultaneously and in hindsight today recognize that in 1801 and in 1807 the famous *Crocodilus* of Cepède or Lacépède (1788) was common knowledge as based on the Nile River crocodile in Egypt. Thus, Cuvier (1807) is in agreement with the tradition of the Y-spelled *Crocodylus* of Laurenti (1768) being the Nile River, and of the I-spelling *Crocodilus* from Latreille (1801) being also the Egyptian Nile.

Except that each of them is a forgotten name (nomen oblitum) that has not been actively employed during modern times, there additionally are three more available I-spelled *Crocodilus* genera that are temporally younger than Cepède (1788), and yet also chronologically older than Cuvier (1807). They are *Crocodilus* Bonnaterre, 1789 (a forgotten name based on Seba's problematical plate 106, which has long been unidentifiable); *Crocodilus* Gmelin, 1789 (when corrected from "*Crocodili*" to *Crocodilus*, a forgotten name spelled exactly the same as in the 10th edition of Linnaeus, and based on *Lacerta crocodilus* Linné, 1758, which is today a spectacled caiman from South America); and *Crocodilus* Schneider, 1801, the spectacled caiman of the coastal zone of the Suriname region (for all intents and purposes based on *Crocodilus sclerops* Schneider of 1801, which taxonomically equals the older *Lacerta crocodilus*, and is today actively employed as *Caiman crocodilus*).

The lectotype specimen of *Lacerta crocodilus* Linnaeus, 1758, is in a museum in Sweden. This specimen was individually designated on page 379 in Hoogmoed and Gruber (1983), and it is a common spectacled caiman without locality data, but (in our opinion and in general consensus) almost surely from the Atlantic coast of South America, and very probably from the Dutch colony of Suriname. We caution that the combination *Jacaretinga crocodilus* might be today recommended for this taxon that CITES currently regulates as *Caiman crocodilus* (Linnaeus, 1758), depending on the genetic affinities of the type species of the genus *Caiman*, namely *Caiman latirostris*.

In addition to the two kinds of *Crocodilus* detailed above (those that are based on the crocodile of the Nile in Egypt, versus those others that are alternatively based on the common spectacled caiman of the northeastern coastal part of South America), we have found a third basic kind of I-spelling *Crocodilus* as a genus-group name, and this time (accomplished below) it is based exclusively and individually on today's *Gavialis gangeticus*. Thus, the alligators group, the crocodiles group, and also the gharial (gavial) have had their own individual genus-group name *Crocodilus* with the I-spelling and based on their own individual selves: *Caiman* or *Jacaretinga crocodilus* is an alligator (Alligatoridae, Caimaninae), *Crocodylus niloticus* and *Crocodilus vulgaris* are the most true crocodile (Crocodylidae, Crocodylinae), and *Gavialis gangeticus* is the true Asian gharial. Obviously *Crocodilus gangeticus* Merck, 1785, is older than the famous and long popular *Crocodilus* of Cepède (1788), and simultaneously the 1785 name is younger than the currently employed *Crocodylus* Laurenti, 1768. The 1768 Y-spelling has temporal (time) precedence over all of the I-spelling *Crocodilus* genera from 1785 to 1807 that are available.

In summary and involving our making a nomenclatural action, in addition to Laurenti's (1768) *Crocodylus*, there are also *Crocodilus* Merck, 1785; *Crocodilus* Bonnaterre, 1789; *Crocodilus* Gmelin, 1789; *Crocodilus* Schneider, 1801; and *Crocodilus* Latreille, 1801, that are available genus-group names, but of these five, only Latreille's (1801) is not today actually a forgotten name, because *Crocodilus* Latreille, 1801, is here explicitly protected by us for the purpose of actively replacing the recently lost *Crocodilus* of Lacépède and its historically important concept of a Nile crocodile genus that is written with the letter-I as a correction of Laurenti's letter-Y spelling.

Also, there have existed the rejected and suppressed names *Crocodilus* Gronovius, 1756 (earlier than 1758); *Crocodilus* Bertrand, 1763 (not binominal); *Crocodylus* Gronovius, 1763 (same as 1756); *Crocodilvs* Meuschen, 1778 (V-spelled, and the work was not binominal); *Crocodilus* Cepède, 1788 (failure to apply the principle of bimoninal nomenclature); and lastly *Crocodilus* Browne, 1789 (repeats his own unavailable 1756 science, and further is not properly binominal).

From a scholarly suite of secondary sources, and with circumstantial evidence supporting and in agreement (the science of later works based on earlier ones), we are convinced that Bonnaterre (29 August) was published

earlier than Gmelin (20 November) in 1789, and we also believe that Schneider (August) was before Latreille (September-October), who was in turn before Daudin (17 December) in 1801. Thus, the total chronological listing is today understood as follows: *Crocodilus* Gronovius, 1756 (unavailable); *Crocodilus* Bertrand, 1763 (unavailable); *Crocodylus* Gronovius, 1763 (unavailable); *Crocodylus* Laurenti, 1768 (available and in current usage universally); *Crocodilvs* Meuschen, 1778 (unavailable); *Crocodilus* Merck, 1785 (available); *Crocodilus* Cepède, 1788 (newly unavailable and suppressed as of 2005); *Crocodilus* Browne, 1789 (unavailable); *Crocodilus* Bonnaterre, 1789 (available); *Crocodilus* Gmelin, 1789 (available); *Crocodilus* Schneider, 1801 (available); *Crocodilus* Latreille, 1801 (available), and lastly and today very importantly *Crocodilus* Cuvier, 1807. It is also true that Daudin (1801) and many other germane works have variously (including secondarily, and whether attributed or not) employed either one or another of the above listed available names.

The type species of *Crocodilus* Cuvier, 1807, was designated on page 35 (Loricata, Crocodili) by Fitzinger (1843) to be *C. vulgaris*, and this Cuvier (1807) species-group name has long (since 1836) been recognized in an informal yet consistent and explicit fashion as having the 1807 published picture of a Nile River adult as its lectotype. In contrast, the type-species of *Crocodilus* Merck, 1785, is not the Nile crocodile (nor the Suriname and Guiana region's common spectacled caiman), but rather is clearly the remarkably long and slender snouted Gharial (gavial, the adult male has the special fleshy "ghara" structure sticking up and surrounding its external nostrils) of the Ganges River in Asia. We find it notable and significant that Merck (1785) translated the English text of Edwards (1756) to German. From this, in our opinion and in good faith, it follows that the words and the suite of highly reliable pictures of today's *Gavialis gangeticus* in Edwards (1756) are the best (earliest and most informative and most famous) physical example of the eponym of the species-group name *Crocodilus gangeticus* Merck, 1785, which refers to the Ganges River distributary (Kolkata, West Bengal, India) provenance of the three Edwards (1756) babies, of which one was illustrated, and (based on our explicit inquiries to the curators of numerous natural history collections in England) all are today presumed lost.

There were two species in the proposition of *Crocodilus* Merck, 1785. One was prominently *C. gangeticus* and obviously based significantly on the Edwards (1756) animals from the Hooghly River in West Bengal, India. The River Hooghly (or Hugli or Hoogli) flows through Calcutta (today Kolkata), and this Hindu holy flow is the westernmost distributary stream of Ganges River water. In Germany there were several Asian Gharial physical specimens with Bengal provenance personally and directly known to Merck (1785). His other 1785 species, *C. longirostris*, denoted some fossils (eg Whitby in Yorkshire, English material from the literature) that merely resemble the modern Gharial, but are not *G. gangeticus* (and are not the so-called Senegal gavial either). There is no doubt that Merck (1785) knew about the anatomy and external appearance of the Nile crocodile, and he stressed that the head is the biggest and most pronounced difference between today's *Gavialis gangeticus* and today's *C. niloticus*.

Additionally and involving our now judiciously making a significant nomenclatural and obviously needed new action, Merck (1785) was aware of the claim of a black longirostrine in Adanson (1757), but clearly the 1757 claim from Michel Adanson was not Merck's (1785) primary basis for *Crocodilus gangeticus*. Rather, and to the contrary, it was the Edwards (1756) and corroboratively some other more vague but reliable references about the decidedly and exclusively Asian (theoretically including Calcutta on the Hooghly) longirostrine reptile that was the basis of the combination *Crocodilus gangeticus* Merck, 1785, which we here designate as the type-species of *Crocodilus* Merck, 1785. This present action gets rid of the confusion (the historical question) of is it a living taxon, or alternatively is it a somewhat look-alike but only very distantly related fossil. The genus *Crocodilus* Merck, 1785, is the living Asian animal, and the combination *C. gangeticus* Merck is a member of the crown clade Crocodylia Loveridge.

We warn that confusingly the species-group name *Crocodilus longirostris* Merck, 1785, denotes distant fossils (some or all of which theoretically might possibly belong outside of today's Crocodylia order), and is completely different from the *Crocodilus longirostris* that was decades later and completely independently employed by Cuvier (1807) for the living animal group (an old and temporary hypothesis) that he called "Grand Gavial (*Crocodilus longirostris*, Schn. *Lacerta gangetica*, Gmel.)". The Cuvier (1807) *C. longirostris* is a junior synonym of *C. gangeticus* Merck, because it is alive and because it is exclusively from Asia. However, Schneider's (1801) original *Crocodilus longirostris* is perhaps more complicated (see citation details at Merck and Schneider in our bibliography), but clearly "Edwards anno 1756" is the prime example (with plate 19 explicitly cited).

The species-group name *Crocodilus longirostris* Schneider, 1801, was based on syntypes because in addition to the Edwards (1756) three examples, there were others known to Merck (1785) and perhaps more. Therefore, because the Edwards plate 19 individual is the only one of the syntypes that is reliably figured and with reliable and explicit and well known place provenance, we today make a nomenclatural action and here declare the single specimen illustrated in plate 19 in Edwards (1756) and its (the iconotype's) data to be newly the lectotype of *C. longorostris* Schneider. We note that in the same (first and top and functionally the diagnosis) paragraph, Schneider (1801) speaks of "Gavial" as an animal's name and "Gangem" as its habitat in Asia, and further it is important that in 1801 he recognized no other name as including the taxon that is today *Gavialis gangeticus*. The unavailable name "*Gangeticus crocodilus*" (as a group of living Asian animals, as opposed to fossils from Yorkshire, England) was in some sense Schneider's (1801) *Crocodilus longirostris*, but because the earlier *Crocodilus longirostris* Merck, 1785, was a taxon of fossils, and because Schneider (1801) cited Merck (1785) as a publication known to him, it has become necessary to make it clear that *Crocodilus longirostris*

Schneider, 1801, is not a western European fossil, but rather is clearly the living and Asian (most famously northern India) distributed Edwards (1756) animal.

We have corrected and upgraded Johann Heinrich Merck's (1785) *Crocodili Gangetici* to *Crocodilus gangeticus* in good faith, because the Latin plural was required by the context in the German sentence in which it was written in Merck (1785) in a footnote. Similarly the context of "*Crocodil. longirostris*" in the same page 81 German footnote suggests the Latin plural *Crocodili* which we here upgrade to *Crocodilus longirostris* Merck, 1785. There is an existing analogy and functional precedent for allowing the upgrading of a Latin plural when in certain circumstances it is employed and situated in some language other than Latin, such as the name *Alligatores* in a French context in Cuvier (1807), which is the universally accepted and CITES regulated genus *Alligator* today.

Peripherally there is potential confusion, because historically there was a now unavailable name, *gangeticus Crocodylus* Camper, 1780, in which the order of the genus and species was reversed. None the less, it is interesting and important that Camper's (1780) concept included the text and plate of pictures in Edwards (1756). Further, we note that Merck (1785) and thus Edwards (1756, translated in Merck) was cited in *Lacerta gangetica* Gmelin, 1789. Lastly, the "gavial" from the Ganges River (such as and explicitly including the Edwards sample from Calcutta) was the extreme longirostrine kind in Lacépède (1788), who explicitly said that the Ganges (Asian) kind is definitely not the same thing as the so-called "Senegal gavial" (from Adanson).

We recommend that CITES should regulate *Gavialis gangeticus* (Merck, 1785) as opposed to *Gavialis gangeticus* (Gmelin, 1789), because 1785 is older than 1789, and because Gmelin (1789) cited Merck (1785) in agreement. We strongly feel that the species-group name *Crocodilus gangeticus* Merck, 1785, should be protected and put into active service. However, we would probably not seriously object if someone someday proposes that Crocodilus Merck, 1785, should be considered to have been overlooked for so long that it is put onto a list of forgotten genus-group names. We stress, however, that this only applies to the genus, because the (Edwards, 1756, in Merck, 1785) species has been present (indirectly but explicitly) in the *Gavialis gangetic*s (based on Gmelin, 1789) species-group name that today enjoys deeply entrenched and universal usage.

The distribution of Gmelin's (1789) *Lacerta gangetica* was Senegal and Ganges, and it was restricted to Ganges River by Heinz Wermuth (1953). Similarly, or at least arriving at the same result, we here designate the Edwards (1756) Calcutta gharial (gavial) as the lectotype of *Crocodilus gangeticus* Merck, 1785, and also of *Lacerta gangetica* Gmelin, 1789. As a result of our present action, these two names now officially become objective synonyms, which (had the 1785 genus been noticed before now) has always (in newly postulated hindsight) been true.

For details about the material and provenance of the Edwards (1756) sample, please see Van Tomme *et al*. (2012) which includes three views of the head of the individual baby gharial that (as a whole plate and its associated text, and now officially by our lectotype designation) owns the name *Gavialis gangeticus,* which in turn is the individual type-species (for nomenclatural purposes) of the genus-group name *Crocodilus* Merck, 1785, by present declaration. It was necessary to restrict the germane syntypes in both Merck (1785 *Crocodilus gangeticus*) and Gmelin (1789 *Lacerta gangetica*) to make sure that there is no Adanson (1757) content confusing the species-group name that has the Ganges as its eponym. We observe here that theoretically the role and function of the lectotype in zoological nomenclature is designed for resolving this exact kind of situation where more than one kind of animal is involved. In this case Asia (Ganges) and Africa (Senegal) were *gangeticus* syntype localities in both 1785 and 1789, and yet only one place (Asia) is correct for the modern and here preserved usage from 1789, now revised to 1785.

This presently discussed pair of lectotype designations (one for Merck, 1785; and additionally one for Gmelin, 1789) agrees with Wermuth (1953) and strengthens the current practice by the IUCN-SSC and others. There is no name-bearing Senegal (Africa) content in the Ganges gharial of Asia, because Adanson (1757; right or wrong about the black longirostrine) is officially (type-locality restrictions do not legally influence nomenclature, but lectotype designations can officially redefine an old syntype-based type locality) merely a paralectotype. It was a good idea (but not fact changing) when Wermuth (1953) restricted the type-locality of *Gavialis gangeticus* to "Ganges-Fluß, Indien" on page 504, but our lectotype designation of the carefully and diligently selected Edwards (1756) Hoogley (Ganges water) River near Calcutta (Kolkata), India illustrations of a single (one of three with identical provenance) crocodilian baby now makes Asia (including the Indian subcontinent) become 100% official.

Various format irregularities and antiquated data are noted in square brackets in our bibliography, including selected old published pictures. We explicitly stress that the earliest published picture of Michel Adanson's Black (Maï-Maï) crocodile is fig. 4 in Ross (2012), and thus there are no old (published before 2012) illustrations of the so-called "Adanson's gavial" from Africa at Senegal. In contrast, the Asian gavial (gharial) became known from two illustrated examples. One was a whole adult (not particularly accurate, but the snout is so long and nearly parallel sided that it could not be anything else) shown in lateral view in Lacépède (1788), and it was later copied several times, including Latreille (1801) and independently by Daudin (1801), and each time it was copied it became the work of a new artist.

The other important illustration (and its provenance data) is a plate of figures that is the iconotype of *Gavialis gangeticus* (Merck, 1785). The lectotype (iconotype) is one of three newly hatched Calcutta (Hugli River) gharials, and is plate 19 in Edwards (1756). Later, selected parts of this plate were copied by Bonnaterre's artist. The provenance of the Edwards (1756) iconotype is 100% trustworthy, and the original 1756

pictures themselves (the work of George Edwards himself) are remarkably good, and they show this dead (preserved in alcohol) *Gavialis gangeticus* baby in detail (although in some pictures modified to look alive), as exemplified by our Figure 1, which is one of four pictures in the 1756 plate.

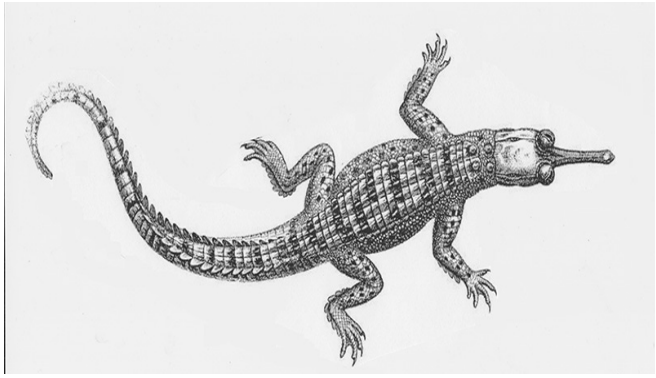

Figure 1. Dorsal view part of the Edwards (1756) plate 19, which is in its entirety and with its detailed text is iconotype and lectotype (and provenance data) of *Crocodilus gangeticus* Merck, 1785; and *Lacerta gangetica* Gmelin, 1789; and *Crocodilus longirostris* Schneider, 1801, all of which now have the same Calcutta, West Bengal type locality.

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