Crocodile Specialist Group, Species Survival Commission

CROCODILES

Proceedings of the 21st Working Meeting of the Crocodile Specialist Group
Manila, Philippines, 22-25 May 2012

(Unreviewed)

2012

IUCN

CROCODILES

**Proceedings of the
21st Working Meeting of the Crocodile Specialist Group
of the Species Survival Commission of the IUCN
convened at Manila, Philippines, 22-25 May 2012**

Dedicated to the late Charles "Andy" Ross (1953-2011)

(Unreviewed)

International Union for Conservation of Nature (IUCN)
Rue Mauverney 28, CH-1196, Gland, Switzerland

2012

Front cover: Philippine Crocodile, *Crocodylus mindorensis*. © Crocodylus Porosus Philippines Inc.

Inner front cover: Charles "Andy" Ross. © Tom Dacey

Literature citations should read as follows:

For individual articles:

[Authors]. (2012). [Article title]. Pp. [page numbers] *in* Crocodiles. Proceedings of the 21st Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

For the volume:

Crocodile Specialist Group (2012). Crocodiles. Proceedings of the 21st Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Table of Contents

Working Group Reports

The Crocodile Specialist Group

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

Foreword

The 21st Working Meeting of the IUCN-SSC Crocodile Specialist Group (CSG) was held in Manila, Philippines, on 22-25 May 2010. It was attended by 176 participants from 29 countries. The biennial CSG Working Meetings, which have been held over the last four decades, are fora in which crocodilian conservation action around the world is both initiated and assessed. This meeting, hosted by the Philippines, was both successful and illuminating.

Following the Crocodile Forum held in the Philippines in 2007, Government, industry and NGOs have worked closely together on active conservation programs for the two crocodilian species that occur in the Philippines, the Saltwater Crocodile (*Crocodylus porosus*) and the endemic Philippine Crocodile (*C. mindorensis*).

The CSG is extremely grateful to Crocodylus Porosus Philippines Inc. (CPPI), the Protected Areas and Wildlife Bureau (PAWB) and the National Museum of the Philippines (NMP), who together hosted the meeting. The Organizing Committee consisted of representatives of all three host organisations, under the leadership of Vicente P. Mercado, President of CPPI. The meeting would not have been possible without the generous financial support provided by these key sponsors.

A highlight of the meeting was the attendance by Michel Lacoste, Chairman of the Board of the French coorporation Lacoste, and Bernhard Limal and Antoine Cadi, from the French NGO Fonds de Dotation pour la Biodiversité (FDB). As part of the "Save Our Logo" initiative, Lacoste, with assistance from FDB, is already supporting five separate conservation projects on crocodilians around the world. A remarkable corporate achievement.

The Working Meeting was preceded by a meeting of the CSG Executive Committee (20 May), and a meeting of the CSG Steering Committee (21 May), which as usual, was open to all participants. The Steering Committee addressed a wide range of current CSG issues and priorities, particularly in Madagascar, Malawi, Colombia and Indonesia (Lake Mesangat, East Kalimantan). The development of a crocodilian capacity building manual, development of best management practices for crocodile farming, standards for keeping crocodiles in zoos, and renewal of the CSG membership, were all issues discussed.

Lake Mesangat in East Kalimantan, the last remaining habitat for Siamese Crocodiles in Indonesia, was discussed in depth. The spread of oil palms into the immediate lake area was a matter of great concern until a private company (PT REA Kaltim) initiated conservation action. The CSG will send a high level delegation to East Kalimantan to meet with representatives of the regional government and industry about the long-term conservation of this unique site. The CSG completed a morphometric study of caimans in Colombia, which provides the quantitative tools for predicting the size of caiman from which skins and leather products have been derived. The goal was to assist Colombia and the Parties to CITES in their efforts to ensure compliance with Colombia's size limits.

For the many people who work on crocodilians around the world, the CSG working meetings are an important event. Working with crocodilians requires a special effort by special people. Crocodilians live in remote and inhospitable places, where access is difficult. Because they range in weight from less than 50 g to over 1000 kg, catching and handling them is always a challenge - not to mention the personal risks involved. In the eyes of the general public, it is often a thankless task, because crocodiles are truly viewed as being "wicked" by most people. Not so amongst CSG members. The CSG Student Research Award Scheme was established in 2009 to encourage students to work on crocodilians: some 50 students around the world have now benefited from the scheme. We see them as tomorrow's crocodilian conservation champions, and future members of the CSG.

CSG Working Meetings, bring together an exceptional array of talented people, from all around the world. For most of them, the time and travel involved is a significant personal cost. The major reward is the ability to share one week with like-minded people, equally passionate about crocodilians. It recharges often tired batteries, stimulates interest, fosters camaraderie, creates new friendships, puts new faces to names, provides a genuinely sympathetic ears for discussion of problems, and most important, provides an opportunity to pass on new results and findings.

The core business of CSG is to help the IUCN and SSC achieve their conservation missions with crocodilians. This involves a raft of different CSG initiatives and activities in different countries, some simple others immensely complex. They are all addressed openly within the Working Meetings. As the complexity of the world expands, so the "biopolitics" of crocodilian conservation becomes more challenging. But the CSG adapts well. We do an exceptional job, usually quickly, and always honestly, transparently and by consensus. That we do it largely as volunteers, with very few paid staff, is remarkable in its own right.

An important key to the success of the CSG is that its membership includes representation from a great diversity of different stakeholders. We can look at the same problem through many different eyes. Particularly important are members representing the international crocodile leather industry. They keep us focused on attainable goals, make sure our concerns about trade in particular species from specific countries are valid, and offer sound advice and a wealth of experience when required.

The Proceedings of the 21st Working Meeting of the CSG will once again be a unique compendium of current information on research problems in crocodilian conservation, management and sustainable use, and the innovative approaches being taken to solve them. It will serve as an important reference source for CSG members and non-members with an interest in crocodilians. We take this opportunity to thank the organizing committee for their efforts in getting the Proceedings published in a timely fashion.

Summary of the Meeting

The 21st Working Meeting of the IUCN-SSC Crocodile Specialist Group (CSG) was held in Manila, Philippines, 22-25 May 2012, and was preceded by a CSG Executive Committee meeting on 20 May, and full Steering Committee meeting on 21 May. The meeting was hosted Crocodylus Porosus Philippines Inc., the National Museum of the Philippines and the Protected Areas and Wildlife Bureau of the Department of the Environment and Natural Resources.

The Organizing Committee consisted of Daniel Barlis, Careen Belo-Solco, Rainer Manalo, Vicente Mercado, Chona Mercado, Benedict Solco, Theresa Mundita S. Lim, Josefina de Leon, Nermalie Lita, Jeremy Barns, Eloy Cercado, Arvin Diesmos, and Ana Labrador. Together with their support staff, they did a marvellous job in preparing and running the meeting.

None of this would have been possible without the generous financial support provided by the major sponsors: Crocodile Porosus Philippines Inc., the National Museum of the Philippines, and the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources.

CSG Chairman Professor Grahame Webb welcomed 176 participants from 29 countries to the meeting (Australia, Argentina, Brazil, Cambodia, Czech Republic, Colombia, Denmark, France, Germany, Hong Kong, Hungary, India, Italy, Japan, Laos, Malaysia, Mexico, Nepal, Netherlands, Papua New Guinea, Philippines, Slovakia, Singapore, South Africa, Sri Lanka, Thailand, United Kingdom, USA, Venezuela). CSG working meetings are normally held each two years, and are the primary international meeting dedicated to crocodilian conservation, management and research. They have become the major forum for discussion of conservation issues involving crocodilians, and for presenting new findings and new directions with research and management. The 21st Working Meeting was no exception, with some truly exceptional presentations.

A highlight of the meeting was the attendance by Michel Lacoste, Chairman of the Board of the French coorporation Lacoste, and Bernhard Limal and Antoine Cadi, from the French NGO Fonds de Dotation pour la Biodiversité (FDB). As part of the "Save Our Logo" initiative, Lacoste, with assistance from FDB, is already supporting five separate conservation projects on crocodilians around the world, including a project on Philippine Crocodiles in northern Luzon, operated by the Mabuwaya Foundation Inc.

A number of important issues were addressed by the CSG Steering Committee prior to the working meeting, including the proposed protection of Lake Mesangat in East Kalimantan (Indonesia), the status of the trade ban on *C. niloticus* from Madagascar, Malawi's export quota, review of Steering Committee appointments and the proposed review of CSG membership following the IUCN World Conservation Congress in September 2012. Important initiatives such as crocodile conservation in Jamaica, outcomes from the CSG meeting on *C. siamensis* held in Bangkok, review of Red List assessments, establishment of a CSG Community Education Group, and the proposed Crocodilian Capacity-Building Manual were also advanced.

A range of topics were covered during the 4-day working meeting, with oral presentations organized into discrete sessions: Management Programs; Populations; Genetics; Disease; Human Dimension; Markets; Conservation; Reproductive Biology; General Biology; and, Physiology. A Poster session also saw a diverse range of topics being covered.

Progress being made with the conservation of the Philippine Crocodile (*Crocodylus mindorensis*), one of the world's most critically endangered species, was covered by various presentations, and included issues such as hybridization, reintroduction, community education, distribution and status. The two main foci of this work are in northern Luzon and Mindanao. The late Andy Ross (1953-2011), who inspired and mentored much of the work now being undertaken in the Philippines, was honoured through a special presentation given by Vic Mercado, with additional testimonials by Grahame Webb, Tom Dacey, Perran Ross and Charlie Manolis. The late Jack Cox (1952-2010), who collaborated with Andy Ross, and who contributed significantly to crocodile conservation in the Asian region, was also honoured.

Working groups were established for the CSG's Veterinary Science, Tomistoma Task Force, Industry and Human-Crocodile Conflict thematic groups, and deliberations are summarised in the Proceedings. The Crocodilian Capacity-Building Manual working group established in 2010 was re-convened to progress this issue. Representatives of most Range States for the Siamese Crocodile (*Crocodylus siamensis*), together with researchers and industry members, met during the course of the meeting, and they have proposed the establishment of a Siamese Crocodile Task Force to facilitate and improve communication, and advance common goals with the conservation and management of this critically endangered species.

No CSG meeting would be complete without social activities. The French cuisine lunch hosted by Michele Lacoste on Tuesday, and the welcome function on Tuesday night hosted by Protected Areas Wildlife Bureau were enjoyed by all. The Wednesday night function featuring entertainment by the Bayanihan Dance Troup, hosted by Crocodylus Porosus Philippines Inc., was another great success. The closing ceremony banquet on Friday night, with the CSG Auction, provided a fitting end to a great meeting.

The auction once again proved popular, with auctioneer Joe Wasilewski and his team working at a furious pace. The record sum of $US5140 was raised, which will go to crocodile conservation efforts in Benin, West Africa. Thanks are extended to all those people who contributed items to the auction, and of course to those who dug deep into their pockets to buy them.

After considerable deliberation, Matthew Shirley (USA) was awarded the Castillos Award for his contribution to crocodilian biology, management and conservation in West and Central Africa.

Following the meeting, participants had the opportunity to go on tours to the many tourist venues around the Philippines, including visiting "Lolong", the largest Saltwater Crocodile (*Crocodylus porosus*) in captivity in the world (6.17 m long), which was captured in Mindanao in 2011.

Host, Sponsors and Donors

Primary Sponsors:
- Crocodile Porosus Philippines, Inc. (CPPI)
- National Museum of the Philippines (NMP)
- Protected Areas and Wildlife Bureau (PAWB)

Secondary Sponsors:
- Afro-Asia Travel and Tours, Inc.
- Avilon Zoo/Ark Avilon Zoo
- Department of Tourism
- Lacoste
- Mirolabs/JK Mecardo and Sons
- Ocean Adventure
- Oihi/Liwayway Marketing, Inc.
- Tanduay Distillers, Inc.
- Tourism Infrastructure and Enterprise Zone Authority
- Wilco Builders' Depot/Coral Agri-Venture Farms, Inc.

Organizing Committee:
- Vincente P. Mercado (CPPI)
- Chona V. Mercado (CPPI)
- Daniel Barlis (CPPI)
- Careen Belo-Solco (CPPI)
- Benedict Solco (CPPI)
- Rainer Manalo (CPPI)
- Director Theresa Mundita Lim (PAWB)
- Josefina L. de Leon (PAWB)
- Nermalie M. Lita (PAWB)
- Director Jeremy Barns (NMP)
- Eloy Cercado (NMP)
- D. Arvin Diesmos (NMP)
- Ana Labrador (NMP)

Support Staff:
- Ramolin Antonio (CPPI/Wilcon)
- Jeremias Bacanto (CPPI/Microlab)
- Nilo Gonzales (CPPI/Microlab)
- Edward Librea (CPPI/Microlab)
- Mitch Meila (CPPI/Microlab)
- Grace Mendoza (CPPI/Micrlab)
- Maria Rhodeza Ramos (CPPI/Microlab)
- Dennis Angelo Romero CPPI/Microlab)
- Nilo Sambile CPPI/Wilcon)
- Richard Sua (CPPI/Microlab)
- Perry Buenavente (NMP)
- Faith Guinto (NMP)
- Donella Tan (NMP)
- Rolly Urriza (NMP)

Our thanks also go to:
- the two special artists, Beth Parrocha-Doctolero and Leonardo Onia Jr., who designed the crocodile-on-the-globe motif and the colourful crocodile featured on the souvenir program;
- Golden Acres Farm Inc. for the snacks provided each day;
- Michel Lacoste for sponsoring the French Lunch on 22 May 2012; and,
- The Department of Tourism for providing the Bayanihan Dance Troupe who entertained us at the special dinner on 23 May 2012.

List of Participants

Abad, Samuel
Local Government Unit, MPDC
Fely Maconacon, Isabela
Philippines
sam_abad@yahoo.com.ph

Abarquez, Althea L.
Ecosystems Management Specialist II
PAWB
Philippines

Abe, Chieko
Japan Leather and Leather Goods Industries Association
7th Floor, 1-12-13 Komagata, Taito-Ku
Tokyo 111-0043
Japan
official@horimicals.com

Ahmad, Rambli
Sarawak Forestry
Lot 218, KCLD, Jalan Tapang
Kota Sentosa
93250 Kuching
Sarawak
Malaysia
rambliahmad@sarawakforestry.com

Ahmad, Abdul Hamid
Director, ITBC
University of Malaysia Sabah
LB 2073
88999 Kota Kinabalu
Sabah
Malaysia
midahmad@gmail.com

Alba, Elenita
Chief, Museum Education Division
NMP
Philippines

Alcala, Angel
Chairman, Board of Advisers
SUAKCREM
2/F SU Marine Laboratory Bldg.
Silliman Beach, Bantayan
Dumaguete City
Philippines
suakcrem@yahoo.com

Antolin, Restituta V.
DENR-Region 2
Philippines

Balbas, Marites
Deputy Director/Community Organizer
Mabuwaya Foundation, Inc.
EIC Building, Isabela State University
Garita, Cabagan
3328 Isabela
Philippines
Mikaela_tess@yahoo.com

Banks, Chris
Manager of Conservation Partnerships
Zoos Victoria
PO Box 74
Parkville, VIC 3052
Australia
cbanks@zoo.org.au

Bantaculo, Emelyn
Executive Secretary
Roy Pate Adventures Corporation
3942 Araro Street
Barangay Palanan
Makati City
Philippines
emelynbantaculo@gmail.com

Baricic, Boris
Panholec 1
Pezinok 90201
Slovakia
boris@next-com.sk

Barlis, Daniel
President and Manager
Valderama Aqua-Culture Inc.
13 Juna Avenue
Matina, Davao City
Philippines
dcbdvo@gmail.com

Barns, Jeremy
Director, NMP
Philippines

Bednar, Jakub
REAL MAKLER
Vinice 293
Svaty Jur 900 21
Slovakia
jakub@farmapython.cz

Belo, William
Treasurer, CPPI
#90 E. Rodriguez Jr. Ave., Q.C.
Philippines
bensolco@coralfarms.com.ph

Benitez, Hesiquio
Director, Liason & International Affairs
CONABIO
Liga Periférico-Insurgentes Sur No. 4903
Col. Parques del Pedregal
México 14010, D.F.
Mexico
hbenitez@conabio.gob.mx

Besign, Joost
Mabuwaya
Natiridad Pension
Netherlands
joost_besign@hotmail.nl

Bezuijen, Mark
PO Box 183
Ferny Creek, VIC 3786
Australia
bezuijen@dodo.com.au

Botero-Arias, Robinson
Mamirauá Institute for Sustainable Development
Estrada do Bexiga, no 2584
Bairro Fonte Boa
CEP 69470-000, Tefé/AM
Brazil
robin@mamiraua.org.br

Brien, Matthew
Charles Darwin University
Ellengowan Drive
Darwin, NT 0909
Australia
matthew.brien@cdu.edu.au

Britton, Adam
PO Box 1281
Howard Springs, NT 0822
Australia
abritton@crocodilian.com

Brueggen, John
St. Augustine Alligator Farm
999 Anastasia Blvd.
St. Augustine, FL 32080
USA
Jbrueggen1@aol.com

Brueggen, Jen
St. Augustine Alligator Farm
999 Anastasia Blvd.
St. Augustine, FL 32080
USA
Jbrueggen1@aol.com

Buenavente, Perry
Zoology Division, NMP
Philippines

Burns, Michael
PO Box 3942
Darwin, NT 0801
Australia
mick@biznt.com

Burtner, Brittany
University of Florida
8510 Big Bend Court
Williamsport, MD 21795
USA
bburtner@ufl.edu

Byrd, Hunter
University of Central Arkansas
1230 Mimosa Drive
Conway, Arkansas 72034
USA
hunterbyrd18@gmail.com

Cadi, Antoine
Scientist Advisor, FDB
France

Caldwell, John
37 Edinburgh Drive
St. Ives
Cambridge
United Kingdom
john.caldwell@mad.scientist.com

Campbell, Hamish
Research Associate
School of Biological Sciences
The University of Queensland
St Lucia, QLD 4072
Australia
hamish.campbell@uq.edu.au

Caraguel, Jerome
Purchase Director, HCP
105 Norset Aus.
Lafayette, LA 70501
USA
jerome.caraguel@rep.2h.com

Caraguel, Charles
School of Animal & Veterinary Sciences
Roseworthy Campus, SA 5371
Australia
charles.caraguel@adelaide.edu.au

Castro Casal, Antonio
Coordinator, Asociacion Chelonia
CL 19A No. 88-24
Colombia
colombia@chelonia.es

Célarié, Laurent
Cameraman, FDB
France

Chan, Salvador
CPPI
2188 Elisco Road
Brgy. Ibayo Tipas
Taguig City
Philippines
salvadorchan824@yahoo.com.ph

Chan, James
Manager, Golden Acres Farm, Inc.
2188 Elisco Road
Brgy. Ibayo Tipas
Taguig City
Philippines
jchan@goldenacres.com.ph

Chiabodo, Olivier
Communication Advisor, FDB
France

Comparini, Simone
President, Pantera SRL
Via Pallesi 7c
56029 Santa Croce sull Arno
Italy
renzocomparini@libero.it

Conners, Steve
General Curator, Zoo Miami
12400 SW 152 St.
Miami, FL 33177
USA
sconner@miamidade.gov

Coro, Alfredo II
Municipal Mayor
Municipality of Del Carmen
Del Carmen, Siargao Islands
Philippines
coro.alfredo@gmail.com

Corpuz, Ma. Luz B.
Chief, Wildlife Regulation Section
PAWB
Philippines

Coutinho, Marcos Eduardo
Scientific Coordinator
Center for Research and Counsen
R. Julieta A/Varenga
609 L. Sanita BR
Brazil
medcoutinho@gmail.com

Cruz, Michael Vincent
Business Development
J.K. Mercado & Sons Agricultural Enterprises, Inc.
Pag-Asa Farms, Pag-asa
Kapalong, Davao 8113
Philippines
mykecruz@JKMercado.com

Cullen, Terry
Director Emeritus
Dragonwood Conservancy
PO Box 878
Milwaukee, WI 53201
USA
tcullen9@gmail.com

Cureg, Myrna
Vice President
Mabuwaya Foundation/Isabela State Uni.
Garito Heights, Cabagan
Isabela
Philippines
myrna_canilan_curey@yahoo.com.ph

Daba, Belen
DENR-Region 10
Philippines

Dacey, Tom
Executive Officer
Crocodile Specialist Group
PO Box 72
Smithfield, QLD 4878
Australia
csg@wmi.com.au

de Leon, Ms. Josefina L.
OIC-Chief, Wildlife Resources Division
PAWB
Philippines

De Silva, K. Anslem Lawrence
Visit. Lecturer & Consult. Herpetologist
Rajarata University
15/1 Dolosbage Rd.
Gampola (CP)
Mihintale
Sri Lanka
kalds@sltnet.lk

Diesmos, Arvin
Scientist 2
Herpetology Section, Zoology Division
National Museum of the Philippines
Padre Burgos Avenue, Ermita 1000
Manila
Philippines
arvin.diesmos@gmail.com

Diaz, Clara Lucia Sierra
Independent Consultant
Cra 13 A No. 102-41
Bogota
Colombia
croco_mangle@hotmail.com

Dizon, Philip
CEO and President
Davao Crocodile Park Inc.
Riverfront Corporate City Diversion Rd.
MA-A, Davao City
Philippines
sonnydizon54@yahoo.com
parkinfo@davaocrocodilepark.com

Durning, Kathleen
San Diego State University
11579 Lake Vicente Drive
Lakeside, CA 92040
USA
lvalenti@sunstroke.sdsu.edu

Elorde, Edwin G.
Municipal Mayor
Municipality of Bunawan
Province of Agusan del Sur
Philippines

Evans, Luke
Biomedical Sciences Building
Museum Avenue
Cardiff CF10 3AX
United Kingdom
lukeevans603@yahoo.co.uk

Even, Eduard (Eddy)
de Groene Wellehoutsnip 23
7827 Kg, Emmen
Netherlands
e.even@planet.nl

Fernandez, Georgina L.
DENR-Region 9
Philippines

Francisco, Bernardo
OIC-Project Director, PWRCC/PAWB
Philippines

Fukuda, Yusuke
Parks and Wildlife Service NT
PO Box 496
Palmerston, NT 0831
Australia
yusuke.fukuda@nt.gov.au

Galeon, Edgardo O.
DENR-Region 4B (MIMAROPA)
Philippines

Gaw, Jake
Director
Avilon Wildlife Conservation Foundation
Ark Avilon Zoo
Frontera Verde, Ortigas Ave. cor C-5
Pasig City
Philippines
joaquingaw@gmail.com

Geczy, Csaba
Veterinary Surgeon
1125 Gyongyvirag ut 3/A
Budapest
Hungary
sbcsaba@gmail.com

Giam, Choo-Hoo
CITES Animals Comm. Member (Alt.)
78 Jalan Haji Alias
Singapore 268559
Singapore
giamc@singnet.com.sg

Gonzales, Lucio T.
Municipal Mayor
Municipality of Pilar
Siargao Island
Surigao del Norte
Philippines

Gonzales, Marcus U.
Municipal Civil Registrar and Provincial
Tribal Chieftain
Municipality of Loreto
Agusan del Sur
Philippines

Grégoire, Elodie
Photographer, FDB
France

Hagen, Chris
Director of Animal Mgt./Herpetologist
Turtle Survival Alliance/Savannah River
Ecology Lab
Drawer E
Aiken, SC 29802
USA
tomistoma@yahoo.com

Haghighi, Ali
University of California Los Angeles
1506 Pembridge Ct.
Bakersfield, CA 93311
USA
haghighi21@gmail.com

Hairston Adams, Colette
General Curator
Gladys Porter Zoo
500 Ringgold Street
Brownsville, TX 78520
USA
cadams@gpz.org

Harbsmeier, Curt
Executive Board Member
Tampas Lowry Park Zoo
5116 South Lakeland Drive
Lakeland, FL 33813
USA
charbsmeier@hdalaw.com

Hedegaard, Rene
Director
Krokodille Zoo
Ovstrupvej 9
4863 Eskilstrup
Denmark
croczoo@hotmail.com

Hedegaard, Nina
Krokodille Zoo
Ovstrupvej 9
4863 Eskilstrup
Denmark
croczoo@hotmail.com

Heflick, Shawn
President
Conservation Rainforest Trust
240 Bay Tree Lane
Palm Bay, FL 32909
USA
sheflick@aol.com

Heng, Sovannara
Deputy Director of Fisheries
Conservation Department
Fisheries Administration
#168 Tonle Basac Chamkamom
Phnom Penh
Cambodia
h.sovannara@gmail.com

Hewlett, Jennifer
Box 232
235 Earls Court Road
London SW5 9FE
United Kingdom
jenn_croc@yahoo.co.uk

Hiver, Adrien
Asia representative, Lacoste
France

Imran, Mohamed Mossadique
Sri Lanka Convention Bureau
AA Building 40, 4th Floor Col-3
Colombo
Sri Lanka
imran@saexhibitions.com

Jeffery, Brian
University of Florida
3205 College Avenue
Davie, FL 33314
USA
bjeffe01@ufl.edu

Jelden, Dietrich
Head, CITES Management Authority
Federal Agency for Nature Conservation
Konstantinstrasse 21
53179 Bonn
Germany
dietrich.jelden@bfn.de

Karnjakesorn, Choomjet
Minister Counsellor (Agriculture)
Thai Embassy
Jakarta
Indonesia
choomjetls@gmail.com

Kopecny, Libor
Raduzova Street 3
16200 Prague 6
Czech Republic
krokodylari@centrum.cz

Kula, Veari
Department of Environment and
Conservation
PO Box 6601
Boroko, NCD
Port Moresby
Papua New Guinea
vearikula@gmail.com

Kullavanijaya, Bundit
Department of Fisheries
CITES Management Authority
Bureau of Fisheries Administration and
Management
Thailand
kulavanijaya@hotmail.com

Labrador, Ana
Assistant Director, NMP
Philippines

Lacoste, Gregory
HCP Int'al Purchasing Assistant/Grader
33 Avenue de Wagram
75017 Paris
France
gregory.lacoste@hcp-tcim.com

Lacoste, Michel
President, Lacoste
France

Lagarte, Mel
Assistant Chief
Museum Education Division
NMP
Philippines

Lance, Valentine
San Diego State University
11579 Lake Vicente Drive
Lakeside, CA 92040
USA
lvalenti@sunstroke.sdsu.edu

Langevin, Béatrice
Clinique vétérinaire
26 700 Pierrelatte
France
bea.langevin@wanadoo.fr

Lapie, Leo
Environmental Affairs Manager
Subic Bay Marine Exploratorium, Inc.
Camayan Wharf
West Ilanin Forest Area
Subic Bay Freeport Zone
Philippines
leolapie@yahoo.com

Larriera, Alejandro
Secretaria de Medio Ambiente
Director de Manejo de Fauna y Flora
Pasaje Privado 4455
Santa Fe-3000
Argentina
alelarriera@hotmail.com

Leblin, Arnaud
Communication Director, Lacoste
France

Lim, Theresa Mundita
Director, PAWB
Philippines

Limal, Bernard
President, FDB
France

Limketkai, Heintje Ong
CEO
Philippines Ostrich and Crocodile Farms
33-35 Gomez Street
Cagayan de Oro City
Philippines
pork@ostrich.com.ph

Limketkai, Bjorn
Vice President - Sales and Marketing
Philippines Ostrich and Crocodile Farms
33-35 Gomez Street
Cagayan de Oro City
Philippines
pork@ostrich.com.ph

Lita, Nermalie M.
Chief, Wildlife Management Section
PAWB
Philippines

Lopez, Maria de la Paz
Sofocles No.-111
Polanco, Miguel Hidalgo
Mexico D.F. Cp. 115650
Mexico
caicrochis@prodigy.net.mx

Macabantog, Abdulkarim M.
ARMM
DENR-Region 12
Macapodi, Mangayao
Philippines

Malla, Sabita
Research Officer, WWF Nepal
Baluwatar, Kathmandu
Nepal
sabita.malla@wwfnepal.org

Manalo, Rainier
Farm Manager
Coral Agri-venture Farm Inc.
Tarlac Capas
Tarlac
Philippines
rimanaloecology@yahoo.com

Manolis, Charlie
Wildlife Management International
PO Box 530
Karama, NT 0812
Australia
cmanolis@wmi.com.au

Martelli, Paolo
Chief Veterinarian
Ocean Park Hong Kong
Aberdeen
Hong Kong
paolo.martelli@oceanpark.com.hk

Martin, Samuel
General Officer
La Ferme aux Crocodiles
Les Blachette
F-26700 Pierrelatte
France
s.martin@lafermeauxcrocodiles.com

McClure, Geoff
Crocodile Consultancy
PO Box 44
Clifton Beach, QLD 4789
Australia
crocconsult@bigpond.com

McLeod, Robby
Research/Education Officer
Koorana Crocodile Farm
290 Eldon Street
Berserker, QLD 4701
Australia
mcleod_robby@hotmail.com

Mercado, Vicente
President, CPPI
2636 Tramo Line Cor. Alvarez St.
Pasay City c/o Microlab
Philippines
vpm@microlabphils.com.ph

Mercado, Chona
CPPI
2636 Tramo Line Cor. Alvarez St.
Pasay City c/o Microlab
Philippines
vpm@microlabphils.com.ph

Merchant, Mark
McNeese State University
450 Beauregard
Kirkman Hall 221A
Lake Charles, LA 70609
USA
mmerchant@mcneese.edu

Meurer, Alexander
Diedesbergweg 6D
55413 Weiler
Germany
ameurer@online.de

Mitchell, Greg
CEO, Bush Development Ltd.
PO Box 160
Gordons, NCD
Papua New Guinea
mitch@topcrocpng.com

Muniz, Manuel
Sofocles No.-111
Polanco, Miguel Hidalgo
Mexico D.F. Cp. 115650
Mexico
moreletii@prodigy.net.mx

Muscher, Rebecca
Department of Herpetology Keeper
San Antonio Zoological Gardens
3903 N St Marys Street
San Antonio, TX 78212
USA
poecilotheriabekky@yahoo.com

Nair, Tarun
Eexecutive Officer
Madras Crocodile Bank Trust/Gharial
Conservation Alliance
Vadanemmeli Village, ECR
Mahabalipuram, TN 603104
India
tarun@madrascrocodilebank.org

Nam, Luon
Luo Na Farm
Wat Po Village
Siem Reap
Cambodia

Naranjo, Renato
Vice President - Sales and Marketing
Philippines Ostrich and Crocodile Farms
33-35 Gomez Street
Cagayan de Oro City
Philippines
pork@ostrich.com.ph

Nifong, James
University of Florida
3840 NW 16th PL
Gainesville, FL 32605, USA
ncboy@ufl.edu

Obanos, Jaime G.
DENR Region 13 (CARAGA)
Philippines

Ondrovic, Stefan
CEO, REAL MAKLER
Vinice 293
Svaty Jur 900 21
Slovakia
zuzana.gluchova@szm.sk

Oposa, Jose Alfonso
Owner/Cooperator, Pulunan Farms Inc.
Trece Marteres City, Cavite
Philippines
uli_oposa@yahoo.com

Orolfo, Ali O.
DENR-Region 7
Philippines

Orolfo, Al
Regional Technical Director
DENR - PAWCZMS region 7
R-7 Greenplains Subd. Banilad Cebu
Philippines
al_orolfo@yahoo.com

Osterhoff, Lauren
Crocodile Conservation Institute
148 Anaconda Trail Cross
South Carolina
USA
crocdoctor@yahoo.com

Oudjani, David
Consultant, BC&S Ltd.
18, rue Naudin
31200 Toulouse
France
david_oudjani@yahoo.fr

Pahl, Kristian Robert
PO Box 530
Karama, NT 0812
Australia
pahl.robert@gmail.com

Pearcy, Ashley
University of Witwatersrand
Organization of Tropical Studies
PO Box 33
Skukuza 1350
South Africa
ashley.pearcy@gmail.com

Pfaff, Scott
Board Member
Crocodile Conservation Institute
PO Box 1060
Columbia, SC 29202, USA
spfaff@riverbanks.org

Phothitay, Chanthone
Deputy of Protected Area Management
Ministry of Natural Resources and Environment
PO 2932
Vientienne, Lao PDR
chanthone2011@hotmail.com

Pine, Anthony
President, The Tomistoma Fund
1965 Chicago Ave, Suite A
Riverside, CA 92507
USA
anthonykpine@tomistomafund.org

Pine, Angela
640 12th Street, Appt 2.
Arcata, CA 95521
USA
apine19@gmail.com

Platt, Steven George
Regional Herpetologist
Wildlife Conservation Society
WCS Myanmar Program
Hlaing Township
Yangon
Myanmar
sgplatt@gmail.com

Plummer Matt
Mainland HoldingsCrocodile Farm
PO Box 196
Lae, Morobe Province
Papua New Guinea 411
crocgm@mainland.com.pg

Pomares, Cayetano
Philippine College of Agriculture
University of Southern Mindanao
Kabacan, Cotabato
Philippines
pomarescayetano@yahoo.com

Principe, Guillermo
Yacares Santafesinos
General Estanislao Lopez 3363
Depto "D"
Argentina
guilleprincipe@yahoo.com.ar

Puentespina, Roberto Jr.
Owner Veterinarian
Malagos Garden Resort
Bolcan Street, Agdao
Davao City 8000
Philippines
drbo@malagos.com

Rafael, Noel
Curator-Conservation Research and Education
Avilon Wildlife Conservation Foundation
Ark Avilon Zoo
Frontera Verde, Ortigas Ave. cor C-5
Pasig City
Philippines
efrafael.avilon@gmail.com

Rebong, Glenn G.
Deputy for Technical Operation
PWRCC/PAWB
PO Box 101
Puerta Princesa City
Palawan
Philippines

Rivas, Glenda
Comm.Officer
RP Adventures Corp.
Araro St., Palanan
Makati City
Philippines

Adnelg_Savir0289@yahoo.com
Rodriguez, Dominic
Research and Conservation Officer
Mabuwaya Foundation, Inc.
EIC Building, Isabela State University
Garita, Cabagan
3328 Isabela
Philippines
Rodriguez.dominic@ymail.com

Ross, James Perran
Departtment of Wildlife Ecology
University of Florida
PO Box 110430
Gainesville, FL 32611
USA
pross@ufl.edu

Sam, Han
Project Manager
Fauna and Flora International
NO-19, ST-360
Phnom Penh
Cambodia
samhanwpo@yahoo.com

Santos, Marivene Manuel
Assistant Chief, Zoology Division
NMP
Philippines

Seashole, Samuel
Board Member/Veterinarian
Crocodile Conservation Institute
148 Anaconda Trail Cross
South Carolina
USA
crocdoctor@yahoo.com

Shirley, Matthew
Department of Wildlife Ecology and Conservation
University of Florida
110 Newins-Ziegler Hall
Gainesville, FL 32611-0430
USA
mshirley@ufl.edu

Sibiongga, Brian
Farm Manager
Coral Agri-Venture Farm Inc.
#90 E. Rodriguez JR. Ave., Libis, Q.C.
Philippines
ben.coralfarms@gmail.com

Siroski, Pablo A.
Aristobulo del Valle 3983
Santa Fe-3000
Argentina
cocokaima@hotmail.com
pablosiroski@yahoo.com

Smith, Cherique
Veterinarian, Zoobic Safari Corporation
#514 CTV2 #9 Magsaysay, East Tapinac
Olongapo City
Philippines
che_zoobic@yahoo.com

Solco, Benedict
CPPI
#90 E. Rodriguez Jr. Ave., Q.C.
Philippines
ben.coralfarms@gmail.com

Solco, Careen
CPPI
#90 E. Rodriguez Jr. Ave., Q.C.
Philippines
ben.coralfarms@gmail.com

Solmu, Godfrid C.
Production Manager
Mainland Holdings Crocodile Farm
PO Box 196
Lae
Morobe Province
Papua New Guinea 411
crocresearch@mainland.com.pg

Stevenson, Colin James
Director
Madras Crocodile Bank Trust
Vadanemmeli Village, ECR,
Mahabalipuram, TN 603104
India
coleosuchus@hotmail.com

Suaroon, Rumthon
Director of Licensing and Management Measures
Department of Fisheries
Thailand
su_aroon@hotmail.com

Takehara, Yoichi
Chairman, CITES Promotion Committee
Japan Leather and Leather Goods Industries Association
7th floor, 1-12-13 Komagata, Taito-ku
Tokyo 111-0043
Japan
official@horimicals.com

Tellez, Marisa
Dept. of Ecology & Evolutionary Biology
University of California
621 Charles E. Young Drive South
PO Box 951606
Los Angeles, CA 90095-1606
USA
marisa_tellez@sbcglobal.net

Temsiripong, Yosapong
Crocodile Cooperatives of Thailand
PO Box 9
Sriracha, Chonburi
Thailand 20110
yosapong@srirachamoda.com

Thongsavath, Oudomxay
Site Coordinator
Wildlife Conservation Society
c/o WCS Laos
PO Box 6712
Vientiane
Lao PDR
othongsavath@wcs.org
Thummachua, Smith
Fisheries Biologist
Department of Fisheries
Kaset Klang, Chatuchak
Bangkok 10900
Thailand
smiththummachua@gmail.com

Tierney, Margaret
c/- PO Box 530
Karama, NT 0812
Australia

Tisen, Oswald Braken
Acting Deputy General Manager
Sarawak Forestry
Lot 218, KCLD, Jalan Tapang
Kota Sentosa
93250 Kuching
Sarawak
Malaysia
oswaldtisen@sarawakforestry.com

Toledo, Esteven U.
Wildlife Resources Division
PAWB
Philippines

Ubang, Christopher Kri
Enforcement Officer Operation
Sarawak Forestry
Lot 218, KCLD, Jalan Tapang
Kota Sentosa
93250 Kuching
Sarawak
Malaysia
ckri@sarawakforestry.com

Ulloa, Giovanni
Independent Consultant
Cra 13 A No. 102-41
Bogota
Colombia
croco_mangle@hotmail.com

Umengan, Arturo V.
Environmental Management Specialist
Local Government Unit
Divilacan
Isabela
Philippines
avumergan@yahoo.com

Umpar, Muripaga T.
DENR-Region 12
Philippines

Van de Ven, Willem
Researcher, Mabuwaya Foundation, Inc.
EIC Building, Isabela State University
Garita, Cabagan
3328 Isabela
Philippines
wacvandeven@hotmail.com

Van Weerd, Merlijn
Director, Mabuwaya Foundation, Inc.
EIC Building, Isabela State University
Garita, Cabagan
3328 Isabela
Philippines
Merlijnvanweerd@yahoo.com

Velasco, Alvaro
Director, Wildlife: Products and Services
Apartado Postal 66597
Caracas, Venezuela
velascoalvaro@tutopia.com

Vendivil, Wilfredo
Chief, Botany Division, NMP
Philippines

Wasilewski, Joseph
Biodiversity Administrator
Jadora International LLC
24305 SW 142 Ave.
Princeton, FL 33032
USA
jawnatsel@bellsouth.net

Webb, Freddy
PO Box 530, Karama, NT 0812, Australia

Webb, Giovanna
Wildlife Management International
PO Box 530, Karama, NT 0812
Australia

Webb, Grahame
Wildlife Management International
PO Box 530, Karama, NT 0812
Australia
gwebb@wmi.com.au

Wiradinata, Erick
Puri Sentra Niaga Blok C/52
Jakarta, Indonesia
raflo_indonesia@gmail.com

Woodward, Allan
Reptile and Amphibian Research
Florida Fish Wildl. Conserv. Commission
1105 SW Williston Road
Gainesville, FL 32601
USA
allan.woodward@mfwc.com

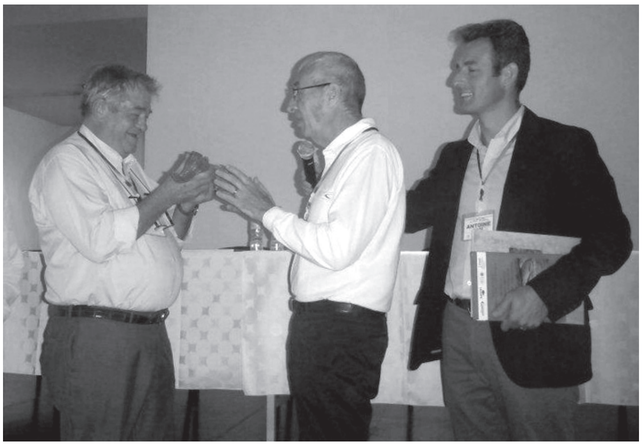
Zuniga, Concordio D.
DENR-Region 4B (MIMAROPA)
Philippines

Colette Adams and Curt Harbsmeier

Allan “Woody” Woodward and Yosapong Temsiripong

Auctioneer Joe Wasilewski and Alvaro Velasco

Matt Plummer, Charles Caraguel, Mark Merchant and Jerome Caraguel

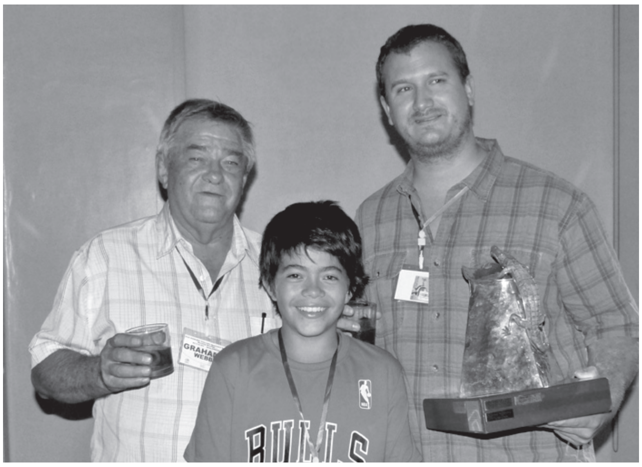


Michel Lacoste (centre), presents Grahame Webb (left) with a crystal crocodile, as Antoine Cadi (right) looks on.

CSG Executive

Val Lance and wife Kathleen Durning

Vic Mercado and Daniel Barlis



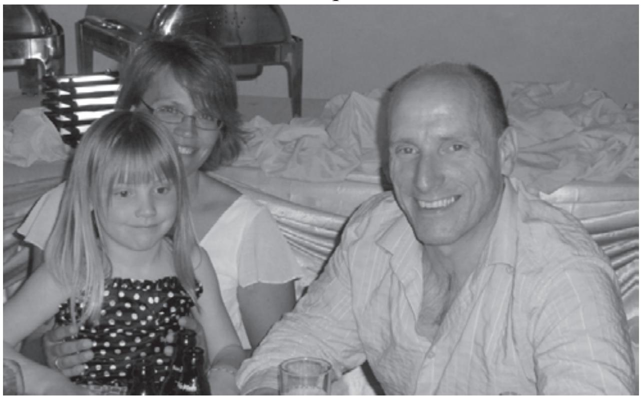
Grahame and Freddy Webb with Matt Shirley, winner of the Castillo Award

Marissa Tellez and Ali Haghighi

John Caldwell, Dietrich Jelden and Beatrice Langevin

Anslem de Silva, Abdul Hamid Ahmad, Rambli bin Ahmad and Imran Mohamed Mossadique

Robert Pahl and Merlijn van Weerd



Rene and Nina Hedegaard, with daughter.

Heng Sovannara and Nam Luon

Dietrich Jelden and Ashley Pearcy

How C. Andy Ross got into Crocodiles, and Some Fuchs Content

Franklin Donald Ross

NCB Naturalis, Box 9517, Leiden 2300RA, the Netherlands

Abstract

This eulogy about the life and work of Charles Andrew (Andy) Ross features his friendship with Karlheinz Fuchs, and details the history of what can be collectively called "the Fuchs subspecies" (1971 and 1974), including direct quotation of the African crocodiles section in an obscure Fuchs book about leather processing. It is concluded that the new Hekkala *et al*. (2011) model involving a cryptic second species of Nile Crocodile requires "Nilekroko-Cryptic" to be added to the Nilekroko names for hypothesis testing, and further that if *Crocodylus cataphractus* became *Mecistops cataphractus* it could help science by simplifying scholarship about African crocodilians.

Introduction

Charles Andrew (Andy) Ross (1953-2011) was the youngest of three brothers born to Donald and Harriet Ross - Franklin (Frank) is the oldest, followed by Bill. Before she married our father, our mother had been a volunteer helper at the American Museum of Natural History (AMNH) in New York City, and while there (Vertebrate Zoology) had worked with reptiles and amphibians enough that later when I began bringing snakes home, she smiled. Thus, Andy spent his early life in a house where his oldest brother kept snakes, lizards and turtles, and enjoyed catching salamanders and frogs, and was reading about herpetology and eventually teaching amphibian and reptile studies at the Massachusetts Audubon Society. Later, while in college, I got seriously into crocodiles, a subject which also fascinated Andy. Thus, at about the time that Andy was graduating from high school (and had not yet decided what to do with his life), it was on purpose that I gave him two live American Alligators, and suggested that he should volunteer at the Smithsonian Institution in Washington, D.C., and explicitly that he should offer his services to Dr. James (Jim) A. Peters, Curator of Amphibians and Reptiles at the US National Natural History Museum. To his credit, Andy took my advice, and did it.

My mentor in Massachusetts was Dr. Ernest Edward Williams, Agassiz Professor of Vertebrate Zoology and Curator of Reptiles and Amphibians at the Museum of Comparative Zoology, Harvard University. Professor Williams once told me that crocodiles were not yet understood, and had suggested that I should work on them. Thus, ever since I was a teenager, Professor Williams arranged for me to have the keys to the museum's outside door and to the Herpetology Department, and a document allowing me to work there at night and on weekends.

By the time I gave Andy the two pet alligators, I was employed by the Royal Ontario Museum (Toronto, Ontario, Canada), in the Department of Vertebrate Paleontology, the curator of which had done his Ph.D. at Harvard, on tooth replacement in crocodiles. My studies from the Harvard collection and library continued in Canada, and when photocopy became available, I began making xeroxes of the crocodilian literature. While at the Royal Ontario Museum, I wrote the appropriate letters and then drove by car to New York to examine the AMNH collection, and to Washington to see what the Smithsonian had for the living crocodiles.

The US National Museum's "dry" crocodiles were stored in a collection of big boxes of drawers, and the tops of the boxes were available at table height to place the specimens for examination. The "wet" crocodiles were in an adjacent room on shelves, and it was easy to bring the wet and the dry material together for comparison. Further, the herpetology library was inside the department, and there was a coffee machine in the Division library, and people sitting around a great big table, many smoking cigarettes. Because of the floor plan, the whole herpetology department walked past the crocodile boxes every time they entered or exited the Division, so working on crocodiles was a social occupation. Every day, Monday to Friday, Dr. Jim Peters led the Division and its visitors to lunch together, and then on their way back, the herpetology staff would stop at the museum's big library to check the new magazines for the purpose of writing reprint requests for the Division's library.

Jim Peters was truly an extra dynamic and personable man, and every Friday night he drank beer and enjoyed much congenial laughter with a group of his fellow Smithsonian Natural History curators (his best friend was in Fishes), and because Dr. Peters was the kind of guy that he was, I was invited along on several Friday early evenings after work. Thus, brother Andy volunteered his services to Jim Peters, he was Franklin's little brother, and now the owner of two alligators that were living in his mother's bathtub. Further, because of the divorce of our parents, Andy was guaranteed free room and food in Washington at his mother's house until he was 21 years old. So Jim Peters didn't have to pay him very much, and hired Andy and put him to work on a project immediately. It was pure coincidence that Jim Peters needed what he called an intelligent ignoramus, meaning someone bright and enthusiastic and yet virgin to the field. The task was proofing the keys in Neotropical Squamata, while knowing only the definitions of characters from the book itself.

The saddest time that I can remember sharing with Andy was while the two of us were alone in Tuxtla Guteirrez, Chiapas, Mexico, and learned of the death of Jim Peters. We were at that time doing the fieldwork for a future paper (Ross and Ross 1974) about the caudal scalation of Central American *Crocodylus*. Like Andy would later, Jim Peters died of illness in a hospital bed in the company of his immediate family, and like Andy, Jim Peters died long before retirement age. Thus, when Andy was "orphaned" at the Smithsonian, it was Dr. George R. Zug who saved the day by not only assuming the vacant curatorship from within, but also by keeping Andy on staff, and assuming the Smithsonian mentorship of the "Charles Andrew Ross" who eventually went to New Guinea, and visited the Philippines and became extremely close friends with Dr. Angel Alcala, and through their combined efforts the Ross and Alcala team essentially single-handedly saved *Crocodylus mindorensis*, from extinction.

The wise and benevolent actions by Jim Peters and George Zug (who later became Chairman of Vertebrate Zoology at the USNM) made a really big contribution to Andy, and in more than just crocodiles, because part of the time Dr. Zug had him working in the Division of Birds (making skeletons), and later marine mammals. Further, Andy has done expeditions on lizards with Dr. James D. Lazell of The Conservation Agency in Rhode Island, USA, and with Riosuke Aoki from Japan. These were decades of Andy being a globetrotter, attending many CSG meetings, and doing fieldwork in India (crocodiles including the Gharial) and the island of Borneo (crocodiles including Tomistoma and *Crocodylus raninus*), and shooting birds on the remote island of New Caledonia.

In the very early 1970s, while still at the Royal Ontario Museum, I completed a manuscript on the New World species of *Crocodylus*, and sent copies to Jim Peters and F. Wayne King. The review from Washington was enthusiastic, but in contrast Dr. King informed me that because I treated *Crocodylus intermedius* as a subspecies of the American crocodile *C. acutus* (as *Crocodylus acutus intermedius*), he would block publication of my paper. The reason that I proposed the trinomial combination for the Orinoco Crocodile was to state a hypothesis in the hope that by doing so it would stimulate someone to falsify it, and I was making the intellectual point that the skull shape in *C. acutus* can be the same as in *C. intermedius* in some cases. There were no descriptions or published photos of the dorsal armor that clearly distinguished the American and Orinoco Crocodiles, and it seemed to me to be in the spirit of science to challenge the recognition of *C. intermedius* as a species, and hopefully stimulate scholarship about the subject, leading to clarity. The Orinoco Crocodile could be regulated by CITES as a subspecies as easily as when listed as a full species. A name is a name, and trinomials count.

At that time Wayne King was working toward CITES, and his reason for blocking my hypothesis was to avoid any controversy about the taxonomic list of crocodilians. It was important to him that the crocodile list should be uncontested at the time of signing CITES into law, and it would be good to keep the list frozen for as long as necessary for the crocodile leather industry to adjust to the new rules, and learn the names of the regulated taxa, and how to identify them. Note that Wayne King (in a letter to me) also argued that the extent of the mandibular symphysis technically separated the two Venezuelan *Crocodylus* from each other, but I say that the supposed distinguishing difference is extremely small (within the range of measurement error), and I still believe that skull shape slightly overlaps between these two taxa, given ontogenetic, geographic, individual and possibly even sexual variation (Ross and Pearcy 2010).

The crocodile list in the very early 1970s was from King and Brazaitis (1971), which was the same as the listing in Wermuth and Mertens (1961). My hypothetical *C. acutus intermedius* was new, and in truth, unnecessary and probably wrong. However, one of the last things that Andy and I discussed on the telephone in 2011 was whether or not *C. intermedius* looks like *C. acutus* (with regard to the dorsal scalation). This remains an unresolved and urgent question for the Crocodile Specialist Group. What are the limits of variation in head shape and scale counts in the Orinoco Crocodile, and how can it be distinguished (as a species or as a subspecies) from the American Crocodile (as a species or as a subspecies)? The geographic and individual variation in *C. acutus* is remarkably large (Ernst *et al*. 1999).

While reviewing the New World *Crocodylus*, in addition to becoming aware of how remarkably little was known about the physical appearance of *C. intermedius*, I had noticed that individual, ontogenetic and geographic variation in head shape and dorsal scale counts made it difficult to distinguish the American crocodile (*C. acutus*) from the Morelet's Crocodile (*C. moreletii*) in Central America. Thus, to test and explore a hypothesis in King and Brazaitis (1971), Andy and I went to Mexico, Belize and Guatemala, catching crocodiles and examining living and preserved collections. We confirmed the presumed overlap in traditional characters, and we also confirmed the new King and Brazaitis (1971) ventral skin character, given new definitions. The Ross and Ross (1974) paper provided CITES with a ventral hide dichotomy that identifies a commercial skin from their region of sympatry as either *C. acutus* or *C. moreletii*. As far as we know, the difference in basicaudal and immediately postcloacal ventral and ventrolateral scalation details works 100% of the time. The whole Morelet's Crocodile was later detailed in Ross (1987).

Back when I gave him the two alligators and the advice that he should volunteer to work for Jim Peters (and George Zug) at the Smithsonian, Andy was living in the Bronx of New York City, and our grandmother on our father's side had an apartment in Manhattan. Andy often visited the AMNH and the Bronx Zoo, and within a short time became friends with Wayne King and Peter Brazaitis. Thus, at the time when CITES was happening, my brother Andy and I knew that Wayne and Peter were handling the crocodile list, and in our estimation it was in good hands. The crocodile taxonomists in the USA and Canada, and in England as well, all agreed that the two new names from Fuchs (1971) would not be recognized. There were no major taxonomic surprises expected. However, some German crocodile people had different ideas, and by the time that the first CITES guide to regulated crocodilian taxa was published in 1983, there was a new arrangement of two subspecies in *C. cataphractus*, and a new schema of 7 subspecies in *C. niloticus*, and further there were too many "spectacled" caiman names at the subspecies level within the *crocodilus* Linnaeus and *yacare* Daudin complex, as detailed below.

Discussion - Part 1: Two spectacled ("common") cayman names too many

During one of our last ever telephone conversations, I asked Andy if Karlheinz Fuchs would be at the 2012 CSG meeting in Manila, and Andy's response was clear. He did not know if Karlheinz was still alive, but (thanks to his being reminded by me) it instantly became Andy's intention to invite him, and Andy expressed hope that his old friend from Germany would be able to attend the CSG meeting. However, Andy died within the next few weeks of that discussion. The following two essays are my attempt to honor this essentially death bed wish.

Based on King and Burke (1989), and before them Medem (1983), Groombridge (1982), Brazaitis (1973) and possibly also King and Brazaitis (1971), the Mato Grosso and Paraguay false names from Germany in the 1970s are not worthy of recognition. It does not matter if the Mato Grosso and Paraguay names are cited as originating in Fuchs (1971), or alternatively in Fuchs (1974a), nor additionally if it is understood that Fuchs (1974a) included a typographical error that was later corrected in Wermuth and Mertens (1977). All of the various spellings are equally invalid because neither Fuchs (1971) nor Fuchs (1974a) qualify under the rules of zoological nomenclature. The M-name and the P-name both lack type specimens, and neither of them was indicated as a new species-group name in 1971 or 1974. It should have been clearly indicated that the M- and P-names were new subspecies. The two skins of which photographs were published in Fuchs (1974a) were not designated as types until later in Wermuth and Mertens (1977), and thus they do not qualify. All type-specimens must be designated in the original type-description.

Neither Brazaitis (1973) nor Medem (1981) mentioned or recognized either the M-name or the P-name, but both of these taxonomic lists recognized other subspecies. Neither Groombridge (1982) nor Medem (1983) recognized the M- and P-names as valid, but both of these lists, which included subspecies, discussed the two false-names, and in the process they employed the spellings from Wermuth and Mertens (1977), and attributed to Fuchs (1974a), as opposed to Fuchs (1971). More recently, King and Burke (1989) reviewed some of the spelling variations, and distinctly rejected the Mato Grosso and Paraguay names from Fuchs (1971, 1974a) and also the revision of Fuchs (1974a) by Wermuth and Mertens (1977).

When tannery engineer Karlheinz Fuchs added his own two new names to the old and established Wermuth and Mertens (1961) list, he knew remarkably little about the rules and practices of zoological nomenclature. It was probably in 1973 that Fuchs received the advice from Dr. Heinz Wermuth (and possibly Dr. Robert Mertens as well) that the spellings of the Mato Grosso and Paraguay names from 1971 should be changed to become more correct latinizations. The newer spellings in Fuchs (1974a) were obviously an attempt to follow that advice, but apparently included a typographical error. This "error" was replaced by a correction in Wermuth and Mertens (1977), and both the M-name and the P-name spellings from 1977 were recognized by Wermuth and Fuchs (1978, 1983), and more recently by Obst (1996).

Essentially every species-group name recognized in Fuchs (1974) was illustrated with a pair of photographs of a commercial ventral skin of the taxon. One photo shows the normal outside surface, and its mate showed the surface inside the animal. These photos were not intended as the type-specimens of latinized names, but rather as illustrations of leather from the various taxa. There was no locality data in Fuchs (1974a) for any of these individual belly hides, including the pictures in the taxonomic accounts of the Mato Grosso and Paraguay names, which in 1974 were recognizable as being the M- and P-names from Fuchs (1971), but spelled slightly differently. Thus, when Wermuth and Mertens (1977) cited the photographs of belly skins in Fuchs (1974a) as the types of the M- and P-names (revised spellings), it was the origin of the so-called type designations. However, this can not be true, because the type of a name must be designated in the original paper, which Wermuth and Mertens (1977) said was Fuchs (1974a), but I say was Fuchs (1971). The pictures were added in 1974, and they were just ordinary photos until they were later interpreted in 1977 as types.

All of the taxonomic account photos from Fuchs (1974) were reprinted in Wermuth and Fuchs (1983), but the pictures and taxonomic accounts of the Mato Grosso and Paraguay names were deleted in Fuchs (2006). As a generality, none of the taxon photos in Fuchs (1974a, 2006) and Wermuth and Fuchs (1983) are useful for scale counts, partly because the cloaca is usually crudely cut from the skin, and partly because of glare and bending, and the photos are too dark or too light, and too small.

The Mato Grosso and Paraguay names in their 1974 spellings were listed in Index B of the 1995 CITES guide (Charette 1995), but were not illustrated in a taxon account in the 1995 text. This was a compromise, but it implied that the M-name and also the P-name were still recognized and regulated by CITES. Most recently, Trutnau and Sommerlad (2006) discussed the M-word and the P-word by name, but did not recognize either of them as valid. In roughly chronological order, the various spellings of the M- and P-names, and notes about whether or not they were recognized, are presented in List 1 below.

List 1. Sixteen spellings of M- and P-names history examples

1. Wermuth and Mertens (1961): these two names had not yet been invented.
2. Fuchs (1971: 202 [p. 8 reprint]): valid in combination with *Caiman crocodilus*, and thus clearly recognized with the spellings *matogrossoiensis* and *paraguayiensis*.
3. King and Brazaitis (1971): not mentioned [if they knew about Fuchs (1971) yet].
4. Brazaitis (1973): not mentioned, and therefore clearly not recognized as valid.
5. Fuchs (1974a: 66, 70): valid in combination with *Caiman crocodilus*, and recognized as *matogrossiensis* Fuchs and *paraquayensis* Fuchs.
6. Wermuth and Mertens (1977: 137-138): valid in combination with *Caiman crocodilus*, and mentioned as *matogrossoiensis* Fuchs, 1971, but actually recognized with its spelling corrected to *matogrossiensis* Fuchs, 1974, and separately they mentioned *paraguayiensis* Fuchs, 1971, and recognized it as valid with the spelling *paraquaiensis* Fuchs, 1974, which in 1977 they corrected to *paraguayensis* Fuchs.
7. Wermuth and Fuchs (1978: 52-53): valid in combination with *Caiman crocodilus*, and recognized as *matogrossiensis* Fuchs and *paraguayensis* Fuchs.
8. Medem (1981): these two names were neither explicitly mentioned nor discussed in general (they do not occur in Colombia).
9. Groombridge (1982: 287, 303): not recognized as valid, but discussed as *mattogrossiensis* (p. 287 typographical error) = *matogrossiensis* (p. 303); and, *paraguayensis* (pp. 287 and 303).
10. Wermuth and Fuchs (1983: both parts): recognized as valid for CITES in combination with *Caiman crocodilus*, and spelled *matogrossiensis* Fuchs, 1974; and, *paraguayensis* Fuchs, 1974 (employing the corrected 1977 spelling).
11. Medem (1983: 24): not valid (clearly rejected), but discussed (see quote in List 2 below) as *matogrossensis* Fuchs, 1974; and, *paraguayensis* Fuchs, 1974.
12. King and Burke (1989: 3, 5-6): not recognized as valid, but in two separate places (*crocodilus* and *yacare*) discussed as *matogrossoiensis* (in 1971) and *matogrossiensis* (in 1974); and, *paraguayiensis* (in 1971) and *paraquaiensis* (in 1974).
13. Charette (1995: Index B): valid for CITES and recognized in combination with *Caiman crocodilus* as *matogrossiensis* and *paraguayensis*.
14. Obst (1996: 450): valid in 1996, and recognized in combination with *Caiman crocodilus* as *matogrossiensis* Fuchs, 1974; and, *paraguayensis* Fuchs, 1974.
15. Trutnau and Sommerlad (2006: 390): not valid in herpetology, but explicitly mentioned in their "Spectacled Caiman" text spelled as *matogrossiensis* and *paraguayensis*, with both tentatively called junior synonyms of *Caiman yacare*, though definitely not appearing in their p. 409 synonymy of their "Yacare Caiman" species.
16. Fuchs (2006): no mention or discussion of these two names.

In addition to lacking type-specimens, Fuchs (1971) was further deficient in lacking any type-locality data. Thus, the M-name and the P-name each had a distribution in 1971, and similarly Fuchs (1974) also later gave a distribution, although in one case he slightly changed the wording, compared with the wording in the 1971 original. The revised 1974 wording of the distributions was later employed by Wermuth and Mertens (1977) as the distributions of the whole individual subspecies taxa, and in 1977 they created a type-locality for the M-name and a separate type-locality for the P-name. Essentially all authors who cite Fuchs (1974a) as the origin of the M- and P-names employ the distributions from Fuchs (1974a) and repeated in Wermuth and Mertens (1977). Similarly, any assertions of type-locality data for the M- and P-names actually originated in Wermuth and Mertens (1977). In approximately chronological order, these sources of geographic assertions are presented in List 2.

List 2. Six localities allegations examples, including F. Medem quote

1. Fuchs (1971: 202-203) [8-9 reprint] said "Mato Grosso-Brillenkaiman" with "Verbreitung: Südbrasilien (Mato Grosso)"; and, separately the "Gran Chaco-Brillenkaiman" with "Verbreitung: Paraguay (Flußsysteme des Rio Paraguay und Parana)".
2. Fuchs (1974a: 66) said "Mato-Grosso-Krokodilkaiman" with "Verbreitung: Süd-Brasilien (Mato Grosso)"; and, separately (p. 70) "Gran-Chaco-Krokodilkaiman" with "Verbreitung: Paraguay (östlich des Rio Paraguay), Rio Verde, Rio Monte Lindo, Rio Negro, Rio Confuso, Rio Pilcomayo".
3. Wermuth and Mertens (1977: 137) said for "*Caiman crocodilus matogrossiensis* Fuchs" that in 1971 (spelled

"*matogrossoiensis*") it had "Patria: Mato Grosso, Brasilien" and in 1974 and 1977 had "Verbreitung: Südliches Brasilien (Mato Grosso)" and new in 1977 "Terra typica: Mato Grosso, Brasilien" was added to Fuchs (1974) in a sneaky fashion; and, separately on page 138 said for "*Caiman crocodilus paraguayensis* Fuchs" that in 1971 (spelled "*paraguayiensis* Fuchs") it had said "Patria: Paraguay", and in 1974 and 1977 it had "Verbreitung: Paraguay (nordöstlich des Rio Paraguay): Rio Verde, Rio Monte Lindo, Rio Negro, Rio Confuso und Rio Pilcomayo"; and, invented newly in 1977, "Terra typica: Rio Verde, Paraguay" was added in a sneaky fashion to Fuchs (1974).

4. Wermuth and Fuchs (1978: 53) said "Mato-Grosso-Krokodilkaiman" with "Verbreitung: Südliches Brasilien (Staat Mato Grosso)"; and, on page 52 said "Gran-Chaco-Krokodilkaiman" with "Verbreitung: Mittleres Süd-Amerika (Paraguay, östlich des Rio Paraguay: Rio Verde, Rio Monte Lindo, Rio Negro, Rio Confuso, Rio Pilcomayo)".
5. Wermuth and Fuchs (1983) said "Mato Grosso crocodile caiman, Mato Grosso spectacled caiman, Brazil caiman" with "Distribution: S. Brazil (Mato Grosso)"; and, also in the skins taxon accounts said "Gran Chaco crocodile caiman, Gran Chaco spectacled caiman" with "Distribution: Paraguay (W of the Rio Verde, Rio Monte Lindo, Rio Negro, Rio Confuso, Rio Pilcomayo)".
6. Medem (1983: 24) said "Las descripciones de *Caiman crocodilus matogrossensis* y *C. c. paraguayensis* como nuevas subespecies son algo extravagantes, en razón a que como holotipos figuran sólo las partes ventrales de pieles exportadas comercialmente: *Caiman crocodilus matogrossensis* Fuchs (1974a: 66; figs. 67-68). Localidad típica: Mato Grosso, Brasil, sin localidad exacta. Este nombre fue repetido por Wermuth y Fuchs (1978: 53; fig. 18e). *Caiman crocodilus paraguayensis* Fuchs (1974: 70; figs. 71-72). Localidades típicas: Los ríos Verde, Monte Lindo, Negro, Confuso y Pilcomayo, situados en el oriente del Paraguay. La designacion fue también repetida por Wermuth y Fuchs (1978: 52; fig. 18d). [paragraph break] Comentarios. La designación de una piel comercial como holotipo, junto con la falta de una localidad típica exacta, es inadmisible según las correspondientes Reglas de la Nomenclatura. El holotipo y los paratipos deben ser designados en base a uno o varios ejemplares enteros, un cráneo, o en casos excepcionales, una piel completa. Por esta razón, la gran mayoría de los herpetólgos profesionales no aceptan la validez de dichas subspecies. [paragraph break] El señor Fuchs, ingeniero quimíco de Höchst Farbwerke en Frankfurt am Main, especializado en la elaboración de substancias químicas para preparar y teñir las pieles de la industria alemana de curtiembre, tiene el mérito de haber llamado la atención sobre la importancia de los osteodermos ('botones', de la capa interna, osificada de cada escama), en la identificación de las pieles comerciales. Es muy cierto que la configuración, el grado de osificación y el tamaño de estos osteodermos del escamado ventral, o su ausencia parcial o total en varios géneros, constituyen caracteres morfológicos adicionales de gran valor para la taxonomía, siempre y cuando exista un experto capaz de distinguirlos. Para ello hay que estudiar, repetidas veces y durante muchos años, miles de pieles de los Crocodylia procedentes del Sur y Centro América, Africa, Asia, Australia, Papua-Nueva Guinea y Las Filipinas. Son los únicos expertos de esta índole los señores Fuchs, King, Brazaitis y Wermuth. [paragraph break] *Caiman yacare* es considerado como subespecie de *Caiman crocodilus* por Fuchs (1974) y otros autores, y denominado *Caiman crocodilus yacare*. Desde el punto de vista sistemático, dos subespecies nunca pueded coexistir en una misma región, como sí pueden hacerlo dos especies. En caso dado que las tres subespecies, *C. s. yacare*, *C. s. paraguayensis* y *C. s. matogrossensis* estén confinadas a un mismo hábitat, hay que elevar nuevamente *C. yacare* a su estado específico. [paragraph break] En el primer caso, la simpatria de las diferentes subespecies dentro de un hábitat bien definido, v. gr. el Mato Grosso, es casi imposible; aún si coexistieran dos especies, habría ocurrido una amplia hibridación (ver Perú y Bolivia). Además la presencia de *Caiman sclerops* en el Mato Grosso es dudosa (Leitão de Carvalho, in litt., 1974; ver Brasil). [paragraph break] Finalmente hay que advertir que la procedencia de las pieles exportadas comercialmente es bastante incierta (v. gr. pieles declaradas de Paraguay son oriundas de Bolivia y el Brasil, ver caza comercial)."

In 1974, there was a second Fuchs book published, and this one was from the Food and Agriculture Organization (Rome, Italy) of the United Nations. Whether the FAO book was published before or after his Die Krokodilhaut book (Fuchs 1974a) is unclear, because neither of these two 1974 sources have a date printed on them. The classification of the caymans in Fuchs (1974b) was the same as in Wermuth and Mertens (1961), and was notably lacking both the M- and the P-names. Thus, neither Fuchs (1974b) nor Fuchs (2006) recognized the Mato Grosso and Paraguay names from 1971 (or alternatively from Fuchs 1974a) as valid. From circumstantial evidence pertaining to African crocodilian subspecies, it appears that Fuchs (1974b) was written in 1973, and published the following year. The taxonomy in the this book lacks the new African Slender-snouted Crocodile subspecies created in 1974 by Fuchs *et al*. (1974b), and it further lacks the 7 subspecies of Nile Crocodiles schema by Fuchs *et al*. (1974a).

Exactly why the Fuchs (1974b) book titled "Chemistry and Technology of Novelty Leather" did not recognize or even mention the M- and P-names is unclear, but the result was a listing of caiman taxa that agreed with that of Wermuth and Mertens (1961), King and Brazaitis (1971) and Brazaitis (1973). Further, although they had not been published yet, the FAO book (novelty leather) was in agreement with the taxonomy in Groombridge (1982), Medem (1981, 1983) and King and Burke (1989) with regard to the M- and P-names. There has been minor controversy about *yacare* being a subspecies or alternatively a species, and further about *crocodilus* or *sclerops*, but neither *Caiman crocodilus*, *Caiman sclerops* nor *Caiman yacare* have the M-name or the P-name included in them today.

The M- and P-names originated in Fuchs (1971), in the magazine Das Leder, published by the German chemical industry as a monthly serial. In my opinion, Das Leder is not an appropriate magazine for the creation of new scientific names, even if hypothetically they had included the designation of types and were properly annotated as new taxa. If Karlheinz Fuchs had not attended CSG meetings and circulated reprints of his 1971 paper, the nomenclatural world would not have known of the existence of the Das Leder article. The Fuchs (1971) M- and P-names were not only empty, but, additionally, they probably could not become available, due to the publication requirements of the Code. For corroborative notes in the Crocodile Specialist Group Newsletter concerning the Mato Grosso and Paraguay names from K. Fuchs (see Ross 2005d, 2006f).

Regardless of whether they became available at all, and further whether they became available in 1971 or alternatively 1974, the Mato Grosso and Paraguay names became very official in Wermuth and Mertens (1977), and further in Wermuth and Fuchs (1978, 1983). At least some of the credit for this development rests on the shoulders of Karlheinz Fuchs, but Andy and I now agree that whatever happened in Germany when Fuchs joined forces with Mertens and Wermuth, it was probably Heinz Wermuth who really created the 1983 recognition of the M- and P-name problem for CITES. In an e-mail dated 1 August 2006, Andy said to me: "Concerning Karlheinz, he is truly a very nice gentleman and our only remaining link to Heinz Wermuth. If he has done a sloppy job, then the blame rests with Heinz, as he should have known better".

Discussion Part 2: Dr. Wermuth's mistake, and K. Fuchs' lengthy quotation

The major relevance of Karlheinz Fuchs to the CSG, and to the crocodiles of the Philippines, is his series of publications concerning the tanning of commercial reptile leather. Anyone seeking to establish a crocodile skin processing industry will find Fuchs to be a valuable asset, and in addition to his recent essays in Trutnau and Sommerlad (2006), and also his own book (Fuchs 2006), there is an earlier book (1974), as opposed to the Fuchs (1974a) "Die Krokodilhaut" book, which also included information about crocodile leather and its processing. The best source of technical advice is still Fuchs (1974b), but it is a very rare item.

Similarly hard to find in libraries is a Fuchs (1969) paper. On the same subject, Medem (1981) said "Karlheinz Fuchs, representante de la industria de curtiembre en Alemania Federal, nos informó durante el Congreso en Frankfurt am Main en mayo de 1976, que la compañía Farbwerke Höchst AG está perfeccionando nuevos productos químicos que se utilizarán próximamente para ablandar los 'botones' (osteodermos) de la piel ventral y así facilitar la curtición (Medem 1977)."

Ross (2005a,c, 2006a-e,g, 2007a) has already detailed some of the problems concerning the African subspecies from Fuchs *et al*. (1974a,b), but I would like to add my consternation concerning the designation of a commercial ventral skin as the holotype of *Crocodylus cataphractus congicus* (Fuchs *et al*. 1974b). In agreement with Medem (1983), I argue that because commercial belly hides lack their heads and dorsal armor, and lack the whole posterior part of the tail, and often have the cloacal region badly damaged, they are inappropriate as types today. Further, these ventral hides very often have misleading and generally vague locality data. The belly skin on which the species-group name *congicus* is based apparently came from somewhere in the Congo basin, perhaps shipped from Kisangani (formerly Stanleyville), or perhaps from Kinshasa, or from Brazzaville. The term "Central Congo" is ambiguous, and at best it merely tells us from what major city this raw piece of leather was shipped to Germany.

I have thought long and hard about how to best contribute to science concerning the Fuchs *et al*. (1974a,b) revisions of *C. cataphractus* and *C. niloticus*, and have decided to quote the original Fuchs (1973) treatment of these two African crocodiles. However, the Fuchs (1973) paper is in German. Therefore, it is the Fuchs (1974b) version in English which follows. The information and presentation in Fuchs (1973: 29-32) is essentially the same as in Fuchs (1974b), which for these two species is pages 9-10.

> *"The Nile Crocodile (Crocodylus niloticus)*
>
> "Size: up to seven metres.
> "Geographical distribution: Africa south of the Senegal river, Lake Chad and Khartoum; extinct or extremely rare to the north of these regions; ranging southwards down to Cape Town but rare south of the Kunene river, the Kalahari desert and the Tugela river near Durban, Madagascar, the Comoro Islands, the Seychelles. It inhabits fresh-water but also brackish and sea water.
> "No other crocodilian species is as notorious as the Nile crocodile. Its size in particular is often widely exaggerated. From parts of skeletons found on Madagascar, a length of about ten metres could be inferred but animals attaining a length of five metres are now quite rare. Depending on its age, the Nile crocodile feeds on insects and vertebrates [(sic) does he mean invertebrates?] but the bulk of its diet consists of fish. Its back skin is generally dark bronze-green with irregular patches, although brownish animals are not rare; the underside has a dirty yellow colour. Professor Dr. F. Stather (Gerbereichemie und Gerbereitechnologie. 4th edition 1971, Akademie-Verlag, Berlin) regards the skin of the Nile crocodile as unsuitable for processing into leather because of the osseous dermal armour which covers the surface

of the entire body. A. Becchino (Richtlinien zur Gebung von Reptilien. Das Leder 3, 1956, pp. 190 & 191) arrives at much the same conclusion since he considers that the osseous dermal skeleton cannot be separated from the corium proper. In fact, the skin of the Nile crocodile is the best-known and most valuable of the classic African Croco skins and is traded under the following names:

"Croco Afrique is the trade name for all crocodile skins from eastern Africa (Burundi, Kenya, Mozambique, Rhodesia, Sudan, Tanganyika, Tanzania). All these skins are very long in relation to their width, the head part is large in area and almost square. The flank scales are oval and arranged in five to six longitudinal rows. Very few osteoderms are embedded in the connective tissue of Croco Afrique, which may be described as a medium-grain type of skin. The caudal part is relatively large in area. The maximum width of the skin is about one point two five metres, the length about four point twenty metres.

"Croco Mada is the commercial description of all crocodile skins of Madagascan origin. These, too, are of the medium-grain type, although the scales are smaller than those of Croco Afrique. The connective tissue of Croco Mada skins is entirely free from osteoderms. The flank scales resemble those of Croco Afrique but are arranged in four or five rows only. A characteristic feature of this type of skin is the double row of broad scales found along each side of the ventro-median line. In the leather trade Croco Afrique and Croco Mada (finished leathers) are often graded together, since the number of skins from Madagascar is very small and the two types of skin resemble one another in scalation.

"Nigeric Non Corré: skins sold under this description are of Nigerian origin and are of the large-grain type. The collar region is slightly ossified in some places, as are the belly scales from the sixth to tenth row of scales counted from the edge of the flanks. However, the bony deposits are not as compact as in Gavial Afrique [*C. cataphractus*] and are therefore hardly noticeable after the grain has been glazed. As far as the tail skin is concerned, the bony deposits occur only along the edge of the first to fourth longitudinal row of caudal scales counted from the anus. The flank scales are arranged in four longitudinal rows and are relatively large. In the case of Croco Nigeric Non Corré the skin trade distinguishes between skins which are only slightly ossified and those which are completely non-ossified.

"Of all the recent crocodilians the Nile crocodile (*C. niloticus*) probably yields the best horn-backs since its dorsals show up most beautifully in the finished leather. [End of p. 9, start of p. 10] The dorsals are arranged in regular longitudinal (six) and transverse (fourteen) rows. Except for those in the two rows nearest to the flanks, they are all rectangular in shape. Those forming the double row down the dorso-median line are never enlarged, as are those of the mugger (*C. palustris*).

"Horn-backs generally allow the species from which the skin is obtained to be identified accurately since the two major distinguishing features, the postoccipitalia and the nuchalia, are still recognizable in the skin material. Figure 26 [which is a mugger, he probably meant fig. 25 which is *C. niloticus*. In fact, both photos are too small and too dark to actually see these scales] shows the postoccipitalia (one row consisting of four oval, keeled osteoderms) and the nuchalia (two rows of prominently keeled osteoderms of which there are four in the first row behind the postoccipitalia and two in the second row).

"The Narrow-Nosed West African Crocodile (Crocodylus cataphractus)

"Size: up to four metres.

"Geographical distribution: western and central Africa (from Senegal south to northern Angola); in eastern Africa encountered only in Lake Tanganyika near Ujiji, it inhabits fresh-water and brackish water. The skin of the narrow-nosed West African crocodile is characterised by extensively ossified anterior ventral shields. Its snout is very long, narrow and pointed, resembling in shape that of the gharial or gavial. Its staple diet consists of fish. Fresh-water lakes are the preferred habitat of this species, which is non-aggressive and fairly harmless to humans. The back is dark olive, the underside yellow with irregular black patches. The skin of the narrow-nosed West African crocodile is traded under the names of 'Gavial Afrique' and 'Nigeric Corré'.

"The Gavial Afrique: Most crocodile skins sold under this name come from the Congo. Their head portion is more pointed and smaller in area than that of Croco Afrique skins. They may be described as being of the large-to-medium-grain type. Throat and collar region are extensively ossified to the gular sac. Massive ossification characterizes the belly skin from the fifth to the twentieth row of ventral shields, while the eleventh and twelfth row are only slightly ossified. The compact connective tissue ossifications are very noticeable also in the finished leather. The tail is fairly extensively ossified from the first to the fifth transverse row and the fifth longitudinal row of scales. The scales on the flanks are non-ossified, oval and arranged in six longitudinal rows.

"The Nigeric Corré: The gular part of this large-to-medium-grain type of skin is less extensively ossified than that of Gavial Afrique but the collar part shows the same degree of ossification. The belly scales are ossified from the fourth to the ninth transverse row counted from the collar, and these ossifications are very noticeable in the grain of the end product. The tail skin shows medium ossification from the first to the sixth or fourth-transverse row of scales. The non-ossified, large, oval flank scales are arranged in four longitudinal rows."

Also relevant to the CITES list of African crocodilians, Fuchs (1973) and Fuchs (1974b) recognized only one kind of *Osteolaemus*:

"The Broad-Fronted Crocodile (Osteolaemus tetraspis)

"Size: up to 1.90 metres.
"Geographical distribution: western Africa south of Sahara desert to central Africa (north-east of Zaire). The broad-fronted crocodile is one of the dwarf-crocodilians. Some authors distinguish two species. It feeds on amphibians and fish and also on fruit - an unusual diet for crocodiles. Young animals are yellow-banded but they may also display irregular spots in all shades from yellow to brown. From a length of forty-five centimetres onwards the pale markings disappear, and once the animal has attained a length of fifty centimetres, its skin is almost black even on the underside. The skin of the broad-fronted crocodile is traded under the name 'Croco Benin'.
"The Croco Benin is a large-grain type of skin. The collar is extensively ossified, as are the belly shields from the sixth to the eleventh row. The tail is completely ossified with the exception of the median line formed by one row of enlarged scales. An unusual feature of Croco Benin is that the ossifications increase considerably towards the tip of [end of p. 10, start p. 11] the tail. The lateral scales vary in size and are arranged in six to eight rows. They are mostly ossified to a varying extent. Croco Benin probably illustrates best the relative lack of pigment in the corium of crocodile skins as compared with lizard skins. The raw skins are blackish brown on the back and flanks; the belly has a cloudy dark brown coloration. After removal of the epidermis in the liming process the belly skin is completely white, while flanks and tail still show a very pale greyish brown pigment. Croco Benin skins are also traded under the name 'Cabindas'."

Considering that CITES regulates each country independently, the African taxa in Fuchs (1973, 1974b) as *Crocodylus niloticus*, *Crocodylus cataphractus* and *Osteolaemus tetraspis* would have been entirely sufficient. The trade names of various commercial ventral hides could have remained what they really were: common names in the leather industry, and not formal and latinized subspecies. The difference between the treatment of the African taxa in Fuchs (1973, 1974b), compared with Fuchs (1974a) is very significant, and I strongly suspect that the change was in some substantial way related to the signing of CITES, and the US Endangered Species List before it.

Karlheinz Fuchs is the only person who knows why the *Crocodylus cataphractus congicus* (Fuchs *et al*. 1974b), subspecies was considered needed in 1974. My best guess is that it circularly confirmed the separation of *Osteolaemus tetraspis* into subspecies with the same set of distributions (the *O. t. osborni* population from the Ituri Forest corresponds with the new *congicus* population of African Slender-snouted Crocodiles). Similarly, Fuchs can perhaps explain why Fuchs *et al*. (1974a) recognized 7 subspecies of *Crocodylus niloticus* with resurrected old names. Like changing from coal power to nuclear, it is a quantum leap from Croco Afrique to *Crocodylus niloticus africanus* Laurenti, 1768, because the latter is not necessarily an African crocodile. It is based on a faulty Seba picture from 1734, as explained in Ross (2006a).

Obst (1996) said about the crocodilians that "since 1961 the inventory of forms has expanded by a small number of previously unrecognized subspecies. Many more subspecies that were not yet accepted at that time have since been revalidated, on the basis of extremely painstaking studies of the scale characteristics. Remarkably, the crocodile leather specialists have turned out to be the most reliable authorities here, familiar with even the smallest details!" This hypothesis is still being tested, particularly with the African taxa; but, in contrast the Latin American common and South American broad-snouted caymans have pretty much stayed as they were in Wermuth and Mertens (1961), with *Caiman crocodilus crocodilus*, *Caiman c. apaporiensis*, *Caiman c. fuscus*, *Caiman c. yacare*, and *Caiman latirostris*. The only difference in Fuchs (2006) and Trutnau and Sommerlad (2006) is that *yacare* is recognized as a full species, in agreement with Medem (1983). Note that in List 2 (above), when Medem (1983) said "*C. s. yacare*" he meant *Caiman sclerops yacare*, which is a synonym of *Caiman crocodilus yacare*. For perspective about *yacare* as a scientific name, see Ross (2005b); and, concerning the question of *yacare* as a species or alternatively as a subspecies, see Ross 2005e.

Conclusions. Some thoughts of my own about African "cryptic" species

In his 1 August 2006 e-mail to me, Andy further said: "I very much encourage you to meet with Karlheinz and hopefully collaborate to clean up some of the obvious problems instead of just pointing them out, as this does little good. He speaks fluent English, and I am sure that he would relish the opportunity to talk systematics. You two might get along famously."

It is approximately four decades since the 7 subspecies of the Nile Crocodile schema was proposed, and one of the taxa, *suchus*, has recently been elevated to a full species, based on DNA evidence. It is no longer possible to set the whole question aside by not recognizing any subspecies, as was done by Ross and Mayer (1983). Rather, as exemplified by Hekkala *et al*. (2011) - "Taking precautionary measures such as recognizing the ancestral lineage as *C. suchus* on the IUCN Red List and reviewing its status, could reduce further loss of at-risk populations." and "Recent survey efforts indicate that *C. suchus* is declining or extirpated throughout much of its distribution. Without proper recognition of this cryptic species, current sustainable use-based management policies for the Nile Crocodile may do more harm than good."), and earlier by Fuchs (2006) and others, there is currently pressure on CITES to regulate *Crocodylus suchus* as a taxon distinct from *C. niloticus*. The data in the new paper by Hekkala *et al*. (2011) suggests to me that tannery engineer Karlheinz Fuchs was possibly correct in Fuchs (1973, 1974b) about Croco Nigeric Non Corré being different from Croco Afrique, and further that Croco Afrique and Croco Mada are generally similar to each other. Concerning recent DNA evidence, and for earlier discussion about cryptic crocodile species in Africa, see Hekkala *et al*. (2010) and Shirley and Eaton (2010).

If I understand Hekkala *et al*. (2011) correctly, the system of Nilekroko hypothetical "taxa" proposed in Ross (2007b,c, 2010) needs to be expanded to now include Nilekroko Cryptic (NK-C), which can be subdivided as NK-C-NileRiver, NK-C-SenegalRiver, NK-C-NigerRiver, NK-C-CongoRiver, and NK-C-IndianOceanDrainages, etc., as needed. The question today appears to be whether Nilekroko-Vulgar wild in the Nile River in Egypt near ancient Thebes was the same species as Nilekroko-Cryptic-NileRiver or not, with it suggested by Hekkala *et al*. (2011) - "That all mummy crocodiles from Thebes [ancient Egypt] and Samoun [ancient Egypt] exhibit the western haplotype suggests both lineages [an eastern clade and a western clade] historically occurred in the lower Nile River. These findings are consistent with early arguments of two *Crocodylus* species in Egypt, including historical accounts that ancient Egyptian priests were cognizant of two forms and selectively used the smaller, more tractable form in temples and ceremonies [Herodotus in Geoffroy Saint-Hilaire 1807]. Analysis of museum specimens from more recent collections provides additional evidence that both lineages were present in the upper Nile in Sudan until as recently as the 1920s.") that the captive Thebes animals were from the Nile, and were NK-C, which they further suggest is NK-WestAfrica and NK-Pedomorph combined.

If we can set Hekkala *et al*. (2011) and Herodotus and Étienne Geoffroy-Saint-Hilaire aside, I would again, as I did in Ross (2005a), ask why would the ancient Egyptian priests exhibit small and non-aggressive adult crocodiles to the public, when it is easy to train the large and dangerous kind to politely and gently, and one at a time (the crocodiles have their own dominance hierarchy), take food without biting the hand that feeds them. It was surely more impressive to enter an enclosure of really big crocodiles, as compared with an enclosure of small and demure ones. The Thebes "crocodile feeding show" was so impressive that we are still discussing it today. However, the possibility of NK-Cryptic being the Thebes Temple animal remains, because any regionally famous captive crocodile exhibit would have been reported by the ancient European explorers of Egypt.

None of the DNA studies of the living African crocodiles that are *Crocodylus*, as opposed to *Mecistops* and *Osteolaemus*, have counted scales or measured skulls (or at least they have not reported the data yet). In contrast, an attempt to tell us how to identify an individual animal, within limits, utilizing visually or tactilely (bending scales to see if they have bone inside them) determinable external characters, not relying on DNA analysis (which is not available in the field, and always expensive, and often involving the need for CITES permits) has been made by my brother's friend Karlheinz Fuchs.

One simple thing that the IUCN's crocodile list for CITES could do, to make scholarship and investigation just a little bit easier, is to recognize the combination *Mecistops cataphractus* (Cuvier, 1824) for the African Slender-snouted Crocodile, and return its type-locality back to "unknown" as it was in 1818 and 1824, and then all the way up to Fuchs *et al*. (1974b). There had been no need to invent a type-locality for the name *Crocodilus cataphractus* Cuvier, 1824, as it had been adequately employed as an undivided species in Fuchs (1973, 1974b). The African Slender-snouted Crocodile can today be effectively regulated without subspecies, and merely on a nation by nation basis. It would probably be unwise for CITES to continue regulating what I call *Mecistops cataphractus congicus*, originally combined with the genus *Crocodylus* Laurenti) (Fuchs *et al*. 1974a). The 1974 two subspecies of *Mecistops cataphractus* hypothesis has not yet been tested.

Andy Ross reviewed crocodilians (explicitly acknowledged for *Crocodylus rhombifer*, but with input on various other taxa) for King and Burke (1989). My current mentor at the Netherlands National Natural History Museum (until recently the RMNH, but now NCB Naturalis), Dr. Marinus (Rinus) S. Hoogmoed was also a King and Burke (1989) crocodilians reviewer, as was my Ross and Mayer (1983) coauthor and trusted colleague Dr. Greg Mayer (still an EEW graduate student at the MCZ at the time). Also, I reviewed many crocodilian taxa for King and Burke (1989), and there were others, including Dr. George Zug of the USNM (Natural History). The list that we recommended included four subspecies of *Caiman crocodilus* (namely *apaporiensis*, *chiapasius*, *crocodilus* and *fuscus*), the full species *Caiman yacare*, *Crocodylus cataphractus* without subspecies, *Crocodylus niloticus* without subspecies, and *Crocodylus mindorensis* as a full species separate from *C. novaeguineae*.

Note that in their *Crocodylus mindorensis* Schmidt account, King and Burke (1989) cited Aoki (1985) as Riosuke (1985) (ie with the author's name in reversed order). I remember one time when Andy remarked about how difficult it is to remember which order his friend's names go, and said that his way of keeping it straight is that crocodile scientist Aoki's nickname is Rio. The correct citation is Aoki, R., sometimes punctuated AOKI, Riosuke.

Literature Cited

Aoki, R. (1985). Beobachtungen an *Crocodylus mindorensis* auf Mindoro, Philippinische Inseln. Herpetofauna 7(34): 6-10.

Brazaitis, P. (1973). The identification of living crocodilians. Zoologica (New York Zool. Soc.) 58(3-4): 59-101.

Charette, R. (1995). CITES identification guide - crocodilians: guide to the identification of crocodilian species controlled under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Environment Canada: Ontario, Canada.

Ernst, C.H., Ross, F.D. and Ross, C.A. (1999). *Crocodylus acutus* (Cuvier): American Crocodile. SSAR Catalogue of American Amphibians and Reptiles (700): 17 pp.

Fuchs, K. (1969). Bestände, Häutenfall und Lederherstellung Paraguays. Leder und Häutemarkt 12: 814-815.

Fuchs, K. (1971). Die südamerikanischen Reptilhäute. Das Leder: Fachzeitschrift für die Chemie und Technologie der Lederhersellung Mitteilungsblatt des Vereins für Gerberei-Chemie und -Technik E.V. (Darmstadt, Germany) 22(9): 197-213.

Fuchs, K. (1973). Die afrikanischen Reptilhäute. Das Leder: Fachzeitschrift für die Chemie und Technologie der Lederhersellung Mitteilungsblatt des Vereins für Gerberei-Chemie und -Technik E.V. (Darmstadt, Germany) 24(2): 29-40.

Fuchs, K. (1974a). Die Krokodilhaut: ein wichtiger Merkmalträger bei der Identifizierung von Krokodil-Arten. Eduard Roether: Darmstadt, Germany.

Fuchs, K. (1974b). Chemistry and Technology of Novelty Leather. [note: "...novelty leathers" (plural) on p. i (title)] Food and Agriculture Organization of the United Nations: Rome.

Fuchs, K. (2006). The Crocodile Skin: Important Characteristics in Identifying Crocodilian Species. Edition Chimaira: Frankfurt am Main, Germany.

Fuchs, K., Mertens, R. and Wermuth, H. (1974a). Die Unterarten des Nilkrokodils, *Crocodylus niloticus*. Salamandra 10(3-4): 107-114.

Fuchs, K., Mertens, R. and Wermuth, H. (1974b). Zum Status von *Crocodylus cataphractus* und *Osteolaemus tetraspis*. Stuttgarter Beiträge zur Naturkunde (Stuttgart, Germany), Serie A (Biologie) (266): 1-8.

Groombridge, B. (1982). The IUCN Amphibia-Reptilia Red Data Book. Part 1. Testudines, Crocodylia, Rhynchocephalia. IUCN-SSC: Gland, Switzerland, xliii & 426 pp.

Hekkala, E.R., Amato, G., DeSalle, R. and Blum, M.J. (2010). Molecular assessment of population differentiation and individual assignment potential of Nile crocodile (*Crocodylus niloticus*) populations. Conservation Genetics 11: 1435-1443.

Hekkala, E., Shirley, M.H., Amato, G., Austin, J.D., Charter, S., Thorbjarnarson, J., Vliet, K.A., Houck, M.L., Desalle, R. and Blum, M.J. (2011). An ancient icon reveals new mysteries: mummy DNA resurrects a cryptic species within the Nile crocodile. Molecular Ecology 20(20): 4199-4215.

King, F.W. and Brazaitis, P. (1971). Species identification of commercial crocodilian skins. Zoologica 56(2): 15-70.

King, F.W. and Burke, R.L. (1989). Crocodilian, tuatara, and turtle species of the world: a taxonomic and geographic reference (compiled for the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora to serve as a standard reference to crocodilian, tuatara and turtle nomenclature). Association of Systematics Collections: Washington, D.C., USA.

Medem, F, (1977). La caza comercial de Babillas en Colombia. Trocha 2o. Especial 30: 1-7.

Medem, F. (1981). Los Crocodylia de Sur America. Volumen 1: los Crocodylia de Colombia. Universidad Nacional de Colombia & COLCIENCIAS: Bogotá, Colombia.

Medem, F. (1983). Los Crocodylia de Sur America. Volumen 2: Venezuela, Trinidad, Tobago, Guyana, Suriname, Guayana Francesa, Ecuador, Perú, Bolivia, Brasil, Paraguay, Argentina, Uruguay. Universidad Nacional de Colombia, & COLCIENCIAS: Bogotá, Colombia. 271 pp.

Obst, F.J. (1996). Commentary on the reprint Wermuth/Mertens (1961): "Schildkröten - Krokodile - Brückenechsen". Pp. 426-506 *in* Schildkröten/Krokodile/Brückenechsen/von H. Wermuth und R. Mertens. - Nachdruck der Ausg. Jena, VEB G. Fischer, 1961 / mit einem ergänzenden Nachtrag von Fritz Jürgen Obst. G. Fischer: Jena, Germany.

Ross, C.A. (1987). *Crocodylus moreletii* Duméril and Bibron: Morelet's crocodile. SSAR Catalogue of American Amphibians and Reptiles (407): 3.

Ross, C.A. and Ross, F.D. (1974). Caudal scalation of Central American *Crocodylus*. Proceedings of the Biological Society of Washington 87(paper 21): 231-233.

Ross, F.D. (2005a). No living crocs left in Western Sahara: an argument about what it should say on their tombstones. Crocodile Specialist Group Newsletter 24(2): 15-21.

Ross, F.D. (2005b). Commercial caiman paper in context: a case of study books (Schmidt is crucial), and then nature. Crocodile Specialist Group Newsletter 24(3): 22-26.

Ross, F.D. (2005c). Transvaal gem is a limited edition. Crocodile Specialist Group Newsletter 24(4): 25.

Ross, F.D. (2005d). More than the spelling was deficient. Crocodile Specialist Group Newsletter 24(4): 25-26.

Ross, F.D. (2005e). Dorsum of *Caiman crocodilus* needs work. Pp. 347-352 *in* Proceedings de la Reunión Regional de América Latina y el Caribe del Grupo de Especialistas en Cocodrilos (CSG/SSC/IUCN), 17 al 20 de Mayo 2005, Santa Fe, Argentina.

Ross, F.D. (2006a). Extremely old names can be dangerous. Crocodile Specialist Group Newsletter 25(1): 18.

Ross, F.D. (2006b). Special crocs do not key to their name. Crocodile Specialist Group Newsletter 25(1): 18-19.

Ross, F.D. (2006c). Substitute name leads to name substitutions. Crocodile Specialist Group Newsletter 25(1): 19.

Ross, F.D. (2006d). African dwarf-croc quandary persists. Crocodile Specialist Group Newsletter 25(1): 19-21.

Ross, F.D. (2006e). Malagasy fossil is not vulgar croc. Crocodile Specialist Group Newsletter 25(1): 24.

Ross, F.D. (2006f). Empty names possibly identified to genus. Crocodile Specialist Group Newsletter 25(2): 17-19.

Ross, F.D. (2006g). African slender-snout belly is possible cline. Crocodile Specialist Group Newsletter 25(2): 18-19.

Ross, F.D. (2007a). *Crocodylus niloticus vulgaris* Cuvier retracted. Crocodile Specialist Group Newsletter 26(2): 21.

Ross, F.D. (2007b). Nilekroko map for hypothesis testing. Crocodile Specialist Group Newsletter 26(2): 21-22.

Ross, F.D. (2007c). Nilekroko Pedomorph-Chad and NK-P-Mauritania. Crocodile Specialist Group Newsletter 26(2): 23.

Ross, F.D. (2010). *Crocodylus suchus* in trouble again. Crocodile Specialist Group Newsletter 29(1): 17-18.

Ross, F.D. and Mayer, G.C. (1983). On the dorsal armor of the Crocodilia. Pp. 305-331 *in* Advances in Herpetology and Evolutionary Biology: Essays in Honor of Ernest. E. Williams, ed. by A.G.J. Rhodin and K. Miyata. Museum of Comparative Zoology, Harvard University: Cambridge, Massachusetts, USA.

Ross, F.D. and Pearcy, A. (2010). Orinoco crocodile pictures needed for illustrating diagnostic characters in keys, and John T's photos might include them. Pp. 219 *in* Crocodiles. Proceedings of the 20th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland. [Electronic version only].

Shirley, M.H. and Eaton, M.J. (2010). African biogeography and its impact on recent developments in the systematics of African crocodiles. Pp. 89-99 *in* Crocodiles. Proceedings of the Second West African Regional Meeting of the IUCN-SSC Crocodile Specialist Group. CSG: Darwin.

Trutnau, L. and Sommerlad, R. (2006). Crocodilians: their Natural History and Captive Husbandry. Edition Chimaira: Frankfurt am Main, Germany.

Wermuth, H. and Fuchs, K. (1978). Bestimmen von Krokodilen und ihrer Häute. Gustav Fischer: Stuttgart, Germany.

Wermuth, H. and Fuchs, K. (1983). Convention on International Trade in Endangered Species of Wild Fauna and Flora. Identification manual (P. Dollinger *et al*., eds., incl. Honegger and King). Volume 3: Reptilia, Amphibia, Pisces. Volume 5: Parts and derivatives 2 (?= or 11). IUCN: Gland, Switzerland (pagination too cumbersome).

Wermuth, H. and Mertens, R. (1961). Schildkröten, Krokodile, Brückenechsen. Gustav Fischer: Jena, Germany.

Wermuth, H. and Mertens, R. (1977). Liste der rezenten Amphibien und Reptilien: Testudines, Crocodylia, Rhynchocephalia. Das Tierreich (Berlin, Germany) 100(1).

C. Andy Ross Papers, Crocodile Scales and Angel Alcala

Franklin Donald Ross

NCB Naturalis, Box 9517, Leiden 2300RA, the Netherlands

Abstract

When, in a recent obituary of Charles Andrew Ross (1953-2011), I said that my brother had authored or co-authored more than 40 scientific books and papers, it was a modest guess. The bibliography of the present paper lists more than 50. Additionally, the scalation of the Philippine Crocodile in Aoki (1985) counts as one of the major achievements of Dr. Andy Ross (honorary Ph.D. awarded by Silliman University). Among our shared interests, we studied the scientific names of crocodilians, and we have tried, whenever possible, to keep the full names and nicknames of our fellow crocodile scientists in print. With heartfelt gratitude and unbounded admiration I sincerely thank Professor Angel C. Alcala for mentoring Andy, and for enabling me to say something new and potentially very useful about the ventral scalation of the living Crocodylia, and it has direct potential for CITES. The starting-point and stopping-point problems associated with the traditional (and variously defined) collar-vent count can now be avoided, and the collar itself is tentatively reinterpreted by me. It is the anterior row of the inter-forelimb scalation complex.

Introduction: Mr. Alligator from the Smithsonian

Back in the early 1970s when Charles Andrew "Andy" Ross and I went to Mexico and Central America and counted the scales on *Crocodylus acutus* and *C. moreletii*, we had postoccipitals in one transverse row, and then two or three transverse rows of nuchals, and then an unarmored space of bare skin at the base of the neck, and then the dorsal body scales to the back edge of the pelvis, and then double-crested caudals, and finally single-crested caudals. We additionally made a special study of lateral and ventral scales near the start of the tail, in the region immediately posterior to the cloacal oval, and whenever possible, we counted the belly scales also. Of these characters, the only scale count that reliably distinguished the two Central American *Crocodylus* species from each other was the subdorsal details in the basicaudal region.

Several years after the Central America trip, Andy and I were examining *Alligator mississippiensis* together in Louisiana, USA, and enjoyed the hospitality of Ted Joanen at Rockefeller Wildlife Refuge in Grand Chenier. To our surprise, it soon became evident that the American Alligator has an often somewhat vestigial transverse row of scales at the anterior end of its thoracic body armor, and (naively on our part) that this dorsal row had not been scored as zero in Central America, because it was completely absent in the American and Morelet's Crocodiles. What we had noticed was the ancestral and theoretically always possible 18th transverse row, counting toward the neck from the base of the tail, PC18 in the terminology of Ross and Mayer (1983).

As detailed in Ross and Mayer (1983), *C. acutus* and *C. moreletii* have zero scales in PC 18, while *A. mississippiensis* always has at least two scales in this row. It was Andy, at Grand Chenier, who termed PC18 as "the row we don't count" (meaning the row that the Ross brothers had not counted in Central America on *Crocodylus*), and we added it to our alligator data sheet. The scale counts reported in Ross (1975a), and later to the American Society of Ichthyologists and Herpetologists in Ross (1977b), and finally to much of the scientific world in Ross and Roberts (1979), all included this *A. mississippiensis* exoskeletal row, but it was not until Ross and Mayer (1983) that its one-to-one relationship with the 18th precaudal (counting away from the sacro-caudal juncture) endoskeletal vertebra became understood. However, understanding the cervico-thoracic juncture region in the American Alligator is different from understanding the nuchals, about which Ross and Mayer (1983) presented two alternative interpretations. It is thus no surprise that Ross and Ernst (1994) reported the neck as postoccipitals and three possible (of which the anterior two are obligatory) transverse rows of nuchals.

The data from Mexico and Central America, and from many museum collections in the USA, produced Ross and Ross (1974), about the special subdorsal scale irregularities (also called "caudal inclusions" or "intercalary rows" or "incomplete whorls") always present in *C. moreletii*, as compared with *C. acutus* which sometimes has small and very few lateral inclusions but never the truly ventral and extensive kind. Later, Andy went to France, and in the Paris Museum examined the large stuffed specimen of a species-group name from Tampico, Mexico, and discovered that the published picture of it was inaccurate. The artist had removed some irregular basicaudal scales, and had created an American Crocodile tail on a Morelet's Crocodile. Therefore, newly armed with the knowledge that the old French picture was misleading, Andy and I employed our neck scalation data to identify the name from 1869 as applying clearly to *C. moreletii* and in our resulting paper (Ross and Ross 1987) we confidently made the assertion that the name *mexicanus* is definitely not in the synonymy of *C. acutus*.

At times I have referred to the Ross brothers as a sibling rivalry, but this concept requires explanation, because Andy and I have always cooperatively shared our discoveries, and the other members of our family often complained that we talked together about crocodiles incessantly. Thus, all through the 1970s, 1980s and beyond, we helped each other at finding and photocopying literature, and most importantly, we shared the same definitions for head measurements, and we counted the dorsal and ventral scales on crocodilians in exactly the same way. One brother's scale counts and cranial size data could be reliably added to, or compared with the the other's. Thus, our combined library and data set of measurements and scale counts grew rapidly. Everything that one brother learned, the other brother soon knew also. It was especially useful for me that Andy researched and functionally co-authored a major and monumental listing of crocodilian literature (The Max Downes Bibliography), which, although never published, I have long had a copy. We eventually further cooperated by dividing the crocodile world into regions of individual expertise, and thus while I was concentrating on the Cuban Crocodile for Ross (1998), Andy was championing the Philippine Crocodile [eg co-authored paper by Messel *et al*. (1992)] and, separately he was investigating the crocodilians of mainland Asia [eg Ross (1975b) about *Gavialis gangeticus*].

Discussion Part 1. Doctor Crocodile of the Philippines

In his "The Philippine Crocodile" circular from Silliman University, Ross (cf. 1980) illustrated *C. mindorensis* as having an obvious transverse row of postoccipital scales, and thus distinguishable from *C. porosus* in the Philippine Islands. This simple scalation dichotomy was further employed in Ross and Datuin (1981a) for separating the Indopacific saltie (*porosus*) from the fresh water endemic (*mindorensis*) in the Philippines, including illustrations of the neck in both taxa. These drawings of neck scales were not included in Ross and Datuin (1981b). There were no scale counts in Ross (1982a), but the historical literature about the finding and naming of *C. mindorensis* was detailed, and further the coloration and ecology and the critical need for conservation was discussed with regard to both of the two crocodile species in the Philippines. Based on his own observations, Andy decided that the need for captive reproduction of *C. mindorensis* was crucial and absolutely urgent, and by the time of Ross (1982b), his internationally funded initiative was tentatively considered a success, and this potential was clearly a credit to the efforts of Professor Alcala. For an excerpt from a letter from Dr. Alcala (to the CSG) about the Silliman University Marine Laboratory, and also a report by Dr. Jose L. Diaz about the separate RP-Japan Crocodile Farming Institute (CFI) development on Palawan [see CSG Newsletter 6 (1987): 14-15, including an aerial photo of the new CFI installation]. The next year, in Alcala *et al*. (1988), the Philippine Crocodile breeding project at Silliman University was reported to the Philippine public. Later, Andy brought the Philippine Crocodile situation up to date at the Thailand meeting of the CSG (Ortega *et al*. 1994).

With the conservation plea published, Andy returned to scale counts, and to documenting the former and present geographic distribution of *C. mindorensis* in Ross and Alcala (1983), which added a table of data supporting the postoccipital scales differentiation between *C. mindorensis* and essentially sympatric Philippine *C. porosus*, and similarly a table of data distinguishing these two species from each other by ventral scale counts (from the collar to the cloacal disturbance) on the belly. The collar-vent character worked for separating these two species in the Philippines with a sample of 44 *C. mindorensis* and 32 *C. porosus*. The C-V range in the so-called Philippine "freshie" was 22 to 25 (average 23.9), compared with 29 to 34 (average 31.7) in the so-called Philippine "saltie". The PC-26 row similarly lacked overlap, because the endemic *C. mindorensis* had 4 to 6 (average 5.6) postoccipital scales, while the widespread *C. porosus* had 0 to 2 (average 0.5) in Ross and Alcala (1983). Of special note is a photograph in Messel *et al*. (1992) showing 6 postoccipitals (3-3) in PC-26, minor nape scales in PC-25 and PC-24; and, three transverse rows of nuchals, including two kinds of bilateral asymmetry. On this juvenile's left side in the anteriormost row (PC 22+23 compound), the lateralmost nuchal scale is subdivided as PC-23 and separately PC-22; and, in the posteriormost row, PC-19 has two small scales (one larger, one smaller) separated from each other by skin.

As detailed in Ross and Mayer (1983) below, *C. mindorensis* somewhat resembles *C. novaeguineae* from Irian Jaya (Indonesian New Guinea) and Papua New Guinea. My impression is that the so-called New Guinea "freshwater" crocodile (*C. novaeguineae*) has more regular and cleaner neck scalation than the so-called Philippine "freshwater" crocodile (*C. mindorensis*), and for comparison with the Messel *et al*. (1992) photograph, there is a photograph in Cox *et al*. (2003).

The Ross and Alcala (1983) article also presented taxon discriminating data about the bones and sutures on the palatal surface of cleaned skulls of *C. mindorensis* and *C. porosus* in the Philippines. Thus, with the skulls, neck scales, belly scales, coloration and distribution of the endemic Philippine Crocodile documented, Andy presented the CSG with an overview about *C. mindorensis* and *C. porosus* (distribution, commercial utilization, farming and conservation) in the Philippine Islands in Ross (1984, 1986).

In Ross (1986), Andy expanded his scope to include *C. novaeguineae* and *C. siamensis*, and comparative data about neck scales and belly collar-vent counts in all four of the species inhabiting the region near the Philippines, along with discussion about New Guinean and Indonesian crocodile history, and the ecology and human utilization of all four taxa. The 1980s were a cosmopolitan time for Andy, and while documenting the situation in Southeast Asia, he co-authored an immense bibliography and set of subject indexes to the literature pertaining to the American Alligator (Brisbin *et al*. 1986a,b), and got his own SSAR catalog account for Morelet's Crocodile published (Ross 1987).

The old fashioned dichotomy between a Philippine "Freshwater" species and a Philippine "Saltwater" species was challenged and explicitly discussed by Ross (2008a), who argued that "*Crocodylus porosus*, the so called 'Saltwater Crocodile' is, in fact, the common and ubiquitous crocodile of the Philippines and found in almost all recognizable freshwater (as well as estuarine) habitats." The same problem can occur in Papua New Guinea, as Ross (2008b) explained, saying that "I have observed both species on banks of the same river within a km of each other. The species are known to commonly overlap" (meaning *C. novaeguineae* and *C. porosus*). Based on his own explorations, Andy has long championed the vernacular name "Indopacific Crocodile" for *C. porosus*, and prominently employed it in his 1989 book "Crocodiles and Alligators" (Ross 1989c,d, 1990 a-c, 1992a,b) but in a review of the book, Whitaker (1990) said "I don't agree with changing the name of the Saltwater Crocodile to 'Indo-Pacific' crocodile... It will remain the 'salty' of croc people all over the world". Note that Rom spelled it "salty" as opposed to "saltie" (which many other authors, myself included, seem to prefer).

Discussion Part 2. Editor of widely read crocodiles book

I have never seen the 10-page long Ross (1978) paper; but in contrast, Andy's book "Crocodiles and Alligators" (originally produced by Weldon Owen Pty. Limited) is extremely widely distributed, and there are three English language releases (Australia, USA, England; 1989c,d, 1992a respectively). There are also French (Ross 1990a), German (Ross 1990b), Italian (Ross 1990c) and Dutch (Ross 1992b) versions [the latter has an added Foreword by Marinus (Rinus) S. Hoogmoed]. All 7 separate printings have exactly the same paginations (see examples of authored text below), except that the index in German is one page shorter. There was also a timely review of "Crocodiles and Alligators" by Heaton-Jones (1989).

Sometimes subtitled "An illustrated encyclopedic survey by international experts", the monumental work "Crocodiles and Alligators" was edited by Andy, and is considered "his" book, but it is a compilation of many individual papers, including a chapter by Ross and Magnusson (1989c,d, 1990a-c, 1992a,b), which did the species accounts for the living taxa. Additionally, Ross (1989b) is the taxonomic list as Andy saw it at the time. Note that he did not recognize any Fuchs subspecies, although some subspecies of common caimans were listed, including one typographical error: *Caiman crocodilus fusckis* (sic) should be *fuscus*. Interestingly, Ross (1989b) consistently correctly spelled Crocodylia with the letter-Y, while in the Introduction (page 10), he sometimes also correctly spelled Crocodilia with the letter-I, reflecting the indecision prevalent in the 1980s (eg Ross and Mayer 1983).

Technically, the Introduction page in the English language editions (1989c,d, 1992a) said "Crocodilia" with an I, while in contrast the Italian (Ross 1990c) and Dutch (Ross 1992b) versions said "Crocodylia" with a Y. The French version (Ross 1990a) did not name the order, and instead employed the vernacular synonym "les crocodiliens". Note that Ross and Magnusson (1990b) said "Unterfamilie Crocodylinae" with the Y-spelling, but the (Ross 1990a) version said "sous-famille des crocodilinés" in French. In Ross and Magnusson (1992b) it is "subfamilie Crocodylinae"; and, in (Ross 1990c) it is "sottofamiglia Crocodylinae; and, lastly, on page 64 it is "subfamily Crocodylinae" in the (Ross 1989a,b, 1992a) English language versions. Nonetheless, Ross (1989a,b, 1990c, 1992a) recognized the Crocodylia, Crocodylidae, Crocodylinae, Alligatorinae and Gavialinae, but Ross (1990a) is different (including "sous-famille des alligatorinés" and "sous-famille des gavialinés"). In all cases, *Tomistoma schlegelii* is discussed and tentatively (and in my opinion, correctly) included within the crocodiles group, as opposed to the alligators or gharial. Concerning the Crocodilia or alternatively Crocodylia spelling question, I today endorse Crocodylia, as recently justified by Ross *et al.* (2010)

The color paintings in Ross and Magnusson (1989c,d, 1990a-c, 1992a,b) are terrible, and Andy was furious about them. As scale counters, he and I freely say that the taxonomic account illustrations are not reliable. Otherwise, however, the book is a classic. It is the first and the best of its kind, and by far the most cited of the so-called "coffee table" books about crocodilians in the scientific literature. There is even a "box" by me about the evolution of the dorsal neck, body and tail scales, citable as F.D. Ross (1989), in which I summarized some of the most important concepts from Ross and Mayer (1983). In the 1990 French translation, my one page box was titled "Variations du bouclier dorsal", and in 1990 in Italian "Variazioni nella corazza dorsale", and in 1992 in Dutch it became "Variaties in rugpantser". In all cases, the page citation for F.D. Ross (1989) is the same, and similarly the Ross and Magnusson (1989c,d, 1990a-c, 1992a,b) chapter, and also Andy's one page taxon listing (Ross 1989c,d, 1990a-c, 1992a,b), all retain their page numbers. This also applies to the Pooley and Ross (1989c,d, 1990a-c, 1992a,b) on "Mortality and predators" (pp. 92-97, 99-101), Fuchs *et al.* (1989c,d, 1990a-c, 1992a,b) on "Crocodile skin products" (pp. 188-195) and Ross *et al.* (1989c,d, 1990a-c, 1992a,b) about "Farming and ranching" (pp. 202-213).

I have often said that "things happen slowly in crocodiles" (meaning crocodile studies), but in the case of "the row we don't count" it is worth remembering that it was in 1972-1973 in Central America (and museum collections) while examining *C. acutus* and *C. moreletii*, that we did not count PC-18, and it was in 1974 in Louisiana that we noticed PC-18 on *A. mississippiensis*, and then in Ross and Roberts (1979) that the American Alligator's anteriormost body row was mentioned in print ("the 18 transverse body scale rows"), and then Ross and Mayer (1983) developed, illustrated and proposed as a global model (in the "peer reviewed" literature), and then explained briefly in the CSG Newsletter (1987 6: 15) as a technical note (written by F.D. Ross), and lastly in F.D. Ross (1989c,d, 1990a-c, 1992a,b) the basic idea and its significance was reported to the world in five languages. In this case, a development in crocodile studies appeared to be happening remarkably fast [see also Aoki (1985) below].

To my surprise, the 1995 guide for the identification of CITES crocodilians, despite being scientifically advised by James Perran Ross and F. Wayne King, who both knew about Ross and Roberts (1979) and Ross and Mayer (1983), did not adopt the new insight concerning the dorsal scalation. The CITES guide counted the number of transverse rows of ventral scales in the collar-vent series, but did not report the number of transverse dorsal rows on the body. It was content to note that in *C. acutus* the "dorsals" (which are universally PC-1 to a theoretically possible PC-18) are not continuous with the nuchals, while in *C johnstoni*, *T. schlegelii* and *G. gangeticus* the dorsals are continuous with the nuchals (meaning that PC-15, PC-16, PC-17, PC-18 and PC-19 are present). Again speaking as a dorsal scale counting person, the taxon account pictures in the 1995 CITES guide are not trustworthy, and (optional) did not show the dorsal scalation from directly above the animal. It was an opportunity lost.

Perhaps in 1995 Wayne King and Perran Ross decided that the Ross and Mayer (1983) method was inappropriate for identifying hornback hides, and too technically difficult on whole animals because it involves feeling the posterior edge of the pelvis, and estimating the level of the out-streched femur bones. However, the result is remarkably accurate for locating the sacro-caudal juncture with true homology, and thus defining the first precaudal transverse row of scales (PC-1), and from it also the level where the tail begins (caudal row 1). Further, the location of PC-1 can be determined often (but not always) by examining a specimen (including flat skins and photos of them) viewed from directly above it. However, because the Ross and Mayer (1983) model for the nuchals and postoccipitals on the neck involved their interpretation as compound rows with uncertainty in several taxa, and because an anatomist specializing in muscles, Dr. Eberhard Frey, had already differed from Ross and Mayer (1983) about vertebral correspondences on the neck (but theoretically not on the body and tail) of the American alligator, it is perhaps understandable that the 1995 CITES guide stayed within the realm of established and traditional practice, and that it handled the variation in neck scales with pictures and a terminology not involving PC (precaudal transverse dorsal row) numbers. Note that, published in 1988, Dr. Frey's dorsal scalation diagrams are, in my opinion, untrustworthy (I would need multiple specimens to confirm his sacro-caudal juncture; and, separately, on the neck, his schema has "PC23" and "PC24" and "PC25" definitely wrong. There is a fundamental difference of interpretation about the postoccipital region, and Frey is in error. I trust Eberhard Frey about crocodilian musculature, but his sample was one specimen, and thus, for the dorsal scalation of *A. mississippiensis*, I recommend Ross and Roberts (1979), and Ross and Ernst (1994), and additionally note that Ross and Mayer (1983) explicitly stated that in the American Alligator, "the most prominent nape row is PC 25, ordinarily with two, but with up to six ossified elements. PC 25 is the postoccipital of Ross and Roberts (1979); in *Crocodylus* this term refers to PC 26."

Three additional works that opted to not report dorsal transverse scale rows with their precaudal ("PC") and caudal ("C", counting posteriorly away from the sacro-caudal juncture) numbers in the Ross and Mayer (1983) terminology were Ross (1987), Ross and Ernst (1994), and Ernst *et al*. (1999). Note that about the Morelet's Crocodile, Ross (1987) said "the neck armor normally consists of four or more postoccipital, and six or more nuchal scales. The tail exhibits ventral and often ventro-lateral intercalary irregularity of the anterior caudal whorls. The scales on the flanks of the rear legs are smooth. The contiguous dorsal scales are asymmetric, often with a reduction in the number of contiguous ossified scales found in some rows across the back at midbody." About the American Crocodile, Ernst *et al*. (1999) said "the cervical shield is larger than the surrounding scales and is normally composed of six (often less, seldom more) scales. The nape has four occipital scales. The dorsal body armour usually has 16 (14-17) continuous precaudal rows that vary in both number and size of scales per row; at least some of the scales are asymmetrical. Midbody scale rows normally have 4 (2-6) contiguous scales per row. Ventral scales are in 26-34 transverse rows."

Things really do happen slowly in crocodile studies. The word "nape" was defined by Ross and Mayer (1983) as the postoccipital (or "occipital") region immediately posterior to the cranial table. The cervical shield is the nuchals cluster. PC-19 to PC-23 are nuchals, and PC-24 to PC-26 are nape scales. Be advised, however, that in the old literature, the words "nuchal" and "nape" can both mean the whole dorsal surface of the neck, and the "nuchal scales" often meant PC-26 (and sometimes PC-25 and PC-24 also), while simultaneously the "nuchals" of today were called the cervical shield. Thus, postoccipitals and occipitals (nape scales, PC-24 to PC-26) are different from nuchals (cervical shield, PC-19 to PC-23) in the SSAR species accounts for *C. moreletii* in 1987, and *C. acutus* in 1999. The "continuous" dorsal armor consists of transverse rows that directly border each other (as opposed to being separated from their neighboring transverse row by a space of unarmored skin). The "contiguous" scales within a transverse row each similarly directly contact their neighbor(s) within the row (as opposed to detached "flank" scales). In these two individual New World *Crocodylus* species, both of which are characterized as being remarkably irregular in scale placement, and sometimes with an isolated scale obviously missing from a transverse row, the definition of contiguous gets slightly stretched in an effort to functionally agree with the global living crocodilian model, in which there is a "carapace" on the body.

Discussion Part 3. The resurrection of *Crocodylus raninus*

Philippine *C. porosus* and *C. mindorensis* received only very minor mention (no descriptive data) in Ross and Lazell (1990: Dinigat and Siargo islands), and also later in Ross and Gonzales (1992: the Catanduanes); and thus in contrast, it was Ross (1990d) about the Kalimantan Island (Borneo Island) *C. raninus*, compared with *C. siamensis* and *C. porosus*, in which Andy returned to presenting scalation data, and in Ross (1990d) he explained that "scale counts follow Ross and Roberts (1979), King and Brazaitis (1971), and Brazaitis (1973, 1974). Dorsal neck armor terminology of Ross and Mayer (1983) is given in parentheses where pertinent".

In Ross (1990d), Andy demonstrated the throat scales as a method of distinguishing the Siamese Crocodile, when compared with any other *Crocodylus* in the Indopacific region. The (Ross 1990d) paper included a graph (Fig. 2) which clearly showed that the postoccipitals (PC-26) group together *C. johnstoni*, *C. novaeguineae*, *C. mindorensis*, *C. raninus*, *C. siamensis* and *C. palustris* as regional species that are distinguishable from *C. porosus*. His sample size for the Philippine Crocodile in Ross (1990d: Fig. 2) was 52 animals. In Ross (1990d: Fig. 3), *C. johnstoni*, *C. novaeguineae*, *C. mindorensis* and *C. raninus* grouped together as distinct from *C. siamensis*, *C. palustris* and *C. porosus* when their numbers of ventral scales in the collar to the cloaca series (C-V, see definition below) were plotted. Lastly, in Ross (1990d: Fig. 5) the throat scales grouped *C. johnstoni*, *C. novaeguineae*, *C. mindorensis*, *C. palustris* and *C. porosus* together, and separated them all from *C. siamensis*. These findings, plus additional comments concerning individual specimens and populations that deviate from the expected (do not exactly agree with the scale counts or other characters of any of the IUCN- or CITES-recognized species in Southeast Asia), were presented by Ross (1994). Additionally, Andy's optimistic opinions about the CFI project were paraphrased in the CSG Newsletter [1994 13(2): 18] report of the 1994 CSG Steering Committee meeting. There is a photo of Andy (centre) at the RP-Japan Crocodile Farming Institute (CFI) captive-breeding facility in Puerto Princessa City, Palawan, in Messel *et al*. (1992).

The Ross (1992) paper clarified *C. raninus* with a lectotype; and, three years later in Ross *et al*. (1995), Andy and others did the same for the Siamese Crocodile. The abstract of Ross *et al*. (1995) was paraphrased by King and Ross (1995). In addition to selected skull characters, there was now a system of scale counts (postoccipitals, collar-vent, and throat) that, when combined, distinguished *C. raninus* from all other *Crocodylus* in the Borneo Island (Kalimantan) region. An official report (Ross *et al*. 1996) was not published, but Wirjoamodjo (1996) provided a short and informative summary of it, and included the news that "two captive crocodiles... exhibited scale patterns similar to the type of *C. raninus* and other probably related crocodiles *C. mindorensis* and *C. novaeguineae* (north coast population)".

Finally, in Ross *et al*. (1998) it was reported that Andy and others had gone to Kalimantan and examined a large number of crocodiles in the wild and also in captivity, and among the latter there were a very few *C. raninus* still alive. Circumstantial evidence indicated that *C. raninus* could still be breeding in the forest, and thus the IUCN was officially offered the opportunity to add *C. raninus* to the CITES list; but alas, this freshwater reptile, more endangered than even the Philippine, Cuban and Siamese Crocodiles, has only approached being recognized as a taxon of concern to CITES. The species "*Crocodylus raninus* Müller and Schlegel 1844" was listed alphabetically between *C. porosus* and *C. rhombifer* in a checklist (World Conservation Monitoring Centre 1993) with the taxonomy and systematics of the living crocodilians probably significantly authored by Brian Groombridge. It was concluded that "the species may be comprised of animals from both Appendix I (Malaysia: Sabah, Sarawak) and Appendix II (Indonesia: Kalimantan) populations; the appropriate listing remains to be determined. The IUCN Red List status category has not yet been assessed."

Note that Das and Charles (2000) was reprinted in 2002 [CSG Newsletter 21(1): 10-11], titled "New record of a freshwater crocodile from Brunei", with the following note from the editors (F.W. King and J.P. Ross). "We reprint the article above with caution due to the continuing uncertainty about exactly to which crocodilian taxon the name '*raninus*' should be applied. C.A. Ross 1990 and 1991 contends that the specimens he has designated differ from both *C. porosus* and *C. siamensis*, but there is little evidence either that it is restricted to Borneo or that it differs significantly from *C. novaeguineae* from the north coast of New Guinea. We are aware of genetic analyses in progress and in press that will shed much needed light on this vexing problem. We also note that the author's reference above to the estuarine habitat of *C. porosus* is in error, the species is known to thrive in fresh water swamps. While the discovery of an additional skull assignable to '*raninus*' sensu Ross 1991 is of interest, the taxonomic position of these specimens and the diversity of freshwater crocodilians in Borneo remains to be determined."

For an update and focus on the endangered population of *C. siamensis* in East Kalimantan, see Kurniati (2005) which cites Cox (2004). Ortega and Regoniel (1994) provide an update on "Conservation, management and farming of crocodiles in the Philippines" and Regoniel *et al*. (1994) on "Distribution and status of crocodiles in Palawan Province". From personal correspondence with Patrick Regoniel (1992 and 1994), I know that he had some bad luck counting the dorsal scales on the *C. mindorensis* at the old CFI, and I hope that his data (n= 368) will be revised and get published. Recently, Ross (2008b) said that "almost all *Crocodylus mindorensis* used as founder stock at the Palawan Wildlife Rehabilitation and Conservation Center (formerly the Crocodile Farming Institute, CFI) were obtained from captive sources." Therefore, the locality data of Regoniel's sample, and others like it, are primarily anecdotal. Today, it can be generally presumed that captive *C. mindorensis* have been transported from one island to another within the Philippines (the whole archipelago), and thus the release of captive-reared stock to the wild is not a simple question (Ross 2008b).

Discussion Part 4. A working lifetime counting scales

Andy was effective at getting papers published, and in the process was a pragmatist. For example, while negotiating the wording in Ross and Ross (1987) about the neck scales of the Tampico, Mexico, crocodile named *mexicanus* Bocourt, 1869, Andy argued that rather than calling the postoccipitals in *C. moreletii* and *C. acutus* as transverse row PC-26, he preferred keeping them as postoccipitals, because he had illustrated them under that name for *C. mindorensis*, and the meaning of the term was widely known. In hindsight, he was perhaps correct because in some taxa there is more than one transverse row, and when PC-25 and PC-24 are present, always vestigially, interpretation becomes very difficult. The CITES guide in 1995 followed the safest model by calling PC-24, PC-25 and PC-26 collectively as postoccipital scales.

A product of the Louisiana (Rockefeller), Georgia (Okefenokee) and Florida (Gainesville and Everglades) trip in 1974 counting scales and taking blood samples, Khan *et al*. (1980) is Andy's (and my) contribution to veterinary research, for which Andy had an explicit US Federal Permit (see Ross 1974). This business of needing a permit to examine protected animals started in the early 1970s, and persists in many places today. It makes studying wild crocodilians extremely difficult, and has slowed or prevented much research that probably should not have been regulated at all. Counting scales and taking blood did not hurt the alligators. The Khan *et al*. (1980) paper reported a haemogregarine parasite in the blood of *A mississippiensis*, similar to Villapa *et al*. (1992).

Sightings of crocodiles on Dalupiri Island in the Batan and Babuyan region of the Luzon Strait in 1990 were noted in Ross (2005), but species identification was not possible. Following up on the Ross (2005) suggestion, Oliveros *et al*. (2005) reported the capture of a Caucauayan Creek crocodile, and asserted that "the presence of six postoccipital scales and 25 transverse ventral scale rows identifies the animal as *C. mindorensis*". See Oliveros *et al*. (2006) for the detailed report on the Batan-group (Luzon Strait) island in the northern Philippines.

Also relevant to crocodilians, Ross and Davenport (1992) reviewed Steve Grenard's (1991) book, and thus Andy got his first publication in the prestigious magazine Copeia. The following year, Ross (1993) reviewed a book about the avifauna of the Philippine Islands, which by then he had explored rather extensively, often in the company of natural history specialists, as evidenced by Kennedy and Ross (1987) and Ross and Ramos (1992) about birds, Ross *et al*. (1988) and Ota and Ross (1994) about several snakes, and Ross (1989a) and Ota and Ross (1990) about lizards. All of these snake, lizard and bird papers dealt directly with the Philippines (and Taiwan), but Ross and Crumley (1982) was about a tortoise from India and Ross (1988) was about birds on New Caledonia.

Discussion Part 5. Scalation of the Philippine Crocodile

Scalation drawings of the endemic Philippine Crocodile are relatively scarce, and of variable quality. The dorsal view of the head-end, showing four thoracic rows, an unarmored space at the level of the front legs, and two transverse rows of nuchals (4 anterior, 2 posterior), and the unarmored space between the nuchals and the postoccipitals (of which 6 of the latter are shown, 3 and 3 in one transverse row that is distinctly separated across the midline) in Ross (cf. 1980) was repeated in Ross and Datuin (1981a,b: Fig. 1a). Additionally, in Ross and Datuin (1981a,b: Fig. 1b) an equivalent dorsal drawing (4 thoracic, 2 nuchal rows as 4 scales over 2, and no postoccipitals) of *C. porosus* was given for comparison; and, also a ventral map of the scalation (throat, collar, transverse belly rows, cloaca, and subdorsal caudal whorls) of a general crocodile (not identified to species) was added.

The identification of the four thoracic transverse dorsal rows of scales shown in Ross (cf. 1980); and Ross and Datuin (1981a,b: Fig. 1a) as probably being PC-14 to PC-17 happened in Ross and Mayer (1983) who illustrated the neck of a specimen of *C. mindorensis* that has three transverse rows of nuchals (Ross and Mayer 1983: Fig. 7c), although PC-19 is somewhat vestigial (reduced to a single large scale, and a smaller one). Keeping in mind that the anteriormost row of nuchals is PC-22 and PC-23 combined together as PC-22+23 compound, and that PC-21 and PC-20 also combine together as PC-20+21 compound, but PC-19 is not a compound row; and, that the nuchals in *Crocodylus* are PC-19 with at most two scales in it, PC-20+21 generally with at most two scales in it, and PC-22+23 usually with four scales in it; and, that the postoccipitals in the Philippine Crocodile are PC-26, the following quotation from Ross and Mayer (1983) is based on 22 specimens (collectively called *novaeguineae*), of which 5 are from the Philippines (Ross and Mayer 1983).

"In *Crocodylus novaeguineae*, the continuous and contiguous precaudal armor is regular in scute dimensions and keel row alignment. As in *C. porosus* and *C. siamensis*, interscute triangles occur. There are 16 or 17 continuous precaudal rows, with 7 to 12, usually 8, contiguous scutes at midbody. Detached flank scutes, though reduced, sometimes form an additional keeled row on each side. The thoracic and cervical armors are separated by spaces of skin. PC 18 is represented by vestiges or elements separated on the midline. PC 19 is absent, or, in a single specimen, rudimentary. PC 20+21 has two scutes, and PC 22+23 has two large median elements, and may have one or two smaller elements on either side. In many individuals, smooth or fine granular skin separates the two cervical rows (PC 20+21 and PC 22+23) or the left and right halves of one or both. Sometimes PC 22 and PC 23 are not compound. All or any combination of cervical scutes may be noncontiguous. There are 4 to 6 scutes in PC 26. PC 24 and PC 25 are sometimes not evident, but are usually present as bluntly keeled scales.

"Previous authors have differed on whether the freshwater crocodiles of the Philippines should be recognized as a species (*mindorensis*) distinct from *C. novaeguineae*, or merely as a subspecies of the latter. Wermuth and Mertens (1977) have elevated *mindorensis* to full species status. Tables 1 and 2 include with *C. novaeguineae* data for a few *mindorensis*. The preceding account of the cervical armor, however, applies only to *C. novaeguineae* proper. *C. mindorensis* differs from *C. novaeguineae* in that PC 19 is better developed, being present as one or two elements in three of five individuals; PC 22+23 has four elements; the scutes of the cervical shield are little or not at all separated by skin; and the nape scutes between the cervical shield and the prominent nape row (PC 26) are better developed, sometimes in two distinct rows. The extremal count of twelve scutes at midbody is from an individual from the Philippines. In general, *mindorensis* has a more well-developed armor than *novaeguineae*, though this conclusion is based on a small sample and should be considered tentative."

The best artwork and most informative suite of drawings of *C. mindorensis* is from Andy's personal (I think they did fieldwork together) friend "Rio" from Japan, and Aoki (1985) is the most important paper about the scalation of the two species of *Crocodylus* in the Philippine Islands. It is certain that Andy was the person who explained the Ross and Mayer (1983) method to Aoki, and as far as I can see, Aoki (1985) got it right. His illustrated analysis of the dorsal armor is correct, and further, he illustrated and detailed the ventral scalation of a *C. mindorensis* specimen accurately as well. He said (page 8) that the collar-vent count is 25 in the Philippine Crocodile, based on its type-description from Karl Patterson Schmidt in 1935. Note that the photo in Oliveros *et al*. (2005) is said to show 25 ventral scale rows, but is not clear enough to verify their count.

I do not pretend to really know if the "Mindoro or Philippines Crocodile" is a species or a subspecies. About it (as "*Crocodylus* n*ovaeguineae mindorensis*") it was recently said that "this population is listed by CITES as a subspecies, although all systematists now recognize it as a full species" (WCMC 1993). Peripherally, yet relevant to their attitude about subspecies in general, WCMC (1993) did not recognize any subspecies in "*Crocodylus cataphractus*" and "*Crocodylus niloticus*" (and thus they declined the opportunity to accept any of the Fuchs subspecies from Africa), but this same 1993 list said that "*Caiman yacare* Daudin 1801 (= *Caiman crocodilus yacare*; includes *Caiman crocodilus matogrossiensis* and *Caiman crocodylus* [(sic) = *Caiman crocodilus*] *paraguayensis*)" for the Yacare Caiman. I am convinced that they discussed two Fuchs subspecies too many in the Latin American caimans. In contrast, however, I have no opinion about the assertion in Aoki (1985) that the Philippine population of the Indo-Pacific Crocodile is *C. porosus biporcatus*. What I can say today is that Rio Aoki deserves credit for bringing the combination *Mecistops cataphractus* (Cuvier) back into common parlance.

Special Section. Two of Rio Aoki's (1985) excellent illustrations

Similar to the treatment of *C. mindorensis* and *C. novaeguineae* in Ross and Mayer (1983) above, I today note that the dorsal scale patterns on the neck of these two species resemble each other to such a remarkable extent that, in truth, I can not predict the locality (Philippines versus New Guinea) of a specimen from photos of its cervical and thoracic scalation. Both taxa have remarkably variable nuchals, and although some individuals have the classic *Crocodylus* four over two (total 6 scutes in the cervical shield), other specimens exhibit various degrees of degeneration of usually the anterior transverse row (PC 22+23 compound), and sometimes it and also PC 20+21 can (both, or either one individually) have lateral scales that contact (or nearly contact) the nuchals, creating the temptation to count these distal elements as contiguous members of a transverse row.

I have seen photographs from Andy that show midline flexible skin separating the left and right halves of PC 22+23 from each other in *C. novaeguineae* (California Academy of Sciences, south coast of Papua), and also in *C. mindorensis* from the Philippines (US National Museum, CAR field series). Similarly, Andy's photos show that PC 22+23 can be reduced in size in comparison with PC 20+21 in both taxa. Further, the flexible space posterior to PC 20+21 can have traces of PC-19 or alternatively PC-18 (it is often impossible to tell which one), or both. Finally, there can be division of PC 22+23 into its component PC-22 and PC-23 transverse rows (to a greater or lesser degree), often asymmetrically; and, in these cases, three transverse rows of nuchals are present, but the third row is not PC-19. The high degree of variability observed among the nuchal scales in *C. mindorensis* and *C. novaeguineae* gives me the impression that having a classical *Crocodylus* shield protecting the neck is not important to these animals. To the contrary, it is apparently obtaining greater flexibility that is happening. The PC-19 to PC-23 region can have thoracic-size scales in extreme cases, but when individual scutes get smaller, there becomes more of them, and intervening spaces of granular skin make the neck shield less rigid.

Similarly, the postoccipital scales on the nape in *C. mindorensis* resemble those on the south coast *C. novaeguineae* in Andy's pictures. The most obvious transverse row is PC-26, but elements of PC-25 and PC-24 can be only slightly smaller. The Jack Cox dorsolateral neck photograph in the CSG Newsletter [22(2): 7] was said to show a "postoccipital scute pattern of two rows of three enlarged scutes" on a southern *C. novaeguineae*. Given bilateral symmetry, I see one enlarged transverse row with approximately three scutes on either side of the flexible skin midline gap, and the smaller scales (PC-25 and PC-24) between the postoccipitals (PC-26) and the anterior row of nuchals (PC 22+23) are too reduced to count.

In the Wayne King truly dorsal view neck photograph of *C. mindorensis* in the CSG Newsletter [11(1): 20], one can see PC-26 as having 6 scales (3 left, midline gap, 3 right), and PC-25 and PC-24 are reduced to become three-dimensional reflective symmetry, meaning functionally working as granular scales similar to the lateral scalation on the neck. Some endemic Philippine and New Guinea *Crocodylus* can have essentially identical neck armor and cervico-thoracic flexibility zones, with PC-17 appearing to be the commonest anterior end of the thoracic zone of the carapace in both taxa.

Museum collections tend to accumulate unusual specimens, and often subjectively select for strange and odd nuchals and other dorsal scalation peculiarities beyond the normal. Some of the pictures that people have sent to me have been totally unexpected extremes of variation. Rather than illustrating known anomalies, fascinating (and sometimes instructive) as they are, my Figure 1 is a drawing of what Andy's friend Rio Aoki thought was a normal and representative *C. mindorensis*.

Figure 1 is appended so that it can fill a whole page. Counting the dorsal scales involves knowing which ones don't count. Thus, because it has been intelligently edited, this drawing from Aoki (1985) is easier to discuss than a photograph (or even a specimen) would be.

Starting at its anterior end, the specimen illustrated in Aoki (1985: Fig. 5) has 6 postoccipital scales in transverse row PC-26, because even though they don't all actually contact each other contiguously, it fits the general *Crocodylus* model. Similarly, this Figure 1 example of *C. mindorensis* has four scutes in PC 22+23, even though the lateralmost scutes at the two distal ends of this compound transverse row lack strict contiguity. They are interpreted as present, but slightly vestigial. The median pair of large scutes in the anterior row of nuchals physically contact each other just enough that they clearly qualify as contiguous, although to a lesser degree than in the transverse row immediately posterior to it (PC 20+21 compound), which has two scutes with complete midline contiguity. Thus, because PC-19 is completely absent in this drawing, the cervical shield consists of six nuchals (four over two), and the the specimen agrees with the Philippine endemic crocodile neck scales in Ross (cf. 1980), and Ross and Datuin (1981a). Also, it agrees with the picture in Ross and Mayer (1983: Fig. 7c), except that my 1983 drawing has two vestigial and bilaterally asymmetrical and noncontiguous scales identified as PC-19. So, the 6 postoccipitals (PC-26) are separated from the 6 prominent nuchals by a space of granular skin, and the 6 nuchals (PC 22+23 compound and PC 20+21 compound) are similarly separated from the thoracic armor by flexible skin; and, finally, sometimes PC-19 is vestigially present.

Having analyzed the neck, the next question concerns where the thoracic dorsal armor really starts. We know that PC-19 is absent in Figure 1, but we do not know if the vestigial transverse row at the anterior edge of the carapace is PC-18 or PC-17. The prediction from Ross and Mayer (1983: Table 1) is 0 to 5 scales in PC-17, with a mode of 4 scutes (often variously vestigial and irregular in size). Further, the same table reported PC-18 as always zero (n= 5 *mindorensis*). So, to see if Aoki's (1985: Fig. 5) is really missing PC-18, and has PC-17 with 4 vestigially represented scales (not truly contiguous, but they qualify as formerly contiguous in this case), we need to find PC-1 and then count from the sacro-caudal juncture going towards the neck (PC-1, PC-2, PC-3, etc.) until the anterior edge of the carapace is reached. This vestigial row that qualifies should be the 17th precaudal row, but Ross and Mayer (1983) predict that it could possibly be PC-16, with both PC-17 and PC-18 absent.

Fortunately, PC-1 can usually be identified on a truly dorsal view photo or extremely careful drawing. It is the transverse dorsal row immediately posterior to the narrowest row across the pelvic region, meaning having the shortest transverse length across the four scales in PC-2. In Figure 1, the tiny extra scale in (and inside) PC-2 does not count, because it is obviously derived from one of the four major scales. However, in contrast, the small scale shown at the left distal end of PC-1 does count, and its presence makes PC-1 slightly wider than PC-2. Thus, Aoki's drawing shows two transverse rows of dorsal caudal scales (C-1 and C-2, counting away from the sacro-caudal division); and, anterior to C-1, there are 17 continuous transverse rows that collectively form this crocodile's carapace.

The widest carapace row at approximately midbelly level is composed of 8 contiguous scales, and at that level there are detached flank scales (one shown slightly separated from each distal end of the contiguous row). Unlike the interscale spaces of granular skin that were tolerated in PC-17, the granular skin separating the carapace from the flank scales in the midbody region (PC-7 to PC-14 in Rio's drawing) is not tolerated. The carapace maximum on this specimen is 8 scales across, and on this individual it happens in PC-6 and all the way forward through to PC-13. Thus, 6 scales across occurs in PC-4 and PC-5, and also in PC-14 and PC-15. That leaves PC-2 and PC-3, and also PC-16 and PC-17 with 4 (because the longitudinal flank row is absent anterior to PC-14, and thus the rules of contiguity change).

So, on the Figure 1 *C. mindorensis*, PC-1 has 5, PC-2 has 4 (with a minor internal anomoly), PC-3 has 4 (slightly wider than PC-2 was), and then the carapace widens further to 6 scutes in PC-4 and PC-5, and to 8 in PC-6. The drawing shows PC-7 with 8 scutes, plus a flanker on the right side (which does not count). As a general rule, PC-1 through PC-9 have the same counts in *C. mindorensis* and *C. porosus*, but from PC-10 to PC-14 the Philippine endemic has more scales per row than the Indo-Pacific Crocodile has (Ross and Mayer 1983: Table 1). Further, the same table reported zero as possible in *C. porosus* in PC-15, PC-16, and PC-17, and always in PC-18.

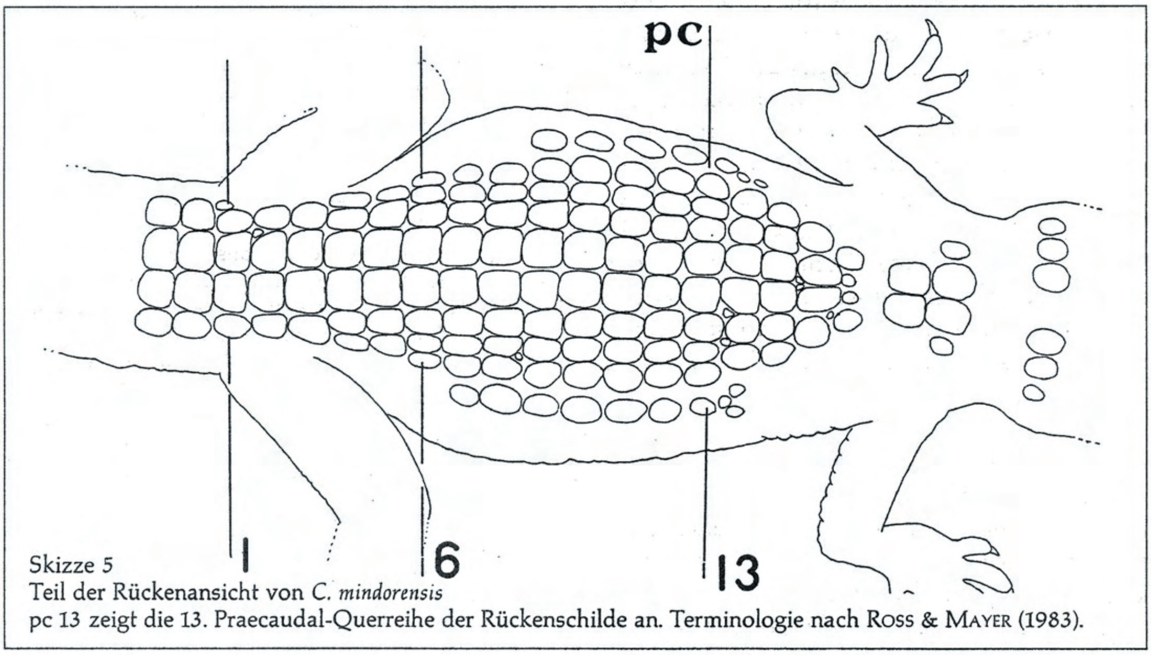


Figure 1. Rio Aoki's dorsal view of a *Crocodylus mindorensis* specimen.

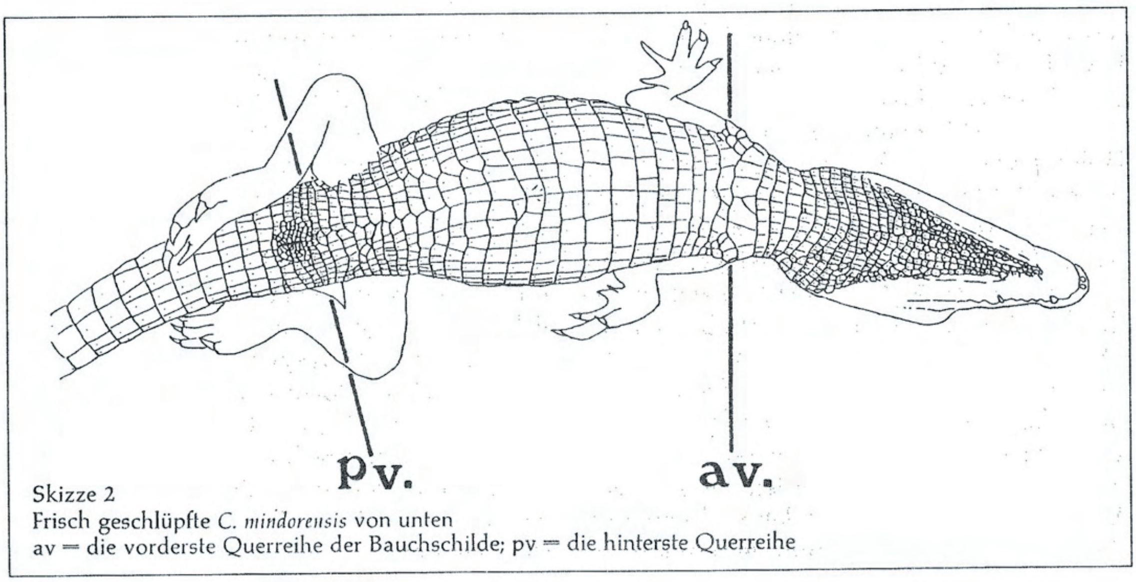


Figure 2. Rio Aoki's ventral view of a *Crocodylus mindorensis* specimen.

Note that the two tiny scales at the posterior edge of the right side of PC-12 in Figure 1 are interscute triangles, which occur in both species, but are strongly developed and more ubiquitous in *C. porosus*. Further note that the Ross and Mayer (1983) sample had only 5 Philippine *C. porosus* out of a total 12 for the species. The exact range of variation in the carapace armor of "salties" from the Philippines remains unknown.

Difficult as it is, the dorsal armor makes more sense than the belly scales, because in the former we know how many transverse rows of scales is ancestral for the crocodile. It is always PC-1 to PC-26 (or PC-27-?) possible. The number of rows is the number of vertebrae. In contrast, there is no known vertebral correspondence on the precloacal ventrum. The postcloacal ventral caudal "whorls" are usually continuous with the dorsal caudal rows, but this is not true on the belly and throat (including the collar). Therefore, there is nothing to do except counting the number of so-called "transverse rows" of scales between the collar and the vent (the C-V count) in Figure 2.

Counting the ventral scales involves seeing everything; and, like many of his other excellent illustrations (he figured the neonate nape of *C. porosus* compared with *C. mindorensis*, and also detailed some caudal scalation differences), this drawing (Figure 2) from Aoki (1985) is as good as a photograph. However, truly ventral view illustrations often do not show the lateral midbelly edges of the properly ventral kind of scales that are arranged in transverse rows. Note that within these rows the elements have the theoretical potential of their osteoderms suturing together, and each scale fills the height of its row (if it takes two scales to fill the row, they are not "ventrals" but are flank scales).

Unfortunately the belly scalation is not strictly bilaterally symmetrical, and there are often small midline anomalies. Different people count the collar-vent series differently. As detailed below, Andy was in the habit of counting the C-V number along the midline, but I prefer to make two counts, one slightly (about one full scale away) to the left of the midline, and one slightly to the right of the midline, and then calculate the average. The posterior end of the C-V count is always extremely small scales, and it is usually difficult to see exactly which transverse row is the first to pass anterior to the cloacal disturbance. In Figure 2, one scale to the left of the midline (from his "pv." to his "av."), I count 25 C-V rows, and on the right side (again one full scale away from the midline) I see 26 C-V rows, and thus the average is 25.5 rows crossing the midline. This kind of difference between the left and right sides is frequently encountered, and given the common ambiguity about which row is the posterior end of the series, one person's C-V count can easily differ slightly from another person's result. Depending on interpretation of where the cloaca stops and the belly scales start, 24 left and 25 right for an average of 24.5 could be correct in Figure 2. It is possible that counting along the midline will yield the same result as the pair of parallel counts, but often the midline count is higher, caused by midline anomalies.

In Figure 2, the 12th "row" posterior to the collar has one big scale on the immediate left-side of the midline, while on the right-side its place is occupied by two scales, one of which is roughly triangular. The advantage to performing the C-V count approximately one full scale away from the midline is that it avoids this problem. Similarly, the midline is a zigzag like a zipper in the region between the hind limbs. The left and right halves of the "rows" in this zipper zone are slightly offset from each other, and trying to count the number of transverse rows that cross the midline gets nasty.

In theory, the opening of the cloaca is surrounded by a roughly circular "cloacal oval" zone of tiny and irregularly shaped special scales. When I look carefully at Figure 2, the vent opening (the black longitudinal slit) seems to have the row that Aoki marked as the posteriormost qualifying ventral body row ("pv.") too close to the slit, and it is possible that if I had the physical specimen in hand, I might select the row immediately anterior to Aoki's row as the posterior end of my collar-vent count. Still, though, it is approximately 25 C-V rows.

Note that Aoki's indication lines for the anteriormost transverse row in the C-V count ("av.") do not extend far enough to reach the midline region where the collar-vent count happens. The collar that separates the throat scales from the belly scales is clearly discernible on this specimen. It has a triangular midline anomaly in it, and the more rectangular scales near its middle are longer than they are wide. Some species have less obvious collars. The roughly triangular shaped group of 7 or 8 small scales at the proximal end of the forelimb (where Aoki's arrows actually point) are neither collar scales nor the first post-collar row. They are something special, and are completely excluded from the CITES collar-vent count.

The collar region in Figure 2 looks exactly like the collars that Andy and I found most common in the New World species of *Crocodylus*. It is hard to see, but Aoki's drawing shows essentially every ventral scale (except the cloacal oval and except the triangular midline anomaly in the collar) as having a single pore centered in the posterior third of it.

Conclusion. Some C.A. Ross words about counting ventral scales

At the Smithsonian Institution in Washington, D.C., my brother Andy is famous for his stamina and efficiency at reducing avian carcasses to their skeletal elements. It was guessed by one of his supervisors that Andy skeletonized somewhere between 600 and 800 birds in a single year. Later, building on his work in the Division of Birds, and building on his earlier work reducing manatee carcasses to bones for the US Fish & Wildlife Service in Gainesville, Florida (where he became friends with James Perran Ross of CSG fame), Andy was given the opportunity to design and then hold the directorship of the USNM's marine mammal skeletonizing facility. An anecdote from Charley Potter (courtesy of George R. Zug) is as follows: "One of my best remembrances of Mr. Ross was his sitting at the fume hood with the sash all the way up (= hood not working worth a damn), smoking a cigarette while washing bird bones with gasoline... gasoline all over the place, the whole place reeking of gas, no gloves, etc., and when I said Hello, he said 'What the fuck do you want?' and then complained about working conditions... in the new lab... which by the by he did have a significant role in designing etc." The paper by Von Endt *et al*. (1999) resulted from Andy's work as a preparator of bird bones.

With Ross (1977a, 2008a,b) as exceptions, it is a general rule that Andy's publications were not written in the first person (except sometimes Acknowledgments). The pronouns "I" and "we" are scarce, as are "my" and "our". Therefore, as my conclusion, the following quotation is from a typewritten letter (to me at the Museum of Comparative Zoology at Harvard University) dated 4 February 1988 (from Andy at the US National Museum of Natural History).

> "I have indeed looked at a lot of *Crocodylus* bellies recently and in fact had call to look at alligatorid bellies briefly as well.
>
> "In brief, the collar is of little use as a diagnostic character, other than the fact that it exists, and as such gives an end or starting point for counting other scales. Lateral collar scales are at best difficult to determine. The median collar scales are perhaps of use by relative size, ie, twice as large or subequal to surrounding scales. Otherwise they are an end point in counting throat scales from the mandibular symphysis. My counting of throat scales goes from the anteriormost ventral scale, normally a single scale, found just posterior to the junction of the mandibles, to the last scale anterior to the collar. I will normally count this three times and take the average count as the value used for analyses. Alligatorids have lower throat scale counts than *Crocodylus*, and within *Crocodylus* the counts are relatively uniform except for mainland southeast Asia *C. siamensis*, which have a 20% higher count than any other species (or '*C. siamensis*' from the Indonesian islands). This fact has not yet been mentioned in the literature, and I intend on publishing it within the next year or so depending on travel. In this paper will be a summary of throat scale row counts for all recent crocodilians.
>
> "Transverse ventral scale rows I count from the row adjacent to and posterior to the median collar scales to the last transverse row anterior to the vent, and as close as possible to counting down the midline. This does not include the scales which encircle the vent, or any partial rows lateral to the vent. Albeit this is an arbitrary point to stop counting, but it is fairly easily defined, even if biologically incorrect. Again depending on the sample size (for the day) I will either count once or 3 times per animal.
>
> "Within Indopacific crocodiles the best use of ventral scales is to split the 'large scale' from 'small scale' species, ie *C. porosus*, *C. palustris*, and *C. siamensis* (small scale species) from what I am considering a species group, *C. mindorensis*, *C. novaeguineae*, *C. johnsoni*, *C. raninus*, and *C. wabi* (ms. name). This difference in ventral scales is well known in the skin trade, ie Singapore small scale = *C. porosus*.
>
> "*Crocodylus cataphractus* also has these large ventral scales but differs from the Indopacific group in other ways.
>
> "In the past I have also counted the number of longitudinal ventral scale rows. I counted these across the belly at the level of the 10th transverse row posterior to the collar. This count has not been of particular use and is sloppy for the same reason as counting collar scales or lateral dorsal scales. Where do you stop/start laterally?
>
> "...all my best, Sincerely, Charles A. Ross, Museum Specialist"

Postscript. Eureka! Attention CSG: those missing and damaged cloacas on flat ventral skins can now possibly cease to be an unavoidable problem

The most difficult and exasperating (confounding and subject to interpretation) part of the collar-vent count is its posterior ending point, and also the region between the hind legs (see Figure 2). The qualifying transverse rows of ventral scales tend to be very small near the cloacal disturbance, and additionally the immediately precloacal skin is often partly removed during the skinning process. Locating and identifying the exact posterior end of the CITES collar-vent (C-V) count is difficult on whole animals, and can be impossible on many commercial ventral hides. Further, the ventral scalation between the hind legs can be damaged and obscured on stuffed specimens and hornback hides.

Something that I had hitherto overlooked is an important improvement on the "large scale" versus "small scale" dichotomy from Alcala (1986). Rather than counting the transverse rows of ventral scales located between the collar and the cloacal vent, Alcala (1986) stopped counting when he reached the functional (transverse scale row) level of the anterior edge of the hind legs. The anterior end of the Alcala (1986) count was called the "axilla" (the armpit), and it is possibly (we are here entering somewhat uncharted waters) the row immediately posterior to the collar, but I believe that it is ordinarily (or possibly always) the second postcollar transverse row that actually reaches the axilla in the living crocodilians (a testable hypothesis).

What Alcala (1986: 52-53) said was that in *C. porosus* "the ventral plates are moderate, 23 to 30 between the axilla and the hind limbs" while, in comparison and contrast, *C. mindorensis* has "very large ventral plates, 16 to 18 between the axilla and the hind limbs" and, thus, there is no overlap of the ranges of variation in the two kinds of Philippine crocodiles. One has 23-30, while the other has 16-18.

In Figure 2 (Rio Aoki's ventral view of a *Crocodylus mindorensis* specimen), starting the Alcala count on the last transverse row before the start of the back leg, and counting forward one full-scale away from the midline, I see 16 rows, plus one additional row located just before the collar, on the left side. Separately, on the right side, again starting at the anterior edge of the rear limb, and then moving inwards towards the midline, and then going anteriorly, I count sixteen scales, plus the row that is immediately posterior to the collar. So, it has 16 or 17 Alcala rows, depending on interpretation of the anterior end of the count. The Figure 2 animal from the Philippines is correctly identified (Alcala's prediction was 16 to 18). The Dalupiri Island animal shown in ventral view in the CSG Newsletter [24(3): 14] appears to have the same Alcala count as Aoki's specimen.

Note that Peters (1964) defined "axilla-groin" as "a standard measurement often used in herpetological taxonomy: the distance in a straight line from the posterior margin of the forelimb insertion to the anterior margin of the hindlimb insertion. Syn.: interlimb length" (diagrammed in his Figure 29 on a salamander and on a lizard), with "axilla" meaning "the armpit; the cavity beneath or behind the insertion of the anterior appendage"; and, Peters (1964:) defined "groin" as "the angle formed by the anterior margin of the hind limb and the body; the slight depression or cavity at the insertion of the hind limb. Syn.: inguen" and the noun "inguen" was defined as the groin, and the differently spelled adjective "inguinal" means "pertaining to or located in the groin" (p. 165).

The Alcala (1986) axilla to groin count of midventral (long axis) region transverse rows is not a straight line between the actual axilla and the actual groin, but rather is roughly parallel to that line. Unfortunately the remarkably clear photograph of the ventral scalation of a *C. raninus* from Kalimantan in Ross *et al*. (1998) has the back legs pressed against the body in the inguinal region, and thus the precise level where the groin occurs is not identifiable. However, this photo is suitable for performing the CITES collar-vent count, and I see 22 rows on the left, and 23 on the right, for an average 22.5 result. The Ross and Alcala (1983) collar-vent count prediction for Philippine *C. porosus* was 29 to 34 scales (average 31.7 rows crossing the midline), so the Ross *et al*. (1998: 76, Fig. 3) illustration is definitely not *C. porosus*. Rather, the 22.5 result agrees much more closely with the Ross and Alcala (1983) prediction for *C. mindorensis* (22 to 25, average 23.9). When I compare the 1998 photograph (*raninus*) with my Figure 2 drawing from Aoki (1985), the region between the back legs on the 1998 *C. raninus* has significantly larger scales than those in *C. mindorensis*, but in both cases the sample size is small.

To avoid confusion, it is important that an author explains if the midline method, or alternatively the parallel pair of counts method produced C-V results. Separately, whenever Angel Alcala's axilla to groin count of transverse rows "crossing" (so to speak) the ventral long-axis midline is reported, the results should not be confused with C-V counts. Further, there is the additional question of whether the Alcala (1986) count is performed along the actual midline, or alternatively one scale away on the left and right sides (I recommend the latter).

Finally, please note that in the most recent CITES identification manual (Charette 1995), the (key, page 4) ventral view drawing of a theoretical crocodilian lacks bilateral asymmetry in the collar-vent region (an extreme rarity, or possibly nonexistent), and the C-V count is shown as being a single series down the middle (along the midline). Thus, C-V results made the CITES way may slightly differ from my pair of parallel counts. My parallel method follows King and Brazaitis (1971). There is no information in any of the publications by Karlheinz Fuchs about whether he counted along the midline, or the alternative "parallel" method.

My brother performed the C-V count the CITES way, but I strongly prefer the 1971 method of "parallel" counts to the left and right sides a full scale away from the midline. The "parallel" counts are not actually truly parallel to each other (they diverge anteriorly), but the level of exasperation is lessened. I do not recall ever seeing a crocodilian belly that was truly bilaterally symmetrical. In the embryo the left and right sides develop independently, and thus, the midline is an ontogenetic development. The American Alligator, for example, can have an umbilicus scar that sometimes makes counting the CITES way impossible. The only good news is that, although it needs work at the "collar" end, and although it requires locating the anterior edge of the attachment of the hind limb (perhaps this is not a problem on flat commercial ventral skins), the Alcala (1986) armpit to the hind limb count of ventral transverse rows of scales avoids the troublesome region between the back legs, and this long-axis interlimb-zone character avoids the ambiguity about where the cloacal oval stops, and simultaneously where the count from the vent to the collar begins.

Setting Peters (1964) aside, the word "groin" has an informal meaning involving the genital region. Especially in humans, the groin can be the space between the legs, as opposed to the anterior and lateral surface where the thigh meets the abdomen. The term axilla-groin, especially when referring to a midline-region count, could possibly be misinterpreted.

The original wording (Alcala 1986: 53 "between the axilla and the hind limbs") is clear in one sense, but we are really talking about the midline region.

The Alcala (1986) counting method deserves consideration by the IUCN for future CITES identification guides, because flat ventral skins that have had their cloacal region cut out of them are commonly traded internationally, and it is often not possible to know if, or to what degree, the immediately precloacal midline-region belly skin is partly missing. So, you find the front edge of one back leg, and locate the transverse row that laterally extends to the true groin (the first one that is anterior to the groove where the thigh meets the abdomen). Then, follow that row towards the midline, and then (one scale before the midline) make a 90^{o} degree turn and perform the longitudinal count going anteriorly towards the collar (and repeat this process on the other side). The collar row does not count, nor does the sometimes peculiar thransverse row immediately posterior to it. The anteriormost qualifying transverse row is the one that actually reaches the axilla (armpit). The functional result is that the former single row of collar scales has become a complex of two collar rows, plus the roughly triangular-shaped and laterally placed zone of extra and irregular scales sandwiched between these two rows. The F.D. Ross interpretation of the ventral inter-forelimb phenomenon now goes all the way across (from one front-leg upper-arm attachment to the other), and the ventral interarm scalation-complex somewhat resembles the shape of an hourglass turned on its side. The two ends are usually thicker than the middle. The traditional collar is the second transverse row (counting near but not actually on the exact midline) anterior to the row that ends at the thoracic surface of the axilla. The transverse row that distally terminates on the trunk at the armpit is the interaxillary row (New Term: connecting one axilla to the other). The transverse row that distally terminates on the trunk at the groin can be called the intergroin row (New Term: connecting one groin to the other). The Alcala (1986) method is really the interaxillary and intergroin inclusive series, because the interaxillary row and the intergroin rows are both included in Angel's long-axis interlimb series. These two newly named rows count in this quicker and more repeatable (collar and vent avoiding) count.

In this new alternative to the traditional C-V model of CITES, the intergroin transverse row (the "groin row") replaces the cloacal oval (vent). The interaxillary transverse row (the "axillary row") replaces the remarkably enlarged posteriormost "throat" (the traditional interpretation) row (the gular collar). The collar stays the collar, but is newly understood as being one of two transverse rows (that cross the midline), plus lateral (distally sandwiched) triangles of extra scales that all collectively constitute the ventral interforelimb scalation phenomenon. Assuming that the interforelimb zone overlies the paired clavicles (the collarbones), we now have a gular (throat) zone, a clavicular zone (between the front legs, and now including the collar), and finally a postclavicular zone that begins with the axillary row. That (the preaxillary region) is one important part of the ventral skin possibly mapped.

Someone should do some dissections to find out if "clavicular" is appropriate for the ventral interforelimb zone. The term "postclavicular" is quicker than post-interforelimb. How does the sternum relate to the collar? Something very basic is happening, and it happens remarkably consistently among the living Crocodylia. The very old fossil *Protosuchus richardsoni* did not have an ossified collar, but it did have a distinctly postclavicular plastron of rectangular osteoderms sutured together as transverse rows crossing the midline. These rows were themselves sutured to each other. The remarkably rigid protosuchian plastron posteriorly stopped at or near the umbilical zone, and thus probably did not reach the groin row.

Would somebody please define the umbilical zone (its range of rows in various taxa) in terms of its relation to the intergroin transverse row, etc. There should be a solution to this puzzle (where is the *Protosuchus* plastron on the modern crocodile?). However, be forewarned that the analysis above has not dealt at all with the "single-button" versus "double-button" ventral osteoderm dichotomy. The *P. richardsoni* plastron was illustrated and discussed in Colbert and Mook (1951), and they also informed us that the tail whorls on their remarkably well preserved fossil had two zones (one "dorsal" and the other "subdorsal") of caudal osteoderms. The dorsal transverse tail rows had a "vertebral segmentation" (one row corresponding with each underlying vertebra), and the subdorsal transverse rows exhibited a "demivertebral segmentation" (two rows of caudal osteoderms for each caudal centrum).

The protosuchian caudal armor was separated from the subdorsal tail scales by a thin horizontal space of granular and thus flexible skin. The dorsal rows were twice as numerous as the subdorsal, and each subdorsal transverse row was approximately equal in size to its neighbors. It was not the modern "double-button" phenomenon in which there are two osteoderms inside one scale, and the anterior osteoderm is considerably smaller in length (but not width) in comparison to its posterior osteoderm mate. Again, something complex but probably real is going on here. The ventral scalation has baffled me for many decades. Do any of the living crocodilians have both single-button and double-button ventral scales? Are there four buttons in a stack (Ant.-Post. thin, thick, thin, thick) in the central pair of enlarged scales of the collar in the 1974 and 2006 picture of a *Paleosuchus* skin from K. Fuchs? [also available in the 1983 CITES manual].

In both Ross and Mayer (1983) and Aoki (1985) there are drawings that show the dorsal caudal armor separated from the subdorsal caudal armor by a horizontal zone of granular skin in the basicaudal area (also illustrated in one of Bill Magnusson's SSAR *Paleosuchus* accounts). In the fossil *Protosuchus* this phenomenon continued along the entire length of the tail.

The ventral and ventrolateral special basicaudal postcloacal scalation in *C. moreletii* is, in extreme cases, two transverse rows of scales within one vertebral segement. The caudal whorl has two scales of equal size below, and one big scale above, and in Morelet's crocodile the basicaudal dorsal segmentation extends and continues to some extent onto the lateral basicaudal surfaces. Thus, somewhere (and irregularly, in a more or less fashion) on the sides of the tail the segmentation switches from vertebral to demivertebral.

There is considerable taxonomic variation in the size and shape of the throat scales as they approach the collar. In some taxa they remain small and somewhat granular, while in other taxa these posterior "gular" scales gradually form into clear transverse rows of rectangular scales and thus closely resemble collar scales in some aspects of size and shape. I think that the traditional "gular collar" is not a true gular row. The CITES collar is the first postgular row.

The subdorsal scalation, including detached longitudinal rows of osteoderms on the flanks of the trunk (see Figure 1), remains not yet understood. Note that embryologically, the detached lengthwise "rows" of enlarged and potentially ossified flank scales are adjacent to the continuous dorsal armor, and only become distinguishable from it ontogenetically, although before hatching. Some taxa have multiple flank rows, and it is often subjective about how many "rows" there are, and at what points they start anteriorly and stop posteriorly, or visa versa. The embryo crocodile curls around its yolk, and at a certain developmental stage the animal's outer surface (its "dorsal body armor region from PC-1 to PC-18) has the dorsal and flank scales (together as a single phenomenon) looking very much like the parallel-sided lengthwise strip (or stripe, like a paved walkway) in *P. richardsoni* (Barnum Brown).

Literature Cited

Alcala, A.C. (1986). Guide to Philippine flora and fauna. Volume 10: Amphibians and Reptiles. Natural Resources Management Center, Ministry of Natural Resources, and University of the Philippines, xvi & 195 pp. [13 volume set. Vol. 13 (published 1986) is General Index (anon. 153 pp. Goodwill Bookstore, Manila) recognizing "Estuarine Crocodile" and "Salt-water Crocodile" and "Philippine Crocodile" as common or local names, and recognizing "*Crocodylus mindorensis* Schmidt" and "*Crocodylus porosus* Schneider" as species]

Alcala, A.C., Ross, C.A. and Alcala, E.C. (1988). Observations on reproduction and behavior of captive Philippine crocodiles (*Crocodylus mindorensis* Schmidt). Silliman Journal 34(1-4): 18-28.

Aoki, R. (1985): Beobachtungen an *Crocodylus mindorensis* auf Mindoro, Philippinische Insel. Herpetofauna 7(34): 6-10.

Brazaitis, P. (1973). Identification of *Crocodylus siamensis* Schneider. Zoologica 58: 43-45.

Brazaitis, P. (1974). The identification of living crocodilians. Zoologica 58(3-4): 59-101.

Brisbin, I.L. Jr., Ross, C.A., Downes, M.C., Staton, M.A. and Gammon, B.R. (1986a). A Bibliography of the American Alligator. United States Department of Energy, Savannah River Ecology Laboratory, National Environmental Research Park: Aiken, South Carolina, USA. SRO-NERP 13.

Brisbin, I.L. Jr., Ross, C.A., Downes, M.C., Staton, M.A. and Gammon, B.R. (1986b). The compilation of a cross-indexed topical bibliography for the American Alligator: a study of trends in the literature concerning an endangered species. Pp. 124-131 *in* Crocodiles. Proceedings of the 7th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Charette, R. (1995). CITES Identification Guide - Crocodilians: Guide to the Identification of Crocodilian Species Controlled under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Environment Canada: Ontario, Canada.

Colbert, E.H. and Mook, C.C. (1951). The ancestral crocodilian *Protosuchus*. Bull. Amer. Mus. Nat. Hist. 97: 143-182.

Cox, J.H. (2004). Status and conservation of the Siamese crocodile *Crocodylus siamensis* in Kalimantan (Indonesian Borneo). Pp. 150-154 *in* Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Cox, J., Middleton, N. and Wattimena, M. (2003). Occurrence of the New Guinea Freshwater Crocodile *Crocodylus novaeguineae* off the Island of New Guinea. Crocodile Specialist Group Newsletter 22(2): 7.

Das, I. and Charles, J.K. (2000). A record of *Crocodylus raninus* Muller & Schlegel, 1844, from Brunei, North-western Borneo. Sabah Parks Nature-Journal 3: 1-5.

Ernst, C.H., Ross, F.D. and Ross, C.A. (1999). *Crocodylus acutus* (Cuvier): American Crocodile. SSAR Catalogue of American Amphibians and Reptiles (700): 17.

Fuchs, K.H.P., Ross, C.A., Pooley, A.C. and Whitaker, R. [1989c,d, 1992a (English), 1990a (French), 1990b (German), 1990c (Italian), 1992b (Dutch)]. Crocodile-skin products. Pp. 188-195 *in* Crocodiles and Alligators, ed. by C.A. Ross. See relevant citation for publishers).

Grenard, S. (1991). Handbook of Alligators and Crocodiles. Kreiger Publishing Company: USA.

Heaton-Jones, T.G. (1989). (Untitled review of Crocodiles and Alligators). Crocodile Specialist Group Newsletter 8(4): 34-35.

Kennedy, R.S. and Ross, C.A. (1987). A new subspecies of *Rallina eurizonoides* (Aves: Rallidae) from the Batan Islands, Philippines. Proceedings of the Biological Society of Washington 100(3): 459-461.

Khan, R.A., Forrester, D.J., Goodwin, T.M. and Ross, C.A. (1980). A haemogregarine from the American Alligator (*Alligator mississippiensis*). Journal of Parasitology 66(2): 324-328.

King, F.W. and Brazaitis, P. (1971). Species identification of commercial crocodilian skins. Zoologica 56(2): 15-70.

King, F.W. and Ross, J.P. (1995). A lectotype for the Siamese crocodile. Crocodile Specialist Group Newsletter 14(3): 21.

Kurniati, H. (2005). (Untitled). Crocodile Specialist Group Newsletter 24(3): 17-18.

Messel, H., King, F.W., Webb, G.J.W. and Ross, C.A. (1992). Workshop on the prospects and future strategy of crocodile conservation in the Philippines. Crocodile Specialist Group Newsletter 11(1): 19-21.

Oliveros, C., Manalo, R., Coñate Sr., E., Tarun, B., Telan, S. and van Weerd, M. (2005). The Philippine crocodile recorded on Dalupiri Island. Croodile Specialist Group Newsletter 24(3): 14-15.

Oliveros, C., Telan, B. and van Weerd, M. (2006). Crocodile surveys on Dalupiri and Fuga. Isla Biodiversity Conservation: Mabuwaya Foundation (available at iucncsg.org/pages/publications).

Ortega, G.V. and Regoniel, P.A. (1994). Conservation, management and farming of crocodiles in the Philippines . Crocodiles. *In* Proceedings of the 2nd Regional Meeting (Eastern Asia, Australia, Oceania) of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ortega, G., Regoniel, P. and Ross, C.A. (1994). Status of crocodiles in the Philippines: an update, 1994. Pp. 151-154 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ota, H. and Ross, C.A. (1990). Record of *Hemiphyllodactylus typus typus* (Reptilia: Sauria) from Lanyu and Lutao Islands, Taiwan. Journal of the Taiwan Museum 43(1): 35-39.

Ota, H. and Ross, C.A. (1994). Four new species of *Lycodon* (Serpentes: Colubridae) from the northern Philippines. Copeia 1994(1): 159-174.

Peters, J.A. (1964). Dictionary of Herpetology: a Brief and Meaningful Definition of Words and Terms used in Herpetology. Hafner: New York.

Pooley, A.C. and Ross, C.A. [1989c,d, 1992a (English), 1990a (French), 1990b (German), 1990c (Italian), 1992b (Dutch)]. Mortality and predators. Pp. 92-97, 99-101 *in* Crocodiles and Alligators, eb. by C.A. Ross. (See relevant C.A. Ross citation for publishers).

Regoniel, P.A., Pontillas, Jr., U.F.A., Leyba, R.A., Kurara, K. and Elvira, E.T. (1994). Distribulion and stalus of crocodiles in Palawan Province. *In* Crocodiles. Proceedings of the 2nd Regional Meeting (Eastern Asia, Australia, Oceania) of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ross, C.A. (1974). Endangered Species Permit: receipt of application. Federal Register (Washington, D.C., USA) 39 (154 - Thursday, August 8, 1974): 28544-28545. [Federal Fish and Wildlife Permit PRT-6-13-C-75Z (Endangered Species Scientific Permit) issued to Mr. Charles A. Ross on 13 September 1974]

Ross, C.A. (1975a). Preliminary study of variation in the American Alligator (*Alligator mississippiensis* Daudin). United States Department of the Interior Report (Contract 14-16-008-855).

Ross, C.A. (1975b). Reflected glow from the eye of the Gharial. J. Bombay Nat. Hist. Soc. 72(2): 557-558.

Ross, C.A. (1977a). Response to Bowler's letter on alligators. Herpetological Review 8(2): 37.

Ross, C.A. (1977b). Scale variation in the American alligator. *In* Program of 1977 Annual Meeting of the American Society of Ichthyologists and Herpetologists (Abstract).

Ross, C.A. (1978). Recent crocodilians of the world and their conservation. Wildlife in Papua New Guinea 78/13: 10 pp. [the 13th issue in 1978, mimeograph, Division of Wildlife, Department of Lands, Surveys and Environment, Konedobu, Papua New Guinea]

Ross, C.A. (cf. 1980). The Philippine Crocodile (this creature faces extinction, unless...). One page, double sided, designed for mailing. Crocodile Research and Breeding Project (founded in 1980), Silliman University Environmental Center, Dumaguete City, Negros Oriental. [includes a lateral view photo of a live *C. mindorensis*]

Ross, C.A. (1981). Project 1489. Philippines, conservation of crocodiles. World Wildlife Fund's WWF Yearbook 1980-81: 152. [cited in 1982 in Brian Groombridge's Red Data book (pp. 337-339), and by Aoki (1985), as "First report on SI/WWF Project 1489: Conservation of Philippine crocodiles"]

Ross, C.A. (1982a). The crocodile must stay. Habitat (Philippines) 3(1): 13-19.

Ross, C.A. (1982b). Final report. Smithsonian Institution/World Wildlife Fund Philippine Crocodile Project. WWF Report (1489): 34.

Ross, C.A. (1984). Crocodiles in the Republic of the Philippines. Pp. 84-90 *in* Crocodiles. Proceedings of the 6th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ross, C.A. (1986). Comments on Indopacific crocodile distributions. Pp. 349-354 *in* Crocodiles. Proceedings of the 7th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ross, C.A. (1987). *Crocodylus moreletii* Duméril & Bibron: Morelet's crocodile. SSAR Catalogue of American Amphibians and Reptiles (407): 3.

Ross, C.A. (1988). Weights of some New Caledonian birds. Bulletin of the British Ornithologist's Club 108(2): 91-93.

Ross, C.A. (1989a). Probable introduction of *Lygosoma bowringi* in Zamboanga City, Philippines. Herpetological Review 20(1): 6.

Ross, C.A. (1989b). Checklist of living crocodilians: Order Crocodylia. Pp. 230 *in* Crocodiles and Alligators, ed. by C.A. Ross. Golden Press Pty. Ltd.: Silverwater, NSW.

Ross, C.A. (ed.)(1989c). Crocodiles and Alligators. Golden Press Pty. Ltd.: Silverwater, NSW.

Ross, C.A. (ed.)(1989d). Crocodiles and Alligators. Facts On File Inc.: New York.

Ross, C.A. (ed.)(1990a). Crocodiles, Alligators et Caimans. Bordas (Encyclopedie Visuelle): Paris. (partly revised by Roland Bauchot and Eric Buffetaut).

Ross, C.A. (ed.)(1990b). Krokodile und Alligatoren. Jahr-Verlag GmbH & Co.: Hamburg, Germany.

Ross, C.A. (ed.)(1990c). Coccodrilli e Alligatori. Libri Illustrati Rizzoli: Milan.

Ross, C.A. (ed.)(1992a). Crocodiles and Alligators. Blitz Editions (Bookmart Ltd.): Enderby, UK.

Ross, C.A. (ed.)(1992b). Krokodillen en Alligators. M&P Uitgeverij: Weert, the Netherlands. [Voorwoord (p. 9) by Dr. M.S. Hoogmoed, Nationaal Naturhistorisch Museum, Leiden].

Ross, C.A. (1990d). *Crocodilus raninus* S. Müller and Schlegel, a valid species of crocodile (Reptilia: Crocodylidae) from Borneo. Proceedings of the Biological Society of Washington 103(4): 955-961.

Ross, C.A. (1992). Designation of a lectotype for *Crocodilus raninus* S. Müller and Schlegel (Reptilia: Crocodylidae), the Borneo Crocodile. Proceedings of the Biological Society of Washington 105(2): 400-402.

Ross, C.A. (1993). Book review. The birds of the Philippines, by Dickinson *et al*. 1991. Wilson Bulletin 105(1): 205-206.

Ross, C.A. (1994). Classic identification of Southeast Asian crocodiles: taxonomy and systematic problems of crocodiles in S.E. Asia. Pp. 57 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ross, C.A. (2005). Philippines (no item title). Crocodile Specialist Group Newsletter 24(1): 12.

Ross, C.A. (2008a). A question of habitat - *Crocodylus mindorensis*. National Museum Papers (Manila) 14: 116-122.

Ross, C.A. (2008b). The genetics of reintroduction - *Crocodylus mindorensis*. National Museum Papers (Manila) 14: 128-132.

Ross, C.A. and Alcala, A.C. (1983). Distribution and status of the Philippine Crocodile (*Crocodylus mindorensis*). Kalikasan: Philippine Journal of Biology 12(1-2): 169-173.

Ross, C.A., Alcala, A.C. and Sison, R.V. (1988). Distribution of *Zoacys luzonensis* (Serpentes: Colubridae) in the Visayan Islands, Philippines. Silliman Journal 34(1-4): 29-31.

Ross, C.A., Blake, D.K. and Onions, J.T.V.[1989c,d, 1992a (English), 1990a (French), 1990b (German), 1990c (Italian), 1992b (Dutch)]. Farming and ranching. Pp. 202-213 *in* Crocodiles and Alligators, ed. by C.A. Ross. (See relevant C.A. Ross citation for publishers).

Ross, C.A., Cox J. and Kurniati, H. (1996). Preliminary survey of palustrine crocodiles in Kalimantan. Unpublished Report.

Ross, C.A., Cox, J.H. Jr., Kurniati, H.A. and Frazier, S. (1998). Preliminary surveys of palustrine crocodiles in Kalimantan. Pp. 46-79 *in* Crocodiles. Proceedings of the 14th Working Meeting Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ross, C.A. and Crumley, C.R. (1982). A range extension of *Geochelone elongata*. J. Bombay Nat. Hist. Soc. 79(2): 429-430.

Ross, C.A. and Datuin, C.P. (1981a). Crocodiles in peril. Canopy International 7(2): 7.

Ross, C.A. and Datuin, C.P. (1981b). Crocodiles in peril. FAO Tigerpaper 8(4): 19.

Ross, C.A. and Davenport, M.L. (1992). Book review. Handbook of Alligators and Crocodiles, by Steve Grenard, 1991. Copeia 1992(1): 266-267.

Ross, C.A. and Ernst, C.H. (1994). *Alligator mississippiensis* (Daudin): American Alligator. SSAR Catalogue of American Amphibians and Reptiles (600): 14.

Ross, C.A. and Gonzales, P.C. (1992). Amphibians and reptiles of Catanduanes Island, Philippines. National Museum Papers (Manila) 2(1991): 50-76.

Ross, C.A. and Lazell, J.D. Jr. (1991). Amphibians and reptiles of Dinigat and Siargo islands, Philippines. Kalikasan: Philippine Journal of Science 119(1990): 257-286.

Ross, C.A. and Magnusson, W.E. [1989c,d, 1992a (English), 1990a (French), 1990b (German), 1990c (Italian), 1992b (Dutch)]. Living crocodilians. Pp. 58-73 *in* Crocodiles and Alligators, ed. by C.A. Ross. (See relevant C.A. Ross citation for publishers).

Ross, C.A., Mayer, G.C. and Bour, R. (1995). Designation of a lectotype for *Crocodilus siamensis* Schneider, 1801. Proceedings of the Biological Society of Washington 108(2): 298-301.

Ross, C.A. and Ramos, T.R. (1992). Distribution of *Centropus viridis* in the Babuyan Islands, northern Philippines. Bulletin of the British Ornithologist's Club 112(3): 180-181.

Ross, C.A. and Roberts, C.D. (1979). Scalation of the American Alligator. United States Department of the Interior, Fish and Wildlife Service (Washington, D.C.), Special Scientific Report: Wildlife (225): 8.

Ross, C.A. and Ross, F.D. (1974). Caudal scalation of Central American *Crocodylus*. Proceedings of the Biological Society of Washington 87(paper 21): 231-233.

Ross, C.A. and Ross, F.D. (1987). Identity of *Crocodilus mexicanus* Bocourt, 1869 (Reptilia: Crocodylidae). Proceedings of the Biological Society of Washington 100(4): 713-716.

Ross, F.D. [1989c,d, 1992a (English), 1990a (French), 1990b (German), 1990c (Italian), 1992b (Dutch)]. Variations in dorsal armor. Pp. 53 *in* Crocodiles and Alligators, ed. by C.A. Ross. (See relevant C.A. Ross citation for publishers).

Ross, F.D. (1998). *Crocodylus rhombifer* Cuvier: Cuban Crocodile. Catalogue of American Amphibians and Reptiles (680): 18.

Ross, F.D. and Mayer, G.C. (1983). On the dorsal armor of the Crocodilia. Pp. 305-331 *in* Advances in Herpetology and Evolutionary Biology: Essays in Honor of Ernest E. Williams, ed. by A.G.J. Rhodin and K. Miyata. Museum of Comparative Zoology, Harvard University: Cambridge, Massachusetts.

Ross, F.D., van Tomme, M. and Kischlat, E.-E. (2010). Order Crocodylia Loveridge, 1946, recommended. Crocodile Specialist Group Newsletter 29(3): 25-26.

Villapa, R.R., Jammerlan, M.L.M. and Tsubouchi, T. (1992). A *Haemogregarine* sp. infection in *C. porosus* and *C. mindorensis*. Crocodile Specialist Group Newsletter 11(2): 9-10.

Von Endt, D.W., Ross, C.A. and Hare, P.E. (1999). Initial results from cleaning small vertebrate skeletons using the enzyme trypsin. Collection Forum 13(2): 51-62.

WCMC (World Conservation Monitoring Centre) (1993). World Checklist of Threatened Amphibians and Reptiles (5th edition). Peterborough (Joint Nature Conservation Committee): England.

Wermuth, H. and Mertens, R. (1977). Liste der rezenten Amphibien und Reptilien: Testudines, Crocodylia, Rhynchocephalia. Das Tierreich (Berlin, Germany) 100(1).

Whitaker, R. (1990). Seven crocodile books. Hamadryad 15(1): 25-27.

Wirjoamodjo, S. (1996). Crocodile surveys in Kalimantan. Crocodile Specialist Group Newsletter 15(1): 7.

National Scenario of Crocodile Conservation in the Philippines

Theresa Mundita S. Lim, D.V.M., CESO III

Director, Protected Areas and Wildlife Bureau,
Department of Environment and Natural Resources, Philippines

Abstract

The Philippines has two species of crocodiles: the endemic Philippine Crocodile (*Crocodylus mindorensis*) and the widely distributed Saltwater Crocodile (*Crocodylus porosus*). Both species are nationally and globally protected under domestic laws and international agreements. Both species are threatened with extinction. The IUCN-SSC Crocodile Specialist Group (CSG) recognized *C. mindorensis* as the most threatened species of crocodile in the world. The report presents the Philippine Government's initiatives to save the species from extinction. It briefly discusses the national laws and policies, existing programs/projects and partnerships to conserve and protect both species. These include the passage of the Wildlife Resources Conservation and Protection Act (RA 9147); the establishment of the Crocodile Farming Institute (CFI), now known as the Palawan Wildlife Rescue and Conservation Center (PWRCC); commercial and sustainable use of *C. porosus*; and other *in-situ* and *ex-situ* conservation activities on both species, in collaboration with both local and international partners.

Philippine Crocodile Conservation in NE Luzon: an Update and a Proposal for a National Philippine Crocodile Reintroduction Strategy

Merlijn van Weerd[1,3], Marites Balbas[1], Willem van de Ven[1], Dominic Rodriguez[1], Sam Telan[1], Jessie Guerrero[1], Edmund Jose[1], Arnold Macadangdang[1], Wilda Calapoto[1], Jan van der Ploeg[1,3], Myrna Cureg[1,2], Robert Araño[1] and Artem Antolin[1]

[1] Mabuwaya Foundation, EIC-Building, ISU Garita, Cabagan, Isabela, Philippines (merlijnvanweerd@yahoo.com); [2] Isabela State University, Cabagan, 3328 Isabela, Philippines
[3] Leiden University, PO Box 9518, 2300 RA Leiden, the Netherlands

Abstract

The critically endangered Philippine Crocodile *Crocodylus mindorensis* is limited in distribution to isolated sub-populations in Mindanao and northern Luzon. Effective conservation of these wild populations, combined with reintroduction of the species in historical distribution areas is necessary to prevent extinction in the wild. Since the discovery of a remnant population in the municipality of San Mariano in Isabela in 1999, we implemented a conservation project here successfully engaging local communities in crocodile conservation. The killing of crocodiles decreased and 5 crocodile sanctuaries were established. The crocodile population is increasing, aided by a nest protection and hatchling head-start program. Positive experiences with community-based crocodile conservation and reintroduction of head-started crocodiles in San Mariano led to a pilot project to release 50 captive-bred sub-adult crocodiles in Dicatian Lake in the Municipality of Divilacan, Isabela in 2009. Monitoring of these crocodiles shows that there are issues with adaptation leading to high mortality rates and human-crocodile conflicts. The lessons learned in San Mariano and Divilacan, experiences elsewhere with crocodile reintroductions and the results of genetic studies can be used to design and refine the national Philippine Crocodile reintroduction and conservation strategy.

Distribution and Status of Crocodiles in Agusan Marsh, Eastern Mindanao, Philippines

Rainier I. Manalo, William T. Belo, Vicente P. Mercado, Benedict O. Solco and Alfonso J. Biñan, Jr.

Crocodylus Porosus Philippines Inc., Pag-asa, Kapalong, Davao Del Norte, Philippines

Abstract

This report contains the result of an exploratory survey conducted in Agusan Marsh Wildlife Sanctuary from November 2011 to March 2012, in the mid-section of Agusan River Basin in Eastern Mindanao, which presents crocodile distribution and condition of the marsh as to crocodilian habitat. Day exploration, night spotlighting and key interviews of informants indicate that the marsh supports extant population of crocodiles, but which are considered remnant and declining. One of the highlights of this survey was the discovery of two remaining habitats that may contain healthy populations of crocodiles in the marsh. Large number of crocodiles were not observed, which might form a viable breeding population in known rivers and lakes. The present distribution, based on current sightings and verified reports, are documented.

Introduction

Two species of crocodiles occur in the Philippines, the Indo-Pacific or Saltwater Crocodile (*Crocodylus porosus*, Schneider 1901) which is widely distributed in the Indo-Pacific region from southwestern India to northern Australia and Papua New Guinea (Ross and Alcala 1983), and the Philippine Crocodile (*Crocodylus mindorensis*, Schmidt 1935), also known as the Mindoro or Philippine Freshwater Crocodile), which is endemic to the country.

The most common and widely distributed *C. porosus* is found in almost all recognizable estuarine and freshwater habitats in the Philippines (Ross 2008). In the early 1980s it was reported to exist in large number in major bio-geographic regions in the country, such as Luzon, Negros-Panay, Mindanao and Palawan. However, due to the continued destruction of its habitats for agriculture and aquaculture projects, and uncontrolled hunting for its valuable hide, wild populations have been severely reduced (Ortega 1996) and the species is now extremely rare in the wild (Mercado 2008). Crocodiles in the Philippines are also considered vermin and the probability of their survival in the wild is low (Messel *et al*. 1992).

The Philippine Crocodile population came into science in 1935 when Karl P. Schmidt, curator of herpetology of the Field Museum of Natural History of Chicago, discovered the species on the island Province of Mindoro, thus it was named *Crocodylus mindorensis*. Forty-seven (47) years after its discovery, Charles A. Ross of the Smithsonian Institution, estimated its remaining wild population to be between 500-1000 mature individuals in 1982. Currently, it has been reported to exist in some areas of Ligawasan Marsh, Agusan Marsh and Pulangui River, Bukidnon Province, and all of the Island of Mindanao. Some was found in Northern Luzon in the areas of San Mariano, Isabela in Northern Sierra Madre Natural Park; Tineg, Abra in Cordillera Region; and Dalupiri Island in Babuyan Channel (Ortega 1998; Hibaya *et al*. 1999; Pontillas 2000; Manalo 2008; Oliveros 2008). But due to population reduction and decline in area of occupancy, extent of occurrence and/or quality of habitat (CSG 1996a), it is now considered as one of the most endangered crocodilian species in the world.

On the other hand, *C. porosus* are found in small numbers in some wetland habitats on a number of Philippine islands - especially Mindanao and Palawan. Their number is exceeding low and now considered to be in hundreds. It is doubtful that any wild populations exist that are large enough to sustain ranching or any other form of sustainable use (Messel *et al*. 1992). Based on Crocodile Farming Institute (CFI) acquisition records from 1987 to 1998, a total of 9 *C. porosus* individuals were caught and acquired from Agusan Marsh, Agusan Del Sur as part of its nucleus captive breeding population (CFI 1999).

With the successful propagation of both species of crocodiles in captivity by the Philippine Government project through CFI, the Protected Areas and Wildlife Bureau (PAWB) as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Management Authority in the Philippines, have granted the Project to use *C. porosus* for commercial breeding purposes in order to sustain its conservation. Both crocodile species are included on Appendix I of the CITES and are legally protected in the Philippines.

Further, in 1993 IUCN-SSC Crocodile Specialist Group (CSG) recommended that a renewed effort should be made to establish an innovative crocodile sanctuary for *C. mindorensis* and *in-situ* protection of *C. porosus*. This would result in safety net population of these crocodiles in the wild and in the long-term could form a base for crocodile ranching by local people. The CFI Project shares the CSG position and recognizes the urgency of this matter, considering the rapid human population growth leading to the destruction of wetland habitats due to population encroachment competing for the much needed wetland fauna habitat and habitat fragmentation.

During the CFI project life, Saltwater Crocodile farming technology was transferred to qualified farmers in 2000, together with a number of farm-bred individuals. To date, more than 70% of the CFI (now Palawan Wildlife Rescue and Conservation Center; PWRCC) captive stock have been dispersed. However, considering the population status of *C. mindorensis* in the wild, the scheme used for *C. porosus* in the early stages of the CFI project could not be adapted without first re-establishing a viable wild population for the species.

At present, it is not known whether Mindanao's declared Protected Areas (PA), like Agusan Marsh Wildlife Sanctuary (AMWS), still have viable populations of both species of crocodiles. Although crocodiles are usually regarded as abundant in the marsh (Ross 1982), there is no reliable population estimate. The mere potential of this habitat to house wild populations of crocodiles made it a priority for scientific studies, and for the possible declaration as a protected crocodile sanctuary and potential crocodile population release site in the Mindanao region. Not to mention the need for a comprehensive population genetics, molecular systematic, and biogeography studies for *C. mindorensis*.

Thus, it is in this context that Crocodylus Porosus Philippines Inc. (CPPI), a consortium of 6 commercial crocodile farms in the Philippines, and the Department of Environment and Natural Resources (DENR), have jointly conducted this study to specifically assess the present status of the marsh with respect to potential crocodilian habitat and determine the present distribution based on current sightings and verified reports.

Methodology

Description of Study Area

Agusan Marsh Wildlife Sanctuary is situated in the mid-section of the Agusan River Basin in eastern Mindanao, between 8^{o} 0' N and 8^{o} 30' N latitude and 125^{o} 40' E and 126^{o} 05' E longitude (Fig. 1). It covers 8 Municipalities of Agusan Del Sur, namely Talacogon, San Francisco, Rosario, Bunawan, Sta. Josefa, Veruela, Loreto and La Paz.

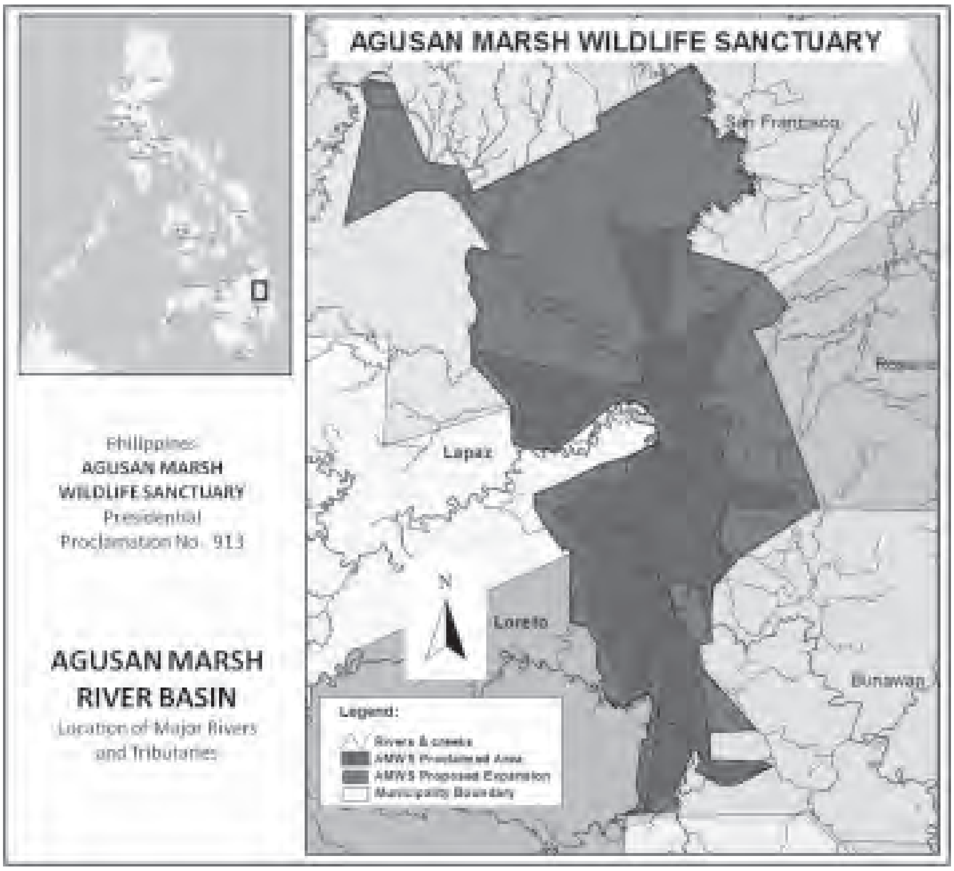


Figure 1. Location of study site showing major rivers and tributaries.

The AMWS is a declared Protected Area by virtue of Presidential Proclamation No. 913 in 1996, and covers an area of 14,836 ha under the National Integrated Protected Areas System (NIPAS). An additional expanded Protected Zone covers 40,868 and 69,201 ha buffers zones, resulting in a total AMWS Management Area of about 110,069 ha. It was conferred as a RAMSAR Site in 1999 as Wetlands of International Importance. The marsh has 7 major wetland habitat types; freshwater swamp forest (with Terminalia, peat swamp and sago forest sub-types), secondary scrub, herbaceous swamp, open water (oxbow/floodplain lakes, pools), flowing water (rivers and streams), cultivated/agricultural areas and marsh areas. The meandering Agusan River flows through the center, and its tributaries form a vast complex of freshwater marshes and waterways.

Research Design and Data Collection

The study was carried out between November 2011 and March 2012, which spans the inundation and recession periods in floodplain areas. We utilized a small outboard motorboat to facilitate movement in tributaries and larger areas, as well as water areas dominated by thickets of water lily. Surveys on foot were carried out in areas that could not be accessed by motorboat.

There were 3 major activities carried out by a team of 3 researchers to assess distribution and habitat (see below), with sustained effort to draw together information in areas identified for conservation. The activities were:

1. Daytime Exploration Survey. Initial reconnaissance surveys were conducted during the day, taking note of major topographical features, underwater hazards, vegetation, wildlife and human habitation. Likewise, this verified the eventual presence of crocodile through crocodile tracks, basking areas, traces of nests and other important visible signs. Water fluctuation and minimum parameters were also observed as reference for night spotlighting. The use of Global Positioning System (GPS) was used to complement information gathered to mark and track specific locations of notable habitat, visual reports and actual sightings.

2. Spotlight Surveys (Night). Following the daytime surveys, a designated spotter, recorder and local navigator conducted spotlight surveys using a high beam light. Observations were made onboard a motorboat or by foot for 3-4 consecutive nights. Surveys proceeded in one direction, either downstream or upstream depending on tidal conditions.

3. Key Informant Interviews. Semi-structured questionnaires were used to gather data on reported sightings by local people, and their knowledge on the presence of crocodile/s in the area. Interviews were conducted depending on the reports of residing communities regardless of age, tribe, occupation and gender of respondents. Information derived from respondents was verified by the conduct of day exploration and night survey for possible event of actual sightings.

Results and Discussion

More than 60% of the expanded protected area coverage was explored and verified for the presence of crocodiles in reported rivers and lakes. Of the areas covered, there were 18 lakes reported as crocodile microhabitat. Twelve of these lakes were verified and surveyed (Fig. 2), while other lakes were inaccessible due to isolation of the area and navigational hazards. During the dry season the marsh is a series of interconnecting riverways and isolated swamps and lakes, with the Agusan River flowing through the center in a well-defined channel. However, during the rainy season, the entire area becomes a large single swamp or a single lake with inundation depths reaching 5 m, at which time the channel of the Agusan River is hardly discernible (ADB 2011).

Of the total lake area surveyed, 38.46% of the area had reports in past 5 years, 23% with reports of human-crocodile conflict, 15.38% provided evidence of crocodiles and another 15.38% with alleged sightings. Eight flowing water habitats were explored, the mainstream of Agusan River, downstream of Simulao, Umayam and Gibong Rivers, including Magsagangsang, Subaon and Mayat Creeks. Reports on frequent sightings in these flowing water habitats were established with occasional clear indications of basking adult crocodiles on the riverbanks.

Distribution and Population Status

Crocodiles in Agusan Marsh were documented in lakes, rivers and creeks. While most of the recent recorded sightings were along the riverbanks of flowing water habitats, some can be seen in channel openings of lakes seeking refuge from strong water currents. Reports of crocodile are common in the Municipalities of Bunawan and Loreto in the South, and Talacogon in the North.

Verified reports from local residents included 16 sightings, 8 (50%) of which were from Loreto (2 sightings confirmed by amateur photographs and some recurrent sightings of alleged C. mindorensis), 5 (31.25%) from Talacogon, and 3 (18.75%) in Bunawan (Table 1). With the proximity of the Municipalities of Bunawan, an agricultural floodplain and Loreto, a river community presents high frequency of interrelated observations on basking crocodiles compared to the Municipality of Talacogon. Residents usually describe observed crocodiles as an outsized *C. porosus* basking along riverbanks of Agusan River mainstream during high water levels.

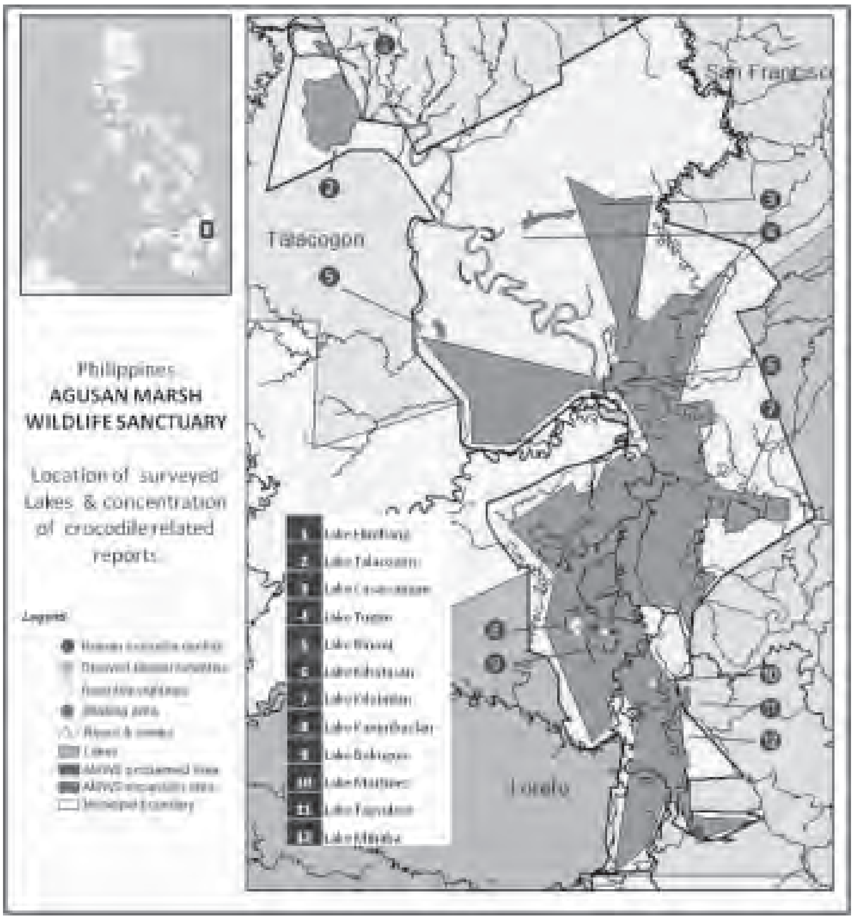


Figure 2. Location of surveyed lakes with reported presence of crocodiles in Agusan Marsh.

Table 1. Reported sightings and verified reports in Agusan Marsh Wildlife Sanctuary. Cm = *C. mindorensis*.

Description	Date Observed	Location
Captured crocodile	Apr 2002	Tagbuaya Creek, Nueva Era, Bunawan
Croc lower jaw retrieved	Jun 2006	Lake Kibatasan, Sabang Gibong, Talacogon
Human Attack	Feb 2009	Lake Martinez, San Marcos, Bunawan
Human Attack	Mar 2009	Lake Mihaba, San Marcos, Bunawan
Captured crocodile	Sep 2011	Magsagangsang Creek, Nueva Era, Bunawan
Observed Basking Area	Jan 2012	Lake Tagsubon, San Marcos, Bunawan
Observed Basking Area	Jan 2012	Lake Tagsubon, San Marcos, Bunawan
Observed Basking Area	Feb 2012	Lake Binoni, Desamparados, Talacogon
Observed Basking Area	Feb 2012	Lake Binoni, Desamparados, Talacogon
Observed Basking Area	Feb 2012	Lake Binoni, Desamparados, Talacogon
Reported Sightings	Feb 2010	Lake Bokugon, Panlabuhan, Loreto
Reported Sightings	Mar 2011	Agusan River, San Isidro, Talocogon
Reported Sightings	Dec 2011	Agusan River, Sabang Gibong, Talacogon
Reported Sightings	Dec 2011	Agusan River, San Marcos, Bunawan
Reported Sightings	Dec 2011	Agusan River, San Marcos, Bunawan
Reported Sightings	Jan 2012	Agusan River, La Flora, Talacogon
Reported Sightings	Jan 2012	Mayat Creek, Maharlika, Talacogon
Reported Sightings	Jan 2012	Lake Martinez, San Marcos, Bunawan
Reported Sightings	Jan 2012	Agusan River, Purok 3, Katipunan, Loreto
Reported Sightings	Feb 2012	Gibong River, Sabang Gibong, Talacogon
Reported Sightings	Feb 2012	Umayam River, Purok 2, Katipunan, Loreto
Reported Sightings (Cm)	2010	Lake Kanimbaylan, Panlabuhan, Loreto
Reported Sightings (Cm)	2010	Lake Kanimbaylan, Panlabuhan, Loreto
Reported Sightings (Cm)	2010	Lake Kanimbaylan, Panlabuhan, Loreto
Photograph sighting	Jan 2011	Agusan River, Katipunan, Loreto
Photograph sighting	Mar 2011	Subaon Creek, Panlabuhan, Loreto
Observed tapetal reflection	Nov 2011	Simulao River, San Marcos, Bunawan

A local informant also reported seeing some small crocodiles (described as *C. mindorensis*) thriving farther upstream of Umayam River in Loreto, in the southeastern part of the Park. The Umayam River has its headwaters connected in the Pulangi River interior of Bukidnon Province, where a *C. mindorensis* population was recorded in 2000 (Pontillas 2000). However, the case of coexistence of both species of crocodiles in the different water bodies of the marsh is still uncertain. It is inferred that authors of several species inventory conducted in AMWS probably made the assumption that *C. mindorensis* crocodiles inhabit the marsh because it is a freshwater area.

The first reported human-crocodile conflict occurred in 2002 when a 19' *C. porosus* was incidentally caught in Tagbuaya Creek, Sitio Mandagaw, Bgy. Poblacion, Bunawan, at the upstream portion of the marsh (Fig. 3). Philippine Daily Inquirer (PDI) newswriter Cassion (2002) reported that the animal was intentionally trapped by a community that blamed it for its dwindling fish catch. Local officials ordered and supervised the release of the crocodile but the crocodile apparently became weak after having been tightly bound and died a day later. While in 2008, a lower jaw of an estimated 8-10' crocodile was retrieved in Lake Kibatasan, Bgy. Sabang Gibong, Talacogon, in the midstream portion of the marsh. A fatal crocodile attack on a young woman was reported in early 2009 in Lake Mihaba San Marcos, Bunawan, a month after an adult male fisherman suffered an injured left thigh from an alleged >18' crocodile in Lake Martinez of the same Municipality. Both lakes are considered floodplain lakes adjacent to each other and share faunal resources through a common waterway.

Dizon (2008) indicated that nesting sites of crocodiles were found at the junction of Agusan River in Lake Mihaba. But interviews suggested that nests were rarely discovered. The most recent evidence on the presence of crocodile is the capture of a 20.1' alleged problem *C. porosus* in 2011 at Magsagangsang Creek, Nueva Era, Bunawan (Fig. 3). Local authorities responded to address human-crocodile conflict that will rescue animals from local folks as its primary goal. Magsagangsang Creek is one of the contributory river tributaries supporting floodplain Lakes Tagsubon, Mihaba and Martinez, all of which drain to the Agusan River Basin.

Figure 3. Saltwater Crocodiles captured in Tagbuaya Creek (left) and Magsagangsang Creek (right) in the Municipality of Bunawan, Agusan Del Sur.

Day exploration and night spotlighting survey activities recorded a juvenile crocodile in shallow waters of the Simulao River, near Agusan River junction in San Marcos, Bunawan, about 2.4 km from Lake Mihaba river drainage to Agusan River. Results indicate that a breeding population is still present in the upper portion of the marsh. Evidence of several individuals in the proximity of the declared wildlife sanctuary was verified by photograph in January and March 2011 in the vicinity of Loreto (Fig. 4). However, despite the series of intensive surveys conducted no breeding size adult crocodiles were sighted in the entire AMWS area. This showed that though present, the crocodile population in the remaining open waters of the marsh can be considered to be relatively small.

Figure 4. Adult crocodiles observed basking in Agusan River in January 2011 (left) and Subaon Creek in March 2011 (right), both in the Municipality of Loreto.

The wariness and low population density of crocodiles dispersed during widespread flooding, congregating in inaccessible areas and resting under thick floating vegetation, contributed to the difficulty in estimating population size. The vast size of Agusan Marsh and the impenetrability of the interior portions limited the survey to areas with reported sightings.

Numerous basking areas characterized by floating vegetation were uncovered in Lake Tagsubon nearby Lake Mihaba in San Marcos, Bunawan, and Lake Binoni in Desamparados, Talacogon. The structure of basking areas evidently relates with that of large size crocodiles inhabiting the area. However, further verification surveys revealed no evidence that attributes to the morphological features of any individuals present. With this results, it can be concluded that the upstream and downstream portion of the wildlife sanctuary could harbor population of crocodiles although not as many as before.

Habitat Assessment

Local residents reported seeing crocodiles in most of the floodplain lakes characterized by the presence of herbaceous swamps forming in the periphery of open water. During periods of inundation, crocodiles are dispersed and reportedly seen in flowing water such as tributaries that connect Agusan River. Generally, there is observed habitat succession from scrub swamp in the interior portions to the isolated open water areas followed by margins of herbaceous swamps linked to flowing water habitats as inflow and drainage areas to Agusan River Basin.

On the other hand, the scrub swamps in the interior portions are characterized by the presence of higher herbaceous swamp community with isolated stands of low-growing trees of *Barringtona* and *Nauclea*. These areas are nearly inaccessible by human activities owing to the thick growth of floating and emergent macrophytes. Forming a load of vegetation are herbaceous swamplands that exhibits a community of transition zone between scrub swamps. In the 1992 AMWS management plan and boundary delineation and land use, reports that the assemblage at the lower elevation areas close to the open water in herbaceous swamp is mainly characterized by common water hyacinth (*Eichhornia crassipes*) and water spinach (*Ipomea reptans*), while a more diverse community consisting mainly of *Saccharum* sp., *Hanguana* sp., *Scleria* sp. and *Acrostichum* sp. were found slightly higher. The emergent species of *Hanguana malayana* (Family Flagellariceae; locally known as "Bangiba") and *Scipiodendron gheari* (Family Cyperaceae; locally called "Baas") intertwined with *Acrostichum* sp. (Arreza 1999) are among the dominant vegetation in similar habitats of Lake Tagsubon in Bunawan and Lake Binoni in Talacogon (Fig. 5).

Figure 5. Basking area composed of dominant vegetation *Hanguana malayana* and *Scipiodendron gheari*.

Davies (1991) established the presence of Haguana malayana only near Lake Manguao in Palawan and in the Agusan River Basin and considered it rare in the Philippines. The observed disturbance in the growth of these vegetations found bordering Lake Binoni and marginally observed in Lake Tagsubon were found to be substantial evidence of basking areas for the crocodiles.

A verified report of sightings and presence of crocodiles mostly associated with herbaceous swampland habitat types of relatively high human activities observed. There were reports of fishermen spotting crocodiles with the head and arch back floating on open water along the peripheral margins of the lake associated with floating vegetation. During the dry season, crocodiles tend to be confined in this habitat type and prefer seclusion towards the upper portion with less disturbed and more inaccessible areas. But due to scarcity of fish and difficult access in the usual fishing area, human settlements tend to move towards the edge of the swamps and in sections along the main waterways and lake systems. Thus, as a consequence crocodiles are driven out of their preferred habitats to move away with humans and human-induced disturbance. Migrating crocodiles ends up in agricultural floodplains, small unidirectional rivers and creeks often blocked by impenetrable growth of water hyacinth (*Eichhornia crassipes*). The scrub swamp and intercession margins of the swamp forest are the potential breeding and nursery grounds while open water habitat of lakes and its tributaries provide grow-out areas for the marsh crocodiles.

People and the Environment

Both species of crocodiles are still being feared as a predator of domestic animals and considered nuisance in most areas in Agusan Marsh. Local informants reported that crocodiles tend to compete with humans for fish. But indigenous people living in floating communities in the area noted that fishes and other aquatic fauna were abundant in areas where crocodiles inhabit. Early human settlers in major lakes witnessed the rapid decline of crocodile population due to indiscriminate hunting in the past and from the current inefficient land and water use activities within the marsh area. Current observations demonstrate that local migrants have infused negative perceptions towards the remaining population of crocodiles where they have the notion of killing over conservation. This could have resulted in a small nucleus of breeding adults from a declining wild population in the marsh. According to Messel *et al*. (1992), removal of these breeding adults depresses the reproductive rate of the wild populations and slows its recovery.

The majority of the settlers in Agusan Marsh were comprised of the indigenous peoples of Manobo. Bracamonte *et al*. (2008) indicated that Manobo underscore practices that conserve environmental resources in harmony with nature. They have strong respect for environmental spirits to seek guidance. Most of all, their notable tribal leaders such as Chieftains and Datu do not tolerate the removal of crocodiles from their respective areas. But these areas show disturbed crocodile behavioral pattern and habitat. As a result, the majority of the reported crocodile sightings were sighted outside the significant territorial boundary of declared AMWS with limited protection compared to that of within the declared sanctuary. The implementation of a "no crocodile hunting" policy, appropriation of proper land and water use system, and regulation of fishing in known crocodile habitats can significantly contribute to the possibility of recovering a significant viable crocodile population in the marsh. The expanded coverage of the AMWS somewhat provided a safety net for the remaining crocodile population of the marsh before they face local extinction.

Conclusions and Recommendations

The Agusan Marsh Wildlife Sanctuary supports few remaining breeder crocodile population that inhabits few areas of fragmented floodplain lakes and tributaries as habitats. Fewer sightings of crocodile imply that the natural wild population has decreased significantly, which can be considered remnant and declining population. There were no large viable populations known to exist in these areas. All that is left are concentrated in minor pockets of similar habitat types in the marsh. Increase in human pressure in river tributaries jeopardizes the existence of crocodiles in major lakes that results in the uneven distribution. The number of fishermen continues to increase as well as the development of fishing practices, leading crocodiles to becoming more mobile in the isolated upper portion of the marsh far from their preferred habitats in their attempt to find more favorable areas with less disturbance.

Based on the current survey findings, the following are recommended:
1. Delineate a strict protection zone designated as critical habitat for the crocodiles in the AMWS, in cooperation with the Protected Areas and Management Board (PAMB);
2. Increase environmental awareness, particularly on the general importance of wildlife conservation with emphasis on crocodiles, habitat, behavior and conservation;
3. Local authorities must develop and implement guidelines to address potential human-crocodile conflict;
4. Conduct a series of follow-up studies on community perceptions towards crocodile conservation; and,
5. Implement mark-release-recapture program for the establishment of more reliable set of data on species status and for future monitoring purposes.

Acknowledgements

This report is the result of a collaborative effort of the Department of Environment and Natural Resources (DENR) Protected Areas and Wildlife Bureau, DENR-Region XIII and Crocodylus Porosus Philippines Inc. We would like to extend our gratitude to the Local Governments of Bunawan, Loreto and Talacogon for their support. We are much indebted to PASu Rufino Miranda and Ana Maria Gunay for their great help in acquiring proper documents. Special thanks to our survey team Alfonso Biñan, Juancho Valer and Jim Besario for assistance in the field and to Ryan Millena, Cristito Asis and Marecris Asis for gathering field information. Finally, we are very grateful to the executive committee members of the AMWS Protected Areas and Management Board for supporting this endeavor.

Literature Cited

ADB (2011). Asian Development Bank TA7258 - PHI Agusan River Basin Integrated Water Resources Management Project. Final Report. Pöyry IDP Consult, Inc. in association with Nippon Koei, U.K. Schema Konsult, Inc. Vol. 1: 19.

AMWS (1992). Agusan Marsh Wildlife Sanctuary management plan and boundary delineation and land use report, DENR Office of the Provincial Environment and Natural Resources, Governance Center, Prosperidad, Agusan Del Sur. Vol. 1: 75.

Arreza, G.R. (1999). A report on the floral survey of Agusan Marsh Wildlife Sanctuary. Unpublished report. Pp. 8-12.

Bracamonte, N.L., Roxas, A.G., Poblete, T.O., Gomez, L.V. and Seronay, R. (2008). Social and economic aspects of the Agusan Marsh Key Biodiversity Area. Pp. 85-97 *in* Proceeding of the 1st Scientific Conference on the Agusan Marsh. Philippine Council for Aquatic and Marine Research and Development, UNESCO: Jakarta.

Cassion, K.E. (2002). Villagers probed for eating, killing croc. Philippine Daily Inquirer Newspaper, 17 April 2002. Vol. 17: 52.

CFI (1996). The Beauty of the Beast: Conserving the Crocodiles of the Philippines, Comprehensive Report (1987-1995). Crocodile Farming Institute: Puerto Princesa City, Palawan, Philippines.

CFI (1999). Crocodile Farming Institute Accomplishment Report 1st quarter 1999. Crocodile Farming Institute: Puerto Princesa City, Palawan, Philippines.

Crocodile Specialist Group (1996a). *Crocodylus mindorensis*. *In* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 28 March 2012.

Crocodile Specialist Group (1996b). *Crocodylus porosus*. *In* IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. <www.iucnredlist.org>. Downloaded on 28 March 2012.

Davies J. (1991). Species of plants identified in the various types of habitats in Agusan Marsh. As cited in: Agusan Marsh Wildlife Sanctuary management plan and boundary delineation and land use report, DENR Office of the Provincial Environment and Natural Resources, Governance Center, Prosperidad, Agusan Del Sur. Vol. 1: 75.

Dizon, N.V. (2008). Socio-economic initiatives of local governments and nongovernment organization in Agusan Marsh. Pp. 98-101 *in* Proceedings of the 1st Scientific Conference on the Agusan Marsh. Philippine Council for Aquatic and Marine Research and Development, UNESCO: Jakarta.

Hibaya, J.C., Manalo, R.I. and Aquino, M.T.R. (1999). Preliminary Assessment of Identified *C. mindorensis* Habitats in the Philippines. Unpubl. CFI Report.

IUCN. (1996). 1996 IUCN Red List Categories. IUCN Species Survival Commission, IUCN Council: Gland, Switzerland. Pp.15-17.

Manalo, R.I. (2008). Occurrence of Philippine Freshwater Crocodile (*Crocodylus mindorensis*) in the Cordillera Central, Abra, Province, Luzon Island, Philippines. National Museum Papers 14: 109-115.

Mercado, V.P. (2008). Current status of the crocodile industry in the Republic of the Philippines. National Museum Papers 14: 26-34.

Messel, H., King, F.W., Webb, G.J.W. and Ross, C.A. (1992). Summary report on the workshop on the prospect and future strategy of crocodile conservation of the two species (*Crocodylus mindorensis*, *Crocodylus porosus*) occurring in the Philippines. Pp. 98-101 *in* Crocodile Conservation Action. A Special Publication of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ortega G.V. (1998). Philippine Crocodile Conservation: comprehensive report. *In* Crocodiles. Proceedings of 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Ortega, G.V. (1996). The Beauty of the Beast: Conserving the Crocodiles of the Philippines. Crocodile Farming Institute Comprehensive Report (1987-1995). 41 pp.

Pontillas, U.F.A. (2000). New breeding sites for the Philippine Crocodile. Crocodile Specialist Group Newsletter 19(2): 10-12.

Ross, C.A. (1982). Final Report: Smithsonian Institution/World Wildlife Fund Philippine Crocodile Project. WWF Report. 32 p.

Ross, C.A. (2008). A question of habitat - *Crocodylus mindorensis*. National Museum Papers 14: 116-122.

Ross, C.A. and Alcala, A.C. (1983). Distribution and status of the Philippine Crocodile (*Crocodylus mindorensis*). Kalikasan, Phil. J. Biol. 12(1-2).

Schmidt, K.P. (1935). A new crocodile from the Philippine Islands. Field Mus. Nat. Hist. Zool. Ser. 20: 67-70.

Establishing a European Support Program for Philippine Crocodile Recovery

Rene Hedegaard

Danish Crocodile Zoo, Ovstrupvej 9, Eskilstrup, Denmark
(croczoo@mail.dk)

Abstract

The Philippine Crocodile is one of the most threatened crocodilians, and has been largely unrepresented within zoos, particularly in Europe. With the historical import of 15 *C. mindorensis* in 2006, not only did four years of work come to fruition for the Danish Crocodile Zoo (DCZ), but an important breeding program for the species could commence within European zoos. Since publication of the Philippine Crocodile National Recovery Plan by the Philippine Department of Environment and Natural Resources (DENR) and Chris Banks in 2000 and its subsequent revision in 2005, importance was placed on expanding breeding programs for the species within zoos. The aim of our project was to establish the first breeding group of Philippine crocodiles within Europe, and to support in situ conservation efforts for the species. Fifteen Philippine Crocodiles were transferred to DCZ under a Memorandum of Agreement between DCZ and the DENR, through its Protected Areas and Wildlife Bureau (PAWB). Under the MOA, DCZ is responsible for all 15 crocodiles and their future offspring, as well as for maintaining the European Studbook for the species. As identified in the National Recovery Plan, the intention of the transfers is to increase support for priority in situ actions. Upon importing the crocodiles to Denmark, one pair was sent to each of 5 European zoos - Chester Zoo, London Zoo, Bergen Aquarium, Zurich Zoo and Cologne Zoo - with the remaining 5 crocodiles (3M:2F) kept at DCZ. As well as establishing educational programs themselves, each of the partner zoos provide funding to the priority conservation programs of the Mabuwaya Foundation in Isabela Province. These funds have been used to set up and maintain a Philippine Crocodile nest protection and head start program. Since 2006, 22 nests have been protected, yielding 141 hatchlings for the head-start program. To date, 68 of these head-started crocodiles have been released back into the wild, significantly boosting the wild population of the Philippine Crocodile. With the continuing support of 6 European zoos under an agreement with the Philippine Government, *C. mindorensis* will benefit not only from captive breeding efforts within the zoos, but also from the direct support to *in-situ* conservation programs.

Environmental Education Mobilizes Community Support for Philippine Crocodile Conservation: Something to be Proud of!

Myrna C. Cureg [1,2], Merlijn van Weerd [2,3], Marites G. Balbas [2] and Jan van der Ploeg [2,3]

[1] College of Development Communication and Arts and Sciences, Isabela State University, Cabagan, 3328 Isabela, Philippines
[2] Mabuwaya Foundation Inc., ISU-Cabagan, 3328 Isabela, Philippines
[3] Leiden University PO Box 9518, 2300 RA Leiden, the Netherlands

Abstract

Crocodile conservation starts with communication. Over the past 10 years, an intensive communication, education and public awareness (CEPA) campaign has informed local communities on Philippine Crocodile conservation in the Northern Sierra Madre, Philippines. In addition to targeting people who live near Philippine Crocodile habitat, information is also provided to visitors of the Philippine Crocodile rearing station in San Mariano town. Here crocodile hatchlings are being raised in captivity, and awareness is raised about Philippine Crocodile conservation among the public at large. We have refined our CEPA strategy on the basis of an evaluation of the impact of various communication means among 500 respondents. Actively involving local communities in crocodile conservation and wetland management has resulted in the successful establishment of Philippine Crocodile sanctuaries. Most of the residents now know that the species is protected by law. Many people take pride in the occurrence of this rare and critically endangered species near their village and actively support *in-situ* crocodile conservation. The Philippine Crocodile population is slowly recovering. This recovery also leads to more human-crocodile conflicts, thereby posing new challenges for effective environmental communication and public advocacy, both at a local and supralocal level.

Using Participatory Video Filming to Engage People in the Conservation of the Philippine Crocodile

Nicolien Pul[1], Jan van der Ploeg[1,2], Marites Balbas[1], Arnold Macadangdang[1], Gerard Persoon[2], Myrna C. Cureg[1,3] and Merlijn van Weerd[1,2]

[1] Mabuwaya Foundation Inc., Cabagan, 3328 Isabela, Philippines (mabuwaya@yahoo.com)
[2] Leiden University, PO Box 9516, 2300 RA Leiden, the Netherlands
[3] College of Development Communication, Arts and Sciences, Isabela State University, Cabagan, Isabela, Philippines

Abstract

Effective communication is essential for community-based conservation. But communicating with people living in remote rural areas is often challenging. We used video and photo cameras as a tool to facilitate a dialogue about the conservation of the critically endangered Philippine Crocodile. People made videos and photos about their experiences with crocodiles and about the use of wetlands. This photo and video material was subsequently used as a starting point for a dialogue with the community. The use of participatory videography and photography gave new insights in the perceptions and concerns of people living in Philippine Crocodile habitat, and enabled a more equal dialogue between conservationists and rural communities.

Introduction

The Philippine Crocodile is a critically endangered species (IUCN 2012). Hunting, fishing and habitat loss have led to the disappearance of the species in most parts of the archipelago (van Weerd 2010). The Mabuwaya Foundation aims to conserve the Philippine Crocodile and its wetland habitat, using a community-based approach (van Weerd and van der Ploeg 2012).

Communication is essential for successful community-based conservation. But language barriers, cultural differences, mistrust, power dynamics and conflicts often hamper interactions between conservationists and rural communities. Posters, billboards and theatre shows are effective tools to raise awareness but do not encourage feedback and active participation. Over the past years the Mabuwaya Foundation has organized community dialogues to exchange information and discuss problems with rural communities (van der Ploeg *et al*. 2009). But people are often shy to speak up in groups. The challenge is to find innovative ways that enable people to express their perspectives on and problems with crocodiles, and discuss issues that otherwise remain unnoticed.

Participatory video can facilitate communication with and between rural communities. The idea is that the making of a video can bring people together to explore issues, voice concerns and tell stories. This process can enable a community to take action to solve their own problems and also to communicate their needs and ideas to decision-makers (Lunch and Lunch 2006)). Participatory video has been applied to put forward issues regarding human welfare and human rights, or to encourage agricultural innovations in India (Gandhi *et al*. 2007). So far this method has hardly been applied to involve people in nature conservation. Therefore, we explored how participatory visual methods (video and photography) can be used to involve rural communities in San Mariano in the conservation of the Philippine Crocodile.

Methods

The research area was the municipality of San Mariano in Isabela, North Luzon, Philippines. Participants were selected from 6 different sitios (villages) that were located near the Philippine Crocodile sanctuaries: sitios Diwagden, San Isidro, Kamalaklakan and Kamarasitan along Disulap River; Dunoy near Dunoy Lake; and Lumalog along Dinang Creek. In total, 26 people participated in the video assignment and 9 people in the photo assignment.

First, we explained to the participants that we were interested in their experiences with crocodiles, and that we wanted them to use film or photography to tell their stories. All participants were informed that their film material would be showed during a community dialogue. In a short workshop the participants were taught how to use a small, easy-to-use HD pocket video camera (Vado HD 720p Pocket Video Camcorder, Creative Labs) or a compact digital photo camera (Powershot A630, Canon; FinePix XP10, Fujifilm). People were asked to take some photos or videos during a few exercises. The main purpose of these workshops was to teach how to handle a camera and to make the participant feel at ease with the camera (see Fig. 1). We then gave the participants one or two assignments: (1) film or photograph during a whole day all moments that you use water; and (2) film or photograph your experiences with the Philippine Crocodile. We tried to encourage people to also film specific problems related to Philippine Crocodile conservation. The participants were given 1-2 days to do the filming or photography.

Figure 1. Workshop on the use of a small video camera. The workshops often attracted a lot of attention of fellow community members. Photograph: Nicolien Pul.

Table 1. Themes and sub-themes of videos and photographs shot by the participants.

Theme/Sub-theme	Video	Photograph
Experiences with crocodiles		
Ecology and behavior	X	
Nest, eggs and hatchlings	X	
Crocodile conservation	X	
Crocodile encounters:		
General	X	
Sightings	X	X
Attacks on humans	X	X
Attacks on livestock	X	X
Traditional values and beliefs	X	
Use of water		
Human use:		
Household activities	X	X
Issues/benefits regarding supply	X	
Health and sanitation	X	X
Agricultural use	X	X
Livestock use	X	X
Broader environment and development issues		
Erosion	X	
Food consumption	X	
Agriculture	X	
Livestock	X	

When the person was finished with the assignment, the captured material was shown back on a laptop. The participant was asked to comment on each of the pictures or videos and these comments were, translated from Ilocano or Tagalog into English, written down or captured on video. Additional questions were asked, based on the comments by the participants. Discussing the material with the participants was very useful: the participants enjoyed watching the videos and photos and the discussion often added extra meaning to the video or photograph that was not apparent when merely looking at the material. These discussions clarified often why the participant took a specific picture.

After translation of the videos and the comments in English, the material was categorized according to theme. The videos were divided over three main themes: (1) experiences with crocodiles; (2) the use of water; and, (3) broader environment and development issues. These themes were subsequently divided in sub-themes (Table 1).

The videos made by the participants were then compiled into short movies (software: Premiere Pro CS4, Adobe) that could be shown back to the community during a community dialogue. We tried to communicate the story as it was filmed by the participants. Compilations were made based on the themes and sub-themes in Table 1. Approximately 5 pictures were selected from each participant to be discussed during the community dialogues. These pictures were selected by the participants themselves or else chosen by us. Comments with pictures were printed in text next to the picture or, in case the comments were videotaped, compiled in a short movie.

Finally, three community consultations were organized in the sitios Diwagden (covering Kamarasitan and Kamalaklakan), San Isidro and Lumalog. Village leaders were informed about the consultations approximately 1-2 weeks in advance, and asked to invite the participants and to inform the community. During the community consultation, the movies and pictures were shown. After every movie or picture session there was discussion for about 5 to 15 minutes. At the end of the consultation a certificate of appreciation was handed to each participant.

Discussion

It was the first time that people in San Mariano were asked to film their perceptions and experiences with crocodiles themselves. The participants learned quickly how to operate the cameras. All cameras were handled with care and returned in good state. The quality of the material captured by the participants was generally acceptable, especially as most participants had no previous experience with digital imaging devices. Only the framing of the videos and photographs was sometimes challenging. Technical issues with video included the mediocre sound quality and sometimes shaky images when no tripod was used; these are inherent to the low-cost low-quality equipment used. Technical issues with the use of the photographic camera were blurry and/or overexposed pictures when the camera was not held steady or when the shutter was pressed too quickly.

People greatly enjoyed making and watching the videos and photographs. The pictures and videos captured a wide range of topics on crocodiles and the use of water resources. Table 2 summarizes the issues with crocodiles and water resources identified by the participants in their videos.

Table 2. Main issues with crocodiles, crocodile conservation and water identified by the participants.

Issues with crocodiles
Crocodile attacks on humans (people are concerned about the safety of their children).
Crocodile attacks on livestock (primarily in sitio Lumalug).
Issues with local governance and crocodile conservation
Lack of awareness regarding local legislation protecting crocodiles and wetlands
Problems with national environmental legislation (feelings of illegitimacy)
Benefit sharing (friction about sharing water pumps; lack of clarity how barangay officials spend breeding reward)
Responsibilities of local wardens (lack of support from local government unit)
Issues with water
Human health (the availability of safe and clean water)
Sanitation (pollution of creeks and rivers)
Water scarcity (irrigation and drinking water).
Erosion (siltation of creeks, flashfloods)

Most of the problems with crocodiles are occurring in sitio Lumalog along Dinang Creek. Here crocodiles regularly attack livestock and in 2010 a pregnant woman was attacked by a crocodile when she was bathing in the creek (van Weerd and van der Ploeg 2012). These attacks have eroded people's support for the conservation of the Philippine Crocodile in this sitio. Attacks on livestock sometimes also occur in the other sitios. Some participants say they don't like it when a chicken or pig gets eaten, but that they understand that the crocodile is hungry.

The participants captured several activities in and around the creeks and rivers. Many participants voiced their concern about the bad quality of their water sources and would like to see that changed. Several participants filmed or photographed activities of people that pollute water sources. The videos and photographs highlighted the importance of sanitation and health for rural communities.

The compiled movies were then shown to the community. People enjoyed very much to see the videos. However, there still was not much discussion. Social structure and hierarchy and the fact that people are shy to speak up will probably always stand in the way for people in this area to participate actively in community consultations. Community consultations are useful to disseminate information, but when the purpose is to exchange experiences and listen to people's concerns, one-on-one discussions or smaller groups on specific topics (for example farmers on land use or women on sanitation) are more effective.

People were generally positive about the participatory video and photo project. For example, one participant felt proud that he was able to make a video even though he had no experience at all with technology and he had no education. Another participant mentioned that this method is a good way to encourage people to protect the Philippine Crocodile and the creeks and rivers.

Figure 2. Philippine Crocodile in Dinang Creek. Photograph: Georgy Languido (sitio Lumalug): "Most people see this crocodile here every day. It's close to the houses. I'm not afraid because the crocodile is asleep".

Figure 3. A girl in Dinang Creek. Photograph: Filamy Bagauisan (10 y; sitio Lumalug). Domingo Robles: "We are afraid that our children and grandchildren will be harmed by the crocodiles. That's the reason why we hate crocodiles".

Figure 4. A boy gives water to the animals. Photograph: Tessie Binlingan (barangay San José). Johnny de Gollo: "A crocodile attacked my pig far from the sanctuary. And the crocodile did not even finish everything: it just ate the intestines of the pig. That's not good. The crocodile is greedy."

Figure 5. Water pump in sitio Lumalug. Photograph: Filamy Bagauisan (sitio Lumalug). Junior Urbano: "In summer the pump is dry and we have no water. The neighbors have conflicts over the pump. The woman that lives closest to the pump wants it as her private pump. People are now ashamed to go there".

Figure 6. Creek in San Isidro. Photograph: Bambina Baliwag (sitio San Isidro). Marilyn Pregillana: "We should not throw garbage, plastics, diapers and dead animals in the river. People should not use the river as toilet. We are the ones who are affected. Do you know what the dirty water gives us? It will cause skin diseases. [...] Don't throw your garbage in the river, so that the river will be clean. [...] That is all we can do to protect the river".

Conclusions

In one of the video clips Patrocinio J. Salarzon, a resident of sitio San Isidrio, describes what usually happened when people encountered a Philippine Crocodile in the past: "In the morning, we visited the net. All we thought was that we caught a large fish in the net, but it was a big crocodile. It almost weighed 16 kilos. Because we didn't know yet that there is a law regarding the crocodile, we killed it." His words show that communication is an essential component (perhaps even a precondition) for the conservation of the Philippine Crocodile in the wild (van der Ploeg *et al*. 2011).

Participatory video can improve communication between rural communities, decision-makers and conservationists. Participatory video highlights the perspectives, problems and priorities of local people, and enables conservationists to address these concerns. For example, it seems essential to prevent Philippine Crocodile attacks on livestock in sitio Lumalug. People often highlighted the need to improve access to safe drinking water and basic sanitation. By linking Philippine Crocodile conservation to human health, conservationists can make the conservation of the species more relevant for local people.

The videos made by the participants can also be used for raising awareness within the community. In many cases the videos documented the knowledge of and experiences with crocodiles of local inhabitants. The stories of neighbors, friends, village leaders and elders are often more convincing than the recommendations of outsiders (van der Ploeg *et al*. 2009). Participatory video and photography can empower rural communities to protect their water resources and the Philippine Crocodile.

Acknowledgements

We thank all community participants for their enthusiastic contribution to the participatory video and photo project. This project was partly funded by a WWF Netherlands INNO Grant.

Literature Cited

Gandhi, R., Veeraraghavan, R., Toyama K. and Ramprasad, V. (2007). Digital Green: Participatory video for agricultural extension. Pp. 21-30 *in* Proceedings of the IEEE/ACM International Conference on Information and Communication Technologies and Development. Bangalore.

IUCN (2012). IUCN Red List of Threatened Species. Version 2012.1. <http://www.iucnredlist.org>. Downloaded on 20 May 2012.

Jeffries, M.J. (2006). Biodiversity and Conservation. Second Edition. Routledge: London.

Lunch, N. and Lunch, C. (2006). Insights into Participatory Video: a Handbook for the Field. InsightShare: Oxford.

van der Ploeg, J., Balbas, M.G. and van Weerd, M. (2009). Do crocodiles have rabies? Initiating a dialogue on *in-situ* crocodile conservation. Crocodile Specialist Group Newsletter 28(3): 8-10.

van der Ploeg, J., Cauilan-Cureg, M., van Weerd, M. and De Groot, W.T. (2011). Assessing the effectiveness of environmental education: mobilizing public support for Philippine crocodile conservation. Conservation Letters 4(4): 313-323.

van der Ploeg, J. and van Weerd, M. (2004). Devolution of Natural Resource Management and Crocodile Conservation. The Case of San Mariano, Isabela. Philippine Studies 52: 346-383.

van Weerd, M. (2010). Philippine crocodile *Crocodylus mindorensis*. Pp 71-78 *in* Crocodiles. Status Survey and Conservation Action Plan, ed. by C. Manolis and C. Stevenson. Crocodile Specialist Group: Darwin.

van Weerd, M. and van der Ploeg, J. (2012). The Philippine Crocodile: Ecology, Culture and Conservation. Mabuwaya Foundation: Cabagan.

Note: A short compilation movie of this project can be watched at: http://www.youtube.com/watch?v=_uuW4b3pwdY.

Status of Siamese Crocodiles (*Crocodylus siamensis*) in Lao PDR

Chanthone Phothitay and Christopher D. Hallam

Abstract

Lao PDR holds a significant proportion of the remaining global population of Siamese Crocodile (*Crocodylus siamensis*). Since its "rediscovery" in Laos in the early 2000s steps have been taken to increase the species legal protection and implement on ground conservation activities. Since this time formal legal protection has been given to the species and currently, there are activities underway in collaboration between the Wildlife Conservation Society (WCS) and Provincial Agriculture and Forestry Office of Savannakhet Province to assist in site-based conservation. This presentation reports on activities thus far, current status of the species and conservation needs.

Community-Based Crocodile Conservation for Siamese Crocodiles in Lao PDR

Christopher D. Hallam[1*], Oudomxay Thongsavath[1], Pakham Outhanekone[1] and Steven G. Platt[2]

[1]Wildlife Conservation Society Lao Program, Vientiane Lao PDR
[2]Wildlife Conservation Society
***Corresponding author: challam@wcs.org**

Abstract

Lao PDR holds a significant portion of the remaining global population of wild *Crocodylus siamensis*. All of the known populations in Lao inhabit wildlands outside of formally protected areas. These remaining populations are under threat from agricultural expansion, habitat loss and illegal hunting. To address this issue Wildlife Conservation Society (WCS) is working with 10 villages in Savannakhet Province of central Lao PDR to set up community-based conservation zones, strengthen village governance, establish village based head-starting programs and village survey teams with the aim of protecting and augmenting the remaining wild populations. In addition, WCS is collaborating with the Lao Zoo to head-start hatchlings collected from the wild, and establish a captive breeding program based on genetically pure Siamese Crocodiles. This presentation reports on accomplishments to date and activities planned for the near future.

New Data on the Conservation Status of the Orinoco Crocodile (*Crocodylus intermedius*) in Colombia

Antonio Castro[1], Manuel Merchán[1], Mario Garcés[1,2], Miguel Cárdenas[1,3] and Fernando Gómez[1,4]

[1]Asociación Chelonia - Colombia, CL 19A #88 24, Bogotá, Colombia; International, c/- Aristóteles, 3, 28027, Madrid, Spain (chelonia@chelonia.es)
[2] Universidad del Valle, Grupo de Investigación en Ecología Animal, Cali, Colombia
[3] Corporación Áreas Naturales Protegidas, CL 78F #42B 16 Sur, Bogotá, Colombia
[4] Servicio de Rastreo Forestal (SERAFO), c/- Pamplona, 56, Bajo J, 26007, Logroño (La Rioja), Spain

Abstract

The critically endangered and endemic Orinoco Crocodile (*Crocodylus intermedius* Graves, 1819) was historically found in the majority of the main rivers of the Orinoco basin. At present, only four relict populations exist in Colombia. From 2010 to 2012, three of these populations were surveyed to update information on conservation status. Other areas where information indicated the potential presence of the species were also prospected. At the same time, areas within the species' historic distribution range were evaluated as potential places for reintroduction. More than 3500 km were traveled by boat, covering stretches of 1258 km in several rivers of the Arauca, Casanare and Vichada Departments in Colombia. Flights were carried out in 2010 in the Meta River basin. This study provides new information about localities, population structure, behavior and threats that inhibit the recovery of the species in the wild.

Introduction

The Orinoco Crocodile (*Crocodylus intermedius*) is the only crocodilian whose geographical distribution is limited to a single hydrologic basin: the Orinoco River basin in Colombia and Venezuela. The species is categorized as "Critically Endangered" by the IUCN and the Environmental Ministry of Colombia (Resolution No 383 on February 23rd 2010). From the beginning of 2010 to the present, the Asociación Chelonia and the Corporación Autónoma Regional de la Orinoquia (Corporinoquia) have been carrying out a project in the Departments of Arauca, Casanare and Vichada to support the conservation of the species in Colombia (Merchán *et al*. 2012), as a complement of other conservation initiatives, framed within the National Program for the Conservation of the Orinoco Crocodile, formulated by the Ministry of Environment of Colombia in 1998.

The intense hunting carried out between 1930 and 1960 in the Llanos of Colombia and Venezuela driven by the commercial trade for its skin nearly led to the species' extinction. In Colombia, at least 252,300-254,000 skins were traded during the hunting period (Medem 1981). At the beginning of the hunting period, 850,000 skins were exported from Venezuela in four years (Medem 1983). Subsequently, Thorbjarnarson (1987) and Antelo (2008) estimated that the Orinoco Crocodile population reached, respectively, at least 2 and 3 million specimens in the Llanos region before 1930.

At present, the Colombian populations of the species are restricted to four specific areas (Fig. 1): 1. the central-southern region of Arauca Department (Cravo Norte, Ele, Lipa and Cuiloto Rivers); 2. the medium course of the Meta River; 3. the Vichada River; and, 4. the southwestern region of Meta Department (Guayabero and Duda Rivers) (Ministerio del Medio Ambiente 2002). Some solitary individuals have been reported in other watercourses outside the mentioned areas.

Methods

From the beginning of 2010 until the present, diurnal and nocturnal surveys were carried out in numerous watercourses of the Arauca, Casanare and Vichada Departments (Table 1), mainly during the low water level season (from November to April). These surveys were carried out to update information on the conservation status of the species and to evaluate the conditions of potential reintroduction habitat areas. Several transport means were used for the sampling activities, meanly metallic and fiber glass hull boats with outboard engines and, less frequently, horses, kayaks and wooden canoe-style boats, 4x4 vehicles, and foot travel. Furthermore, several aerial itineraries were carried out in the medium course of the Meta River and tributaries with two types of aircraft ("trike" and "air cam"), which allows flights at low altitude and slow speed. Global positioning devices were used to obtain the geographical references for the individuals and tracks registered.

Sandy beaches, riverbanks and water surface were prospected during the diurnal surveys to look for individuals and trails, which were always led by one or more local inhabitants who were familiar with the area. Stops were made to interview riverine inhabitants or fishermen to obtain present or past information about the species. The estimated total length of the individuals was compared to the track measures when possible.

Nocturnal surveys were carried out using 1,000,000 and 2,000,000 cd spotlights and long range flashlights. Because the presence of insurgent groups complicated the security situation in some of the survey areas, it was not possible to carry out spotlight surveys in some watercourses.

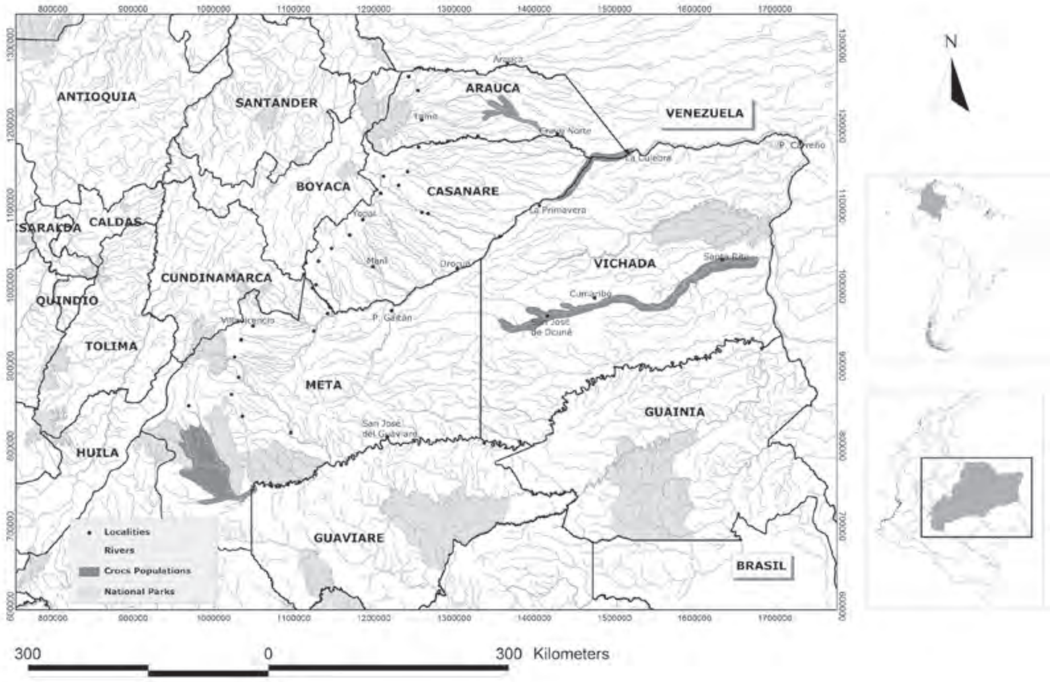


Figure 1. Location of the four relict populations of *C. intermedius* in Colombia (dark grey).

Table 1. Watercourses surveyed in the Arauca, Casanare and Vichada Departments (Colombia).

Sub-Basin	River/Creek	Total Dist. (km)	Stretch Dist. (km)	Spotlight Survey (km)	Visits	Months
Meta	Cravo Sur	116.4	31.4	7.3	3	Aug/Sep/Nov 10
	Güira	7.5	7.5	-	2	Sep/Nov 10
	Caimán	4.8	2.4	-	1	Sep 10
	Güirripa	Spot	Spot	-	1	Sep 10
	Canacabare	24.0	12.0	12.0	1	Nov 10
	Meta	1353.0	322.0	135.0	5	Aug/Nov/Dec 10/Mar 11/Feb 12
	Duya	8.7	8.7	-	1	Aug 10
	Guanapalo	89.6	44.8	44.8	1	Nov 10
	Gandul	14.3	7.2	7.2	1	Nov 10
	Yatea	Spot	Spot	-	1	Nov 10
	Guachiría	36.0	18.0	-	1	Nov 10
	La Hermosa	80.4	40.2	40.2	1	Nov 10
	Picapico	37.0	18.2	18.2	1	Feb 12
	Aguasclaras	28.4	14.2	14.2	1	Feb 12
	Ariporo	31.6	26.8	-	2	Oct 10/Feb 11
	Chire Nuevo	Spot	Spot	-	2	Oct 10/Feb 11
	El Toro	7.0	3.5	-	1	Oct 10
	El Indio	4.0	2.0	-	1	Oct 10
Cravo Norte-Ele-Lipa	Cravo Norte	254.0	127.0		1	Apr 12
	Ele	88.0	44.0	14.2	1	Apr 12
	Lipa	28.0	14.0	19.5	1	Apr 12
Casanare	Casanare	164.0	82.0	76.0	1	Feb 12
Vichada	Vichada	1234.0	402.0	52.0	2	Dec 10/Feb 11
Orinoco	Orinoco	57.7	30.5	-	1	Mar 11
Dagua-Mesetas	Dagua	Spot	Spot	-	1	Mar 11
	Mesetas	Spot	Spot	-	1	Mar 11
Total		3668.4	1258.4	440.6		

Results

Arauca Population

Between 9 and 12 April 2012, 185 km of river in the central-southern region of the Arauca Department (14 km of the Lipa River, 44 km of Ele River and 127 km of Cravo Norte River) were surveyed by boat during the day and at night to detect the presence of Orinoco Crocodiles and their tracks on beaches and riverbanks. Thirty specimens were observed and 5 nests were visually identified (Tables 2 and 3). Also, 4 nests were noted from information provided by local inhabitants (two were flooded and two were destroyed by humans). Because of the rapid increase in water levels this year, 3 nests were totally flooded (two were referenced and one was verified) and another one was partially flooded. In the latter case the nest was found 2.5 m away from the shore of the river, although the water had penetrated the nest from the bottom. From this nest 12 hatchlings were produced, 12 eggs had not yet hatched and 16 eggs and hatchlings were lost. This nest was watched by two local inhabitants who told us that it was laid on 10 January; the eggs hatched 91 days later on 12 April. The other 4 nests identified seemed to hatch successfully according to the information received, although we could not locate the hatchlings near the nest area. The same information source noted that 42 hatchlings hatched from one of these nests.

Table 2. Location of nests and hatching success.

Nest	River	Coordinates		Hatching Success
1	Cravo Norte	N 06° 31’42.1”	W 70° 48’39.2”	Successful
2	Cravo Norte	N 06° 27’59.3”	W 70° 37’22.1”	Successful
3	Cravo Norte	N 06° 23’33.0”	W 70° 25’43.4”	Partially successful
4	Cravo Norte	N 06° 23’24.2”	W 70° 25’57.3”	Successful
5	Cravo Norte	N 06° 23’24.2”	W 70° 25’57.3”	Flooded (same beach as Nest 4)

Ardila *et al*. (2002) detected 11 nests in 2001 (two of them just “potential”): 6 in the Ele River and 5 in the Cravo Norte River. The 5 nests detected by Asociación Chelonia were located in the Cravo Norte River. Nest 4 and 5 (Table 2) were found on the same beach, 2.5 m from each other. The nests detected by Asociación Chelonia do not geographically coincide with any of the nests detected in 2001 (although the 2001 locations were not detailed precisely in the publication, only plotted in a detailed map) (Fig. 2).

The specimens registered in 2012 were: 3 adult (estimated TL >2.5 m) and one sub-adult crocodiles in the Lipa River (0.28 ind./km); 7 adults and 2 sub-adults in the Ele River (0.2 ind./km); 8 adults and 9 sub-adults in the Cravo Norte River (0.13 ind./km) (Table 3; Fig. 3). The majority of the specimens were located during the day. Because of the highly problematic security situation in the area, only 19.5 km were surveyed at night in the Ele River and 14.2 in the Lipa River.

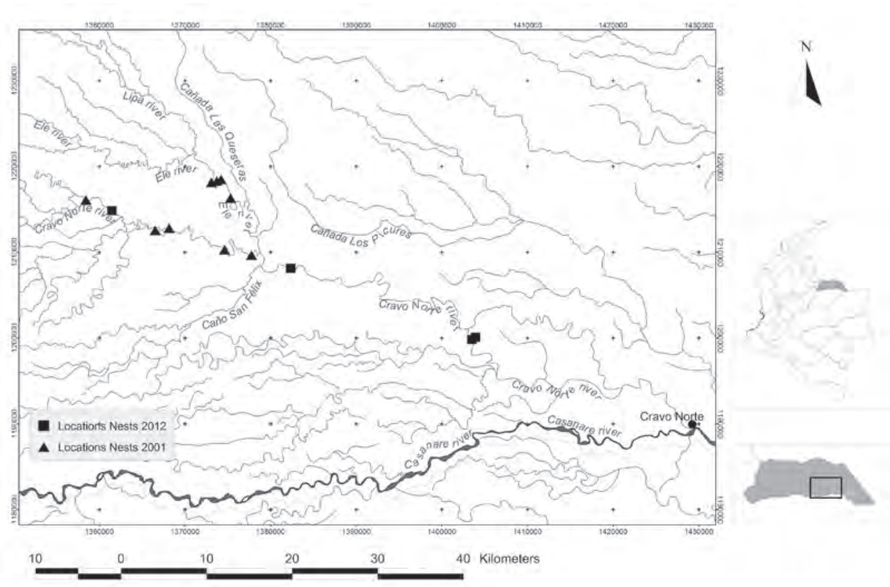


Figure 2. Locations of Orinoco Crocodile nests detected in 2001 and 2012 in the Cravo Norte-Ele-Lipa River system (Arauca Department).

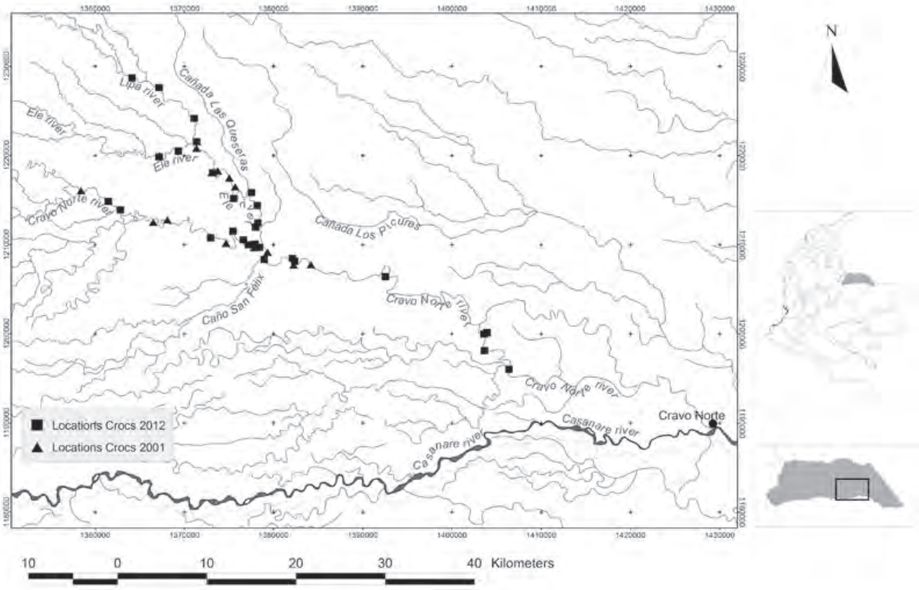


Figure 3. Locations where Orinoco Crocodiles were observed in 2001 and 2012 in the Cravo Norte-Ele-Lipa River system (Arauca Department).

Table 3. Details of Orinoco Crocodiles detected in the Cravo Norte-Ele-Lipa River system (Arauca Department). TL= total length.

Nest	Date	River	Detection	Est. TL (m)	Coordinates
L1	Apr 12	Lipa	Visual	4.5	N 06°35’17.30”, W 70°43’16.20”
L2	Apr 12	Lipa	Visual	2	N 06°36’42.90”, W 70°43’24.70”
L3	Apr 12	Lipa	Visual	2.6	N 06°38’35.70”, W 70°45’31.30”
L4	Apr 12	Lipa	Visual	4	N 06°39’12.01”, W 70°47’10.40”
E1	Apr 12	Ele	Visual	3	N 06°34’43.50”, W70°44’22.80”
E2	Apr 12	Ele	Visual	3	N 06°34’23.10”, W 70°45’33.30”
E3	Apr 12	Ele	Visual	3	N 06°31’49.20”, W 70°41’02.90”
E4	Apr 12	Ele	Visual	4	N 06°32’10.80”, W 70°39’57.80”
E5	Apr 12	Ele	Visual	1	N 06°33’23.50”, W 70°42’17.80”
E6	Apr 12	Ele	Visual	2.8	N 06°31’23.40”, W 70°39’37.10”
E7	Apr 12	Ele	Visual	1	N 06°31’23.40”, W 70°39’37.10”
E8	Apr 12	Ele	Visual	3.3	N 06°30’19.90”, W 70°39’35.20”
E9	Apr 12	Ele	Visual	3.5	N 06°30’05.30”, W 70°39’43.50”
C1	Apr 12	Cravo Norte	Visual	0.5	N 06°28’50.50”, W 70°39’30.10”
C2	Apr 12	Cravo Norte	Visual	4	N 06°29’18.40”, W 70°40’28.70”
C3	Apr 12	Cravo Norte	Visual	1.5	N 06°29’50.40”, W 70°41’05.80”
C4	Apr 12	Cravo Norte	Visual	4.5	N 06°29’26.70”, W 70°42’27.80”
C5	Apr 12	Cravo Norte	Visual	4	N 06°31’10.70”, W 70°47’55.50”
C6	Apr 12	Cravo Norte	Visual	4.5	N 06°31’42.10”, W 70°48’39.20”
C7	Apr 12	Cravo Norte	Visual	2.7	N 06°29’00.60”, W 70°40’10.80”
C8	Apr 12	Cravo Norte	Visual	2	N 06°29’02.00”, W 70°39’46.00”
C9	Apr 12	Cravo Norte	Visual	1	N 06°28’06.20”, W 70°39’12.90”
C10	Apr 12	Cravo Norte	Visual	2	N 06°28’09.60”, W 70°37’30.10”
C11	Apr 12	Cravo Norte	Visual	3	N 06°27’59.28”, W 70°37’22.08”
C12	Apr 12	Cravo Norte	Visual	1.5	N 06°27’00.60”, W70°31’52.00”
C13	Apr 12	Cravo Norte	Visual	3.6	N 06°27’00.04”, W70°31’51.38”
C14	Apr 12	Cravo Norte	Visual	3	N 06°23’34.34”, W70°25’44.00”
C15	Apr 12	Cravo Norte	Visual	1	N 06°23’29.03”, W 70°25’54.60”
C16	Apr 12	Cravo Norte	Visual	2	N 06°22’28.70”, W 70°25’53.60”
C17	Apr 12	Cravo Norte	Visual	1	N 06°21’19.60”, W 70°24’24.60”

Lugo and Ardila (1998) estimated an Orinoco Crocodile population of 50 adults for this region, having also surveyed a short stretch of the Cuiloto River. Ardila *et al*. (2002) estimated a population of 54 individuals for the same area. A comparison of the specimens, eggs and/or nests detected in the last 3 surveys, with available data, is shown in Table 4 and Figure 4.

The higher relative density registered in 2001 seems to be due to the concentration of the survey in the stretches of the Cravo Norte and Ele Rivers where the major part of the individuals seem to inhabit (the zone located between the confluence of the Ele and Lipa Rivers and the confluence of the Cravo Norte and Ele Rivers). Out of this core area, upstream and downstream, the relative density seems to be lower.

Table 4. Numbers of Orinoco Crocodiles, eggs and nests detected in the Arauca population in 1995 (Lugo and Ardila 1998), 2001 (Ardila *et al*. 2002) and 2012 (Chelonia). Hatchlings: numbers in brackets correspond to number of nests where hatchlings came from. Eggs: numbers in brackets corresponds to number of nests where eggs came from. Nests: negative numbers correspond to number of nests predated by humans; p: potential beach for nesting; f: flooded nest; r: nest referenced by local inhabitants.

River	Year	km	Adults	Sub-adults	ind/km	Hatchlings	Eggs	Nests
Cravo Norte River	1995	100	10	2	0.12	2	-	-
Ele River	1995	73	12	-	0.16	-	-	-
Lipa River	1995	10	1	-	0.10	-	-	-
Cuiloto River	1995	20	4	-	0.20	32	-	-
Total	1995	203	27	2	0.14	34	-	-
Cravo Norte River	2001	60	8	2	0.16	-	-	4 +1p
Ele River	2001	30	11	2	0.43	120 (4)	126 (3)	5 +1p
Lipa River	2001	10	1	0	0.10	-	-	-
Total	2001	100	20	4	0.24	120	126 (3)	11 (-7)
Cravo Norte River	2012	127	8	9	0.13	54 (2)	82 (2)	5 (-2f)
Ele River	2012	44	7	2	0.20	-	-	4 (-2r)
Lipa River	2012	14	3	1	0.28	-		
Total	2012	185	18	12	0.16	54	82	9 (-4)

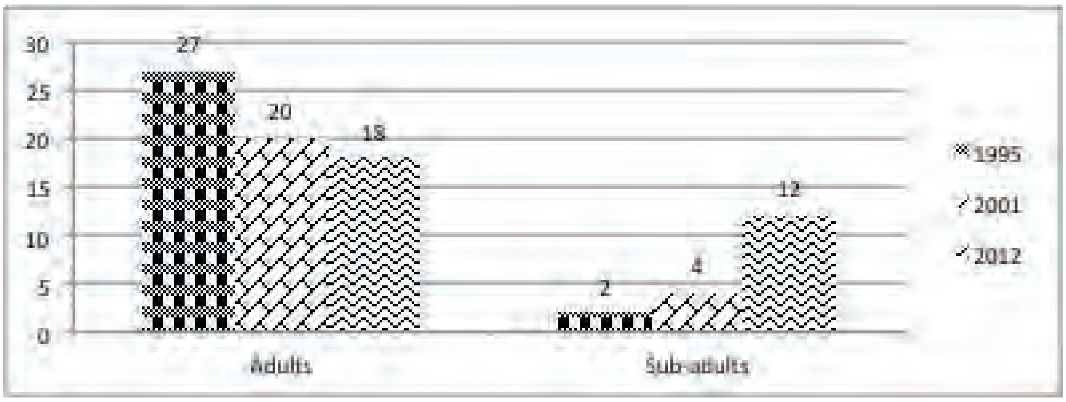


Figure 4. Numbers of adult and sub-adult Orinoco Crocodiles detected in the Arauca population in the dry season of 1995, 2001 and 2012.

One Orinoco Crocodile skull (62 cm long) was found on a property within the area. On the basis of head size we estimate that the individual was an adult of approximately 3.72 m length. The skull presented a hole on the right side of the snout, 30 cm from the anterior extreme, which seems to have been made by a bullet. According to the local inhabitants, this specimen was very emaciated when it was seen a few weeks before it was found dead, so we can assume that the shot prevented the animal from feeding, eventually causing its death. We also received information about the killing in January of other adult specimen. In March, another source informed us about the killing of 3 adults because they had fed on cattle, but we could not verify if they were the same individuals as the other two mentioned.

Vichada River Population

A stretch of 402 km of the Vichada River was surveyed in December 2010 and February 2011, from the place known as El Retorno (20 km upstream from the port of Cumaribo) to Santa Rita. Two specimens were visually detected (Fig. 5) in the same spot of the river (Pozo Caimán) - one in December and another in February (Table 5). Another specimen was detected by its tracks on the beach El Cejal located 10 km downstream from Pozo Caimán (Castro *et al*. 2011a,b) (Fig. 6).

Table 5. Details on Orinoco Crocodiles.

Crocodile	Date	River	Detection	Estimated Size (m)	Coordinates
V1	Dec 10	Vichada	Visual	3-3.5	N 04°31’43.5”, W 68°53’19.1”
V2	Feb 11	Vichada	Visual	2.4	N 04°31’43.5”, W 68°53’19.1”
V3	Dec 10	Vichada	Trail	>2.5	N 04°32’31.7”, W 68°50’13.9”

The specimen observed in December seemed to respond to noises made from the boat. According to our guide’s indications, we made a noise hitting the hull of the boat for about two minutes. The crocodile emerged on the inner side of the meander, showing only its nostrils, eyes and skull roof. After submerging and emerging three times, the specimen displayed a territoriality behavior with its snout pointing towards the center of the river and almost perpendicular to the shore. The behavior consisted in showing the entire dorsal surface of the head, body and tail, coming about two meters closer to the boat. Then, it simultaneously raised its head and tail in an arched position and made a violent lateral movement with the tail. The head tilt became more pronounced, with an open mouth that later closed violently two times, producing two audible snaps. Posteriorly it produced a grunt and slapped its jaw against the surface of the water, followed by the expulsion of air from the mouth and producing bubbles before it submerged back into the water. This behavior is almost the same, with some variations, as that described by Medem (1981), Thorbjarnarson and Hernández (1993), Colvée (1999) and Antelo (2008) for males in captivity in Colombia and Venezuela.

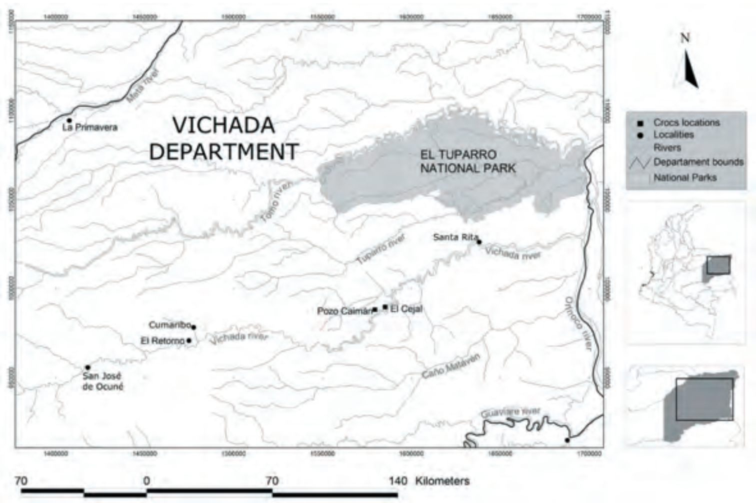


Figure 6. Locations (Pozo Caimán and El Cejal) in the Vichada River where specimens were detected .

Figure 5. Orinoco Crocodile observed in Pozo Caimán, Vichada River (Vichada Department) in February 2011.

We were informed by a local inhabitant that a female nested on 28 December 2010. The nest contained, according to the same source, 41 eggs, which did not hatch. This nest seems to be the only one identified in this stretch of the river. As local people know its location, the eggs are collected for consumption year after year. The information collected in the area indicates that, in at least the last three years, no hatchling or juvenile has been observed by local inhabitants in this stretch (Merchán *et al*. 2012).

The specimen detected in February was observed several times at different hours over two days; although a trail on the beach of the meander was detected, the specimen was not observed out of the water. No other specimen was detected in the area during this survey. Because of the exhibited behavior, size and proximity to the site nest, we suppose that it could be a female, but do not have enough information to be certain.

Lugo and Ardila (1998) estimated seven adult Orinoco Crocodiles in the stretch, from the locality of Cumaribo to the mouth of the river, based on information provided by local inhabitants in 1996, and registered the presence of four hatchlings in a 50-km stretch between Cumaribo and La Raya in 1995.

Middle Course of the Meta River Population

A total stretch of 322 km along the middle course of the Meta River was surveyed on five occasions (August, November and December 2010, March 2011 and February 2012) from the mouth of the Cravo Sur River to the locality of La Culebra (Vichada). Stretches of several tributaries (236.9 km) of the Meta River were also surveyed (Table 1). No Orinoco Crocodiles or tracks were detected in the stretches of the rivers and creeks traveled during these visits. The width of the Meta River and the presence of several branches with sand islands increase the area to be surveyed.

Most of the information collected from local populations, riverine inhabitants and fishermen indicates that the probability of the species' presence is higher from the area known as La Vorágine and downstream the river. Here, some riverine inhabitants indicate the occurrence of two or three specimens. Another specimen is mentioned in the place known as La Constancia, 42 km downstream from La Vorágine (Fig. 7).

Figure 7. Locations where Orinoco Crocodiles are detected in the Meta River.

Nesting does not seem to have been detected by local inhabitants in the last two years. Although there is information about a nesting beach in the area of La Vorágine dating before 2010, the source indicated that the eggs were collected for consumption every year, so there has not been evidence of hatchlings or juveniles in the area in the last few years.

Lugo and Ardila (1998) estimated the presence of 15 adults in the stretch of the Meta River between La Primavera and La Culebra based on information from local populations. She also recorded one juvenile in La Vorágine in 1994. Additionally, from the information collected, the author indicated the presence of nests, hatchlings and juveniles for that year.

Discussion

Arauca Population

Thirty specimens (18 adults and 12 sub-adults) were observed in 185 km (0.16 ind./km) of the Cravo Norte-Ele-Lipa River system (Arauca Department). The relative density of individuals is similar to the density reported by Lugo and Ardila (1998), although the distance traveled in 1995-1996 was slightly higher, including part of the Cuiloto River.

The killing of adult specimens due to local inhabitants' and cattle ranchers' fear and the supposed predation on cattle could be reducing the number of adult crocodiles in the wild. This seems to be decreasing the number of adults in this population, while the number of sub-adults seems to be increasing.

The total number of nests (referenced and detected) in 2012 is close to the number cited by Ardila *et al.* (2002) from the 11 nests detected in 2001. Our data implies the presence of at least 9 reproductive females in the surveyed area. In 2012, at least two nests (referenced by local inhabitants) were preyed upon humans for consumption. Another two nests were totally flooded, one was partially inundated because of this year's fast water level rise, and four are estimated to have hatched successfully. There was no information about the flooding of Orinoco Crocodile nests in this area before, so we likely need to take into account the possibility that aspects related to climate change and the alteration of the hydrological dynamics of the river system could play an important role on the recovery of the Orinoco Crocodile populations now and in the next few years.

Analyzing the data obtained, and comparing it with past surveys, this population seems to maintain its viability, despite the killing of adult specimens and the harvest of some nests. The number of individuals seems to have been maintained over the last fifteen years, with a possible variation in the population structure (age classes).

This population could be considered the most well conserved in Colombia. Also, several threatened species coexist with the Orinoco Crocodile in the area, so it would be highly recommendable to promote the creation of a protected area to effectively protect the crocodile population and the ecosystems necessary for their survival.

In the Arauca department other areas exist where the species has been reported by the local population. One of these areas is the eastern region of the department, adjacent to the Venezuelan border, where the species seems to be present, but specimens could not be recorded by investigators who visited the sector (Luis F. Anzola, pers. comm.). In this area the Capanaparo and Cinaruco Rivers are born before flowing into Venezuelan territory. These two watercourses are home to an important Orinoco Crocodile population in Venezuela, within the Santos Luzardo National Park, where reintroductions have been implemented during the last two decades. In the Capanaparo river 1264 Orinoco crocodiles were reintroduced since 1991, while in the Cinaruco River 396 have been released since 2001 (Omar Hernández, pers. comm.).The conservation status of the area, the low density of the human population and the region's isolation are features to consider regarding the possibility of establishing a bi-national protected area where reintroductions could be implemented in the future.

Vichada River Population

Lugo and Ardila (1998) estimated this population of no more than 15 adult specimens very dispersed along the course of the river (about 500 km), including the presence of reproductive events and hatchlings. The Asociación Chelonia team observed only two individuals (402-km stretch): one male and one individual (sex not determined). Another individual was noted through the detection of several trails on a beach. All of the specimens were concentrated in a stretch of 10 km. A nest was reported in this area by local inhabitants who are familiar with the location and the female's fidelity to the specific site. No hatchlings or juveniles had been seen at least during the last three years in the stretch of the river surveyed.

The Vichada River is located in an isolated area, with a very low density of human inhabitants. It is considered, in its eastern part, a limit between the high-plain savannas of the Llanos region and the transitional forest that forms an ecotone between the Orinoquia and the Amazonia, with the presence of some areas of the Guiana shield. A large part of its right margin is the northern limit of the widespread indigenous reserve of "Selva de Matavén", with little indigenous communities found along its course. Furthermore, the ecosystems of the area are well-conserved and anthropic influence is small. Boat traffic is low and the majority is from small boats and canoes among the riverine communities and to the capital of the department, Cumaribo. There is more intense fishing activity during the dry season, but generally low impact devices (hooks, bow and arrow) are used, so that the probability of accidental death by drowning in fishing nets seems to be very small.

The low number of reproductive events, the practice of egg harvest for human consumption and the low density of crocodiles seems to have prevented the natural recovery of this population, despite the low human pressure. We estimate that the natural recovery of this population at present is not possible, so that effective protection measures should be carried out, preferable with an active participation of the local communities.

The planning of large agriculture and forestry projects in the high plain of the Vichada Department during the next few years could increase the human pressure on the areas near the Orinoco Crocodile population's range.

Middle Course of the Meta River Population

We consider this population to be the most threatened of the four relict populations in Colombia. The easy access to the area, the transit of boats, fishing pressure and the effects of the transformation of the ecosystems in the higher course of the river constitute important threats for the crocodiles of the Meta River.

In the surveys implemented by the Asociación Chelonia team in the Meta (Table 1), no specimen or tracks were detected. Based on the information provided by fishermen and riverine inhabitants, the crocodile population is estimated as less than 15 dispersed individuals, located along a 110-km stretch between La Vorágine and La Culebra (or Nueva Antioquia). Information provided by riverine inhabitants indicates that before 2010 at least one nest site was known in the area of La Vorágine, but its eggs were collected annually. This reproductive event has not been recorded again since 2010.

Due to these factors, we estimate that the natural recovery of this population is very complicated, keeping in mind the potential increase in human pressure in the area related to the implementation of oil, agriculture and forestry activities.

Acknowledgements

We thank the Corporación Autónoma Regional de la Orinoquia (Corporinoquia, Colombia) for its cooperation and assistance to carry out our fieldwork and other labors in the Casanare, Arauca and Vichada Departments (Colombia). We also thank the Fundación Biodiversidad (Environment Ministry, Spain), Fonds de Dotation pour la Biodiversité - Save Your Logo (http://www.fdbiodiversite.org/fr, France) and the Lacoste Company (France) for supporting the Orinoco Crocodile Conservation Project. We wish to show our gratitude to Dra. Myriam Lugo for the information provided, Rebecca L. Greenberg for the revision of the manuscript, Rafael Antelo and Luis F. Anzola for their collaboration and support in some of the surveys and all the people who helped us in many different ways to the implementation of the project.

Literature Cited

Antelo, R. 2008. Biología del caimán llanero o cocodrilo del Orinoco (*Crocodylus intermedius*) en la Estación Biológica El Frío, Estado Apure, Venezuela. PhD Thesis, Departamento de Ecología, Universidad Autónoma de Madrid, Spain. 286 p.

Ardila-Robayo, M.C., Barahona, S. L., Bonilla, P. and J. Clavijo. 2002. Actualización del status poblacional del Caimán Llanero (*Crocodylus intermedius*) en el Departamento de Arauca (Colombia). Pp. 57-67 *in* Memorias del Taller para la Conservación del Caimán del Orinoco (*Crocodylus intermedius*) en Colombia y Venezuela, ed. by A. Velasco, G. Colomine, G. Villarroel and M. Quero. MARNR and UCV: Caracas.

Castro, A., Merchán, M., Gómez, F., Garcés, M. F. and Cárdenas M. (2011a). Nuevos datos sobre presencia de caimán llanero (*Crocodylus intermedius*) y notas sobre su comportamiento en el río Vichada, Orinoquia (Colombia). Biota Colombiana 12 (1): 137-144.

Castro, A., Merchán, M., Gómez, F., Garcés, M. F. and Cárdenas M. (2011b). New locality records for Orinoco crocodile (*Crocodylus intermedius*) in Colombia. Crocodile Specialist Group Newsletter 30(3): 12-14.

Colvée, S. (1999). Comportamiento reproductivo del caimán del Orinoco (*Crocodylus intermedius*) en cautiverio. PhD thesis, Universidad Simón Bolívar, Sartenejas, Edo. Miranda, Venezuela. 321 p.

Lugo, L.M. and Ardila, M.C. (1998). Programa para la conservación del caiman del Orinoco (*Crocodylus intermedius*) en Colombia. Proyecto 290. Programa Research Fellowship NYZS. Wildlife Conservation Society. Proyecto 1101-13-205-92 Colciencias. Universidad Nacional de Colombia, Facultad de Ciencias, Estación de Biología Tropical Roberto Franco, Villavicencio. Unpublished report (cited with author permission).

Medem, F. (1981). Los Crocodylia de Sur América. Los Crocodylia de Colombia. Vol. I. Ministerio de Educación Nacional. COLCIENCIAS: Bogotá.

Medem, F. (1983). Los Crocodylia de Sur América. Vol. II. Universidad Nacional de Colombia. COLCIENCIAS: Bogotá.

Merchán, M. (ed.), Castro, A., Cárdenas, M., Antelo, R. and Gómez, F. (2012). Natural History and Conservation of the Orinoco Crocodile (*Crocodylus intermedius*) in Colombia. Asociación Chelonia Monographs. Vol. V. Madrid. 238 p.

Ministerio del Medio Ambiente. (2002). Programa Nacional para la Conservación del Caimán Llanero *Crocodylus intermedius*. Ministerio del Medio Ambiente: Bogotá D.C., Colombia. 32 p.

Thorbjarnarson, J.B. (1987). Status, Ecology and Conservation of the Orinoco Crocodile. Preliminary Report. FUDENA-WWF. 74 p.

Thorbjarnarson, J.B. and Hernández, G. (1993). Reproductive ecology of the Orinoco crocodile (*Crocodylus intermedius*) in Venezuela. II. Reproductive and social behavior. Journal of Herpetology 27: 371-379.

Recovery of Saltwater Crocodiles (*Crocodylus porosus*) Following Unregulated Hunting in Tidal Rivers of the Northern Territory of Australia

Yusuke Fukuda[1], Grahame Webb[2,3], Charlie Manolis[2], Robyn Delaney[1], Mike Letnic[4], Garry Lindner[5] and Peter Whitehead[1]

[1] Northern Territory Department of Natural Resources, Environment, the Arts and Sport, PO Box 496, Palmerston, NT 0831, Australia
[2] Wildlife Management International Pty. Limited, PO Box 530, Karama, NT 0813, Australia
[3] School of Environmental Research, Charles Darwin University, NT 0909, Australia
[4] School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia
[5] Parks Australia, Australian Department of Sustainability, Environment, Water, Population and Communities, GPO Box 71, Jabiru, NT 0886, Australia

Abstract

Saltwater Crocodiles (*Crocodylus porosus*) in the Northern Territory of Australia were protected in 1971, after a severe population decline resulting from 26 years of intense commercial hunting. By that time the wild Saltwater Crocodiles were rarely sighted anywhere and was commercially extinct in areas where they had once been abundant. Standardized monitoring by spotlight surveys started in 1975 and provided relative density indices over time (1975-2009) as a unique record of the post-protection recovery of a wild crocodilian population. We examined the survey data for populations at 12 major tidal rivers, individually and as a single subpopulation. The pattern of recovery in the subpopulation in both abundance and biomass was approximated by logistic curves, predicting 5.26 non-hatchling crocodiles weighing 387.64 kg sighted per kilometre of river in 2010. We predicted potential carrying capacity as 5.58 non-hatchling crocodiles (5.73% increase from 2010) weighing 519.0 kg (25.31% increase from 2010). Individual rivers showed largely different abundance and biomass among rivers. The statistical model that best described the recovery in individual rivers was not always logistic. However, where it was logistic, expected carrying capacity of different rivers showed considerable variation in abundance and biomass. The variation indicates various progress of recovery among the rivers, resulting from different habitat quality. Recovery occurred despite various consumptive uses, particularly a widespread egg harvest. We suggest that the Saltwater Crocodile population of the Northern Territory is achieving full recovery from uncontrolled hunting in 1945-1971.

Introduction

In the 19th Century, when the north of Australia was first surveyed and settled by Europeans, Saltwater Crocodiles (*Crocodylus porosus*) were widespread and reportedly abundant (Messel *et al*. 1981; Webb *et al*. 1984; Searcy 1984). For tens of thousands of years prior to European settlement, hunting and egg harvest by Aboriginal people must therefore have been within sustainable levels (Webb *et al*. 1984). Intense commercial hunting for skins started in 1945-1946, peaked in the early 1950s and continued until Saltwater Crocodile was protected in the three northern States (1969-1974). By that time the status of wild Saltwater Crocodile populations was only known in general terms. Wild crocodiles were rarely sighted anywhere and were commercially extinct in areas where they had once been abundant (Webb *et al*. 1984).

Saltwater Crocodiles in the Northern Territory of Australia became protected in 1971. In the same year preliminary spotlight and track surveys were undertaken to try and locate any remnant populations of substance (Messel *et al*. 1981). Anecdotal evidence suggests crocodile densities within tidal rivers in 1971 were in the range of 0.1 to 0.2 Saltwater Crocodiles sighted per kilometre in spotlight counts (G. Webb, Wildlife Management International, unpublished report), and these were often wary crocodiles that would dive well before the boat could approach them (Webb and Messel 1979). An extensive standardized spotlight counting survey program was introduced in 1975 to quantify the post-protection changes in population abundance and structure (Messel *et al*. 1981; Webb *et al*. 1984). These standardized surveys were largely restricted to navigable tidal rivers and creeks, which historically contained a large proportion of the wild saltwater crocodile population. These habitats are also largely intact along the coastline in the Northern Territory. The size distribution of crocodiles sighted in surveys up to 1975 was strongly biased towards small juveniles, hatched from 1971 (after protection), and by the wild population at the time of protection was estimated to be about 3000 non-hatchlings (Webb *et al*. 1984, 2000). Non-hatchlings are defined as total body length >0.6 m and body weight >0.5 kg, which in the annual surveys excludes young-of-the-year (Webb and Messel 1978b).

General results from the survey program indicate that the protected population expanded greatly, despite ongoing natural mortality (predation and cannibalism) and losses to various anthropogenic causes, including incidental catch in commercial barramundi net-fishing operations (since before protection); Aboriginal harvest for food (since before protection); removal of problem crocodiles to improve safety for people and livestock (since 1979); capture of some adults for captive breeding in commercial crocodile farms (since 1980) and for direct production of skin and meat (since 1997); and introduction of an egg harvesting program (since 1983), in which landowners are permitted to sell wild Saltwater Crocodile eggs to commercial crocodile farms (Messel *et al*. 1981; Webb *et al*. 1984; Webb and Manolis 1989; Walsh and Whitehead 1993; Lindner 2004). The average size of a crocodile in the population also increased steadily. By 1998, the wild population in the Northern Territory was estimated to be about 70,000-75,000 non-hatchlings with a population structure biased towards >1.8-m animals (Webb *et al*. 2000). The Northern Territory's recovered Saltwater Crocodile populations became the iconic flagship of the Top End (far north of Australia) tourist industry (Ryan 1998; Tremblay 2001a,b).

Since the mid-1990s, abundance of Saltwater Crocodiles in some tidal rivers in the Northern Territory appears to be stabilizing, despite the mean size of animals in the population still increasing (Webb *et al*. 2000). This stabilizing abundance may indicate a population asymptote is being reached, which in turn could reflect carrying capacity in some rivers (Webb *et al*. 2000; Parks and Wildlife Service of the Northern Territory [PWSNT] 2005; Leach *et al*. 2009).

We examined population recovery trends in terms of abundance and biomass in the 12 major tidal rivers subject to regular and standardized monitoring from the1970s to 2009 (38 years since protection). Changes in relative abundance (non-hatchling crocodiles sighted per kilometer of river surveyed) and relative biomass (mass of crocodiles sighted per kilometre of river surveyed) were quantified for each river and for a subpopulation comprising all rivers combined. We determined which of three simple models (linear, exponential, logistic) best described the underlying recover trends.

Methods

Study area

The Northern Territory of Australia lies between 128°E and 138°E in longitude, and 10°S and 26°S in latitude. The climate is tropical monsoonal (wet-dry). Saltwater Crocodiles occur in high densities in the tidal water but also known to be abundant in a wide range of other waterbodies including rivers, lagoons, and floodplains (Messel *et al*. 1981; Webb and Manolis 1989). The 12 tidal rivers (Fig. 1, Table 1) we examined all meandered across floodplains, with saline, brackish, and freshwater sections contiguous with each other. Historically (1945-1946), this sample of rivers was reported to contain medium (1-5 crocodiles/km) to high (6-12 crocodiles/km) densities of Saltwater Crocodiles (Webb *et al*. 1984). Salinity in all rivers decreased with distance upstream from the sea and varied seasonally as a salt wedge moved progressively upstream in the dry season (May to Oct.) and downstream in the wet season (Nov. to Apr.). There were two complete tidal cycles each day, with tidal range at the mouth reaching 7 m on spring tides and declining with distance upstream. Freshwater input into the rivers was highly seasonal (wet season) but not subject to controlled water release (there are no upstream dams). Low levies to stop saltwater intrusion have been built on sections of the Mary River mainstream (at Shady Camp Billabong and on tributaries of Sampan Creek) and on some sidecreeks of the Adelaide River but not in the mainstream sections of the Adelaide River where surveys were undertaken (Whitehead *et al*. 1990). Mangroves and floodplain sedges and grasses formed most of the fringing vegetation in saline areas. *Melaleuca*, *Eucalyptus*, *Pandanus* and *Bamboo* species dominated non-saline areas. River banks were mostly muddy in the downstream saline areas and, in upstream areas, comprised various soil types, including sand and rock.

The dominant land use in different catchments included nature conservation, cattle and buffalo (*Bubalus bubalis*) grazing, and Indigenous customary use (Table 1). All rivers were subject to Indigenous customary hunting for food, which included minor harvests of crocodiles and eggs (Lanhupuy 1987; Webb and Manolis 1993). Crocodile eggs were also commercially harvested in these rivers, except for the West Alligator and South Alligator Rivers. The extent of direct harvesting of non-hatchling crocodiles permitted in these 12 rivers in the 38 years since protection was limited (<200 non-hatchlings per year; Leach *et al*. 2009; Y. Fukuda, Northern Territory Department of Natural Resources, Environment and the Arts and Sport, unpublished report). Most rivers were closed to commercial fishing since before protection and, in some others, where fishing was originally permitted in the river mouth, bans were imposed later.

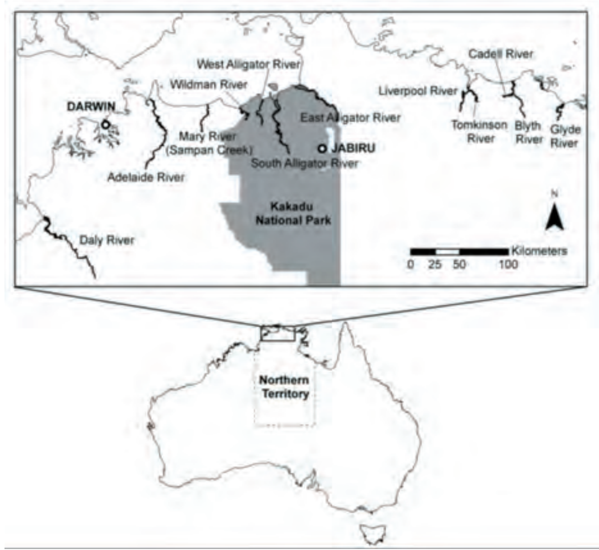


Figure 1. Locations of the 12 tidal rivers in the Northern Territory of Australia in which we examined changes in Saltwater Crocodile populations, 1975-2009.

Crocodile Survey

Since 1975 spotlight surveys have followed a standardized procedure (Messel *et al*. 1981; Bayliss *et al*. 1986; Bayliss 1987). Surveys are conducted during the dry season, between June and October, when water levels are low. Specific sections of river, including both the mainstream and accessible sidecreeks are traversed at night by boat. Surveys are restricted to either side of low tide, when mudbanks are exposed and crocodiles are mostly at the water's edge and not hidden amongst fringing vegetation. The water surface, banks, and fringing vegetation are scanned with a spotlight and crocodiles are located by their distinctive reflective eye shine. They are approached as close as possible to estimate their total body length in 0.3-m intervals and to confirm species (Freshwater Crocodiles [*C. johnstoni*] extend down into the tidal parts of some rivers). If no size estimate is possible they are recorded as "eyes only". Given that eyes-only animals tend to be large crocodiles (Webb and Messel 1979; Webb *et al*. 1989), we regarded them all as non-hatchlings in our study. The length of the survey route was measured along the mid-line of streams in kilometres to the nearest 0.1 km, originally using survey maps (Messel *et al*. 1982) but in later years standardized to more accurate distances measured with a Geographic Information System. Most of the available surveys had the same or similar start and finish points, such that mean densities are considered directly comparable from year to year. For the East Alligator and South Alligator Rivers, a few years had shorter distances than other years. In this case, we corrected the relative densities in abundance and biomass (see below) by 1.21 and 1.19, respectively, for the East Alligator River and 1.31 and 1.33, respectively, for the South Alligator River. We derived these correction factors from the proportion of crocodile counts in the missing section of rivers in other years.

Table 1. Monitoring rivers and spotlight survey datasets for Saltwater Crocodiles in the Northern Territory, 1975-2009.

River	Dominat Land Use	Mean Length Surveyed (km)	Year First Surveyed	Year Last Surveyed	Number Years Surveyed	Years Excluded
Adelaide R.	Grazing, Indigenous customary use	135.7	1977	2009	25	1998
Blyth R.	Indigenous customary use	47.4	1975	2008	29	1998
Cadell R.	Indigenous customary use	28.6	1975	2008	29	1998, 2003
Daly R.	Grazing, Indigenous customary use	86.7	1978	2009	22	None
East Alligator R.	Nature conservation	49.0	1977	2007	23	1994, 2006
Glyde R.	Indigenous customary use	43.9	1975	2008	11	None
Liverpool R.	Indigenous customary use	57.1	1976	2008	27	1998
Mary R.	Grazing, Indigenous customary use	41.4	1984	2009	18	None
South Alligator R.	Nature conservation	55.4	1977	2007	19	None
Tomkinson R.	Indigenous customary use	53.3	1976	2008	27	1998, 1999, 2003
West Alligator R.	Nature conservation	38.1	1977	2007	18	1994
Wildman R.	Nature conservation	32.6	1978	2007	18	1994

We used only survey data from the mainstreams of the rivers (rather than sidecreeks) because visibility biases increase with narrowing stream width (Webb *et al*. 1989). We excluded from analysis some surveys in some years because they did not follow the standardized survey procedures and were surveyed during unfavorable conditions (eg wet seasons, high tides) or included only a small proportion of the standardized mainstream survey section (Table 1). Following Messel *et al*. (1981), we excluded hatchlings (<0.6 m) due to high variance in both annual nest abundance and hatching success (Y. Fukuda, unpublished report). We applied no corrections for visibility bias (Webb *et al*. 1984, 1989; Bayliss *et al*.1986; Bayliss 1987). Thus, we express abundance as relative rather than absolute density, that is, the number of non-hatchling Saltwater Crocodiles sighted, rather than the number present, divided by the midstream length of river surveyed (km). Observer bias in the number of crocodiles sighted within a spotlight survey (presence-absence) appeared slight (Webb *et al*. 1989). When estimating sizes of crocodiles sighted, some observers were more precise than others, and thus had more over- and underestimates, although mean values for a given size class were usually within 0.3 m of the real size (Choquenot and Webb 1987; Webb *et al*. 1989). We did not consider either source of error further.

To estimate approximately the changes in the relative biomass of crocodiles sighted in surveys since protection, we used the following procedures. We converted estimated sizes recorded in a survey to biomass using equations in Webb and Messel (1978b). We assumed animals recorded as eyes only (no size estimates) were in the same proportions as non-hatchlings whose size had been estimated. We subdivided these eyes-only observations into two size classes: 0.6-1.8 m and 1.8-5.1 m total body length, with mean sizes of 1.35 m and 3.45 m, respectively, and predicted body weights of 7.11 kg and 156.08 kg, respectively. We added the biomass from eyes-only observations to that from the non-hatchlings whose size had been estimated and divided by the length of river surveyed. We thus obtained an estimate of biomass of crocodiles sighted per kilometre of river surveyed.

We examined general changes in the population size structure throughout the period of recovery in two ways. Firstly, following Messel and Vorlicek (1987), we examined changes in the percentage of <1.8-m individuals in 12 rivers by fitting a linear regression. Secondly, we constructed a size-frequency histogram of crocodiles sighted in the surveys of all the rivers in a common year for each decade (1970s-2000s). In both cases, we excluded "eyes only" records.

Model Fitting and Selection

We plotted river-specific trends in crocodile abundance (crocodiles sighted/km) and biomass (kg/km) over time, using Program R (Version 2.12.0, http://cran.r-project.org/, accessed 15 May 2011). Given the small sample sizes (11 to 29 annual surveys per river), we used three simple candidate models for describing the population growth pattern: linear, exponential, and logistic regressions.

The linear regression was described as: y = ax + b, where y = crocodile density, x = years since protection in 1971 (ie 1971 = 0, 1972= 1,...), a = the average population density growth rate within the limits of survey, and b = predicted population density in 1971 (x= zero). The exponential regression was described as: $y = be^{ax}$, where e = the base 2.71828. The logistic equation was described as: $y = d/(1 + e^{r(z-x)})$, where d= mean asymptotic density, r= intrinsic rate of increase, and z= the year since protection in 1971 with maximum growth rate (inflection point).

We then selected the model that best described the underlying pattern of population growth over time in each river using information theoretic procedures [see Burnham and Anderson (2002) for detailed discussion on model selection]. We calculated the model selection parameters: Akaike's Information Criterion corrected for small-sample bias (AICc), differences in AICc (Δi) and Akaike weight (wi). Smaller AICc values indicate greater support for a model in describing the underlying trend through the data. For a measurement of the actual fit of each model, we calculated the standard error of the estimate (SEE, also called residual standard error). We also calculated coefficient of determination for the linear model. We did not calculate coefficient of determination for the exponential and logistic models because there is no direct equivalent to coefficient of determination for nonlinear models [see Hoetker (2007) and Spiess and Neumeyer (2010) for detailed discussion on pseudo-R^2 measures against r^2).

Integrating the 12 River Survey Results

To examine trends in a larger subpopulation of all 12 rivers combined, we used the models of best fit for each river to predict a mean abundance and biomass density for each year in 1971-2010. This approach was more realistic than using the survey data itself because 1) annual variation in crocodile counts largely reflects annual variation in the proportion of the total Saltwater Crocodiles within the river mainstreams at the time of each survey, rather than real fluctuations in the population; and 2) availability of surveys in the 12 rivers differed among years. We multiplied mean survey distance for each river by the predicted densities for each river for each year, in both abundance and biomass, thus estimating total counts and total biomass for each river for each year. We combined these totals for each year and subdivided them by the total survey length in all 12 rivers (682 km) to show trends in abundance and biomass in the subpopulation over time. We fitted the same three growth models to the combined data and selected the best fit model by the information theoretic procedures to describe the mean trend in the combined population over time.

Results

We fit all three models to the abundance data for nine rivers, and we fit two models (linear and exponential) for three rivers (Cadell, East Alligator and Tomkinson) because the logistic model did not converge (Fig. 3). Model selection criteria (Table 2) revealed that the logistic model was supported much more strongly than the other models in five rivers (Adelaide, Liverpool, Mary, South Alligator, West Alligator). The exponential model was supported for East Alligator and Tomkinson, but with almost equal support for the linear model in East Alligator. Finally, the linear model was supported most strongly in five rivers (Blyth, Cadell, Daly, Glyde, Wildman). Only the Cadell River showed a slight decline over time with a poor fit.

When we applied the three models to the survey data expressed in terms of biomass density (Fig. 4), which captures the increasing mean size of crocodiles over time, the model selection criteria indicated the logistic model had the strongest support (wi in Table 3) for all models tested in six rivers (Blyth, Cadell, Liverpool, South Alligator, West Alligator, and Wildman). The exponential model was supported most strongly in four rivers (Adelaide, Daly, East Alligator, Tomkinson), and the linear model was supported most strongly in Glyde and Mary Rivers.

In the five rivers in which abundance was best described by a logistic model (Adelaide, Liverpool, Mary, South Alligator, West Alligator), the predicted carrying capacity (asymptote) was highly variable (4.33, 2.79, 12.14, 4.86 and 2.74 non-hatchlings/km respectively). In the six rivers in which biomass was best described by a logistic model (Blyth, Cadell, Liverpool, South Alligator, West Alligator, Wildman), variation among the rivers was also high (203.69, 109.15, 104.59, 304.47, 146.12 and 370.35 kg/km respectively).

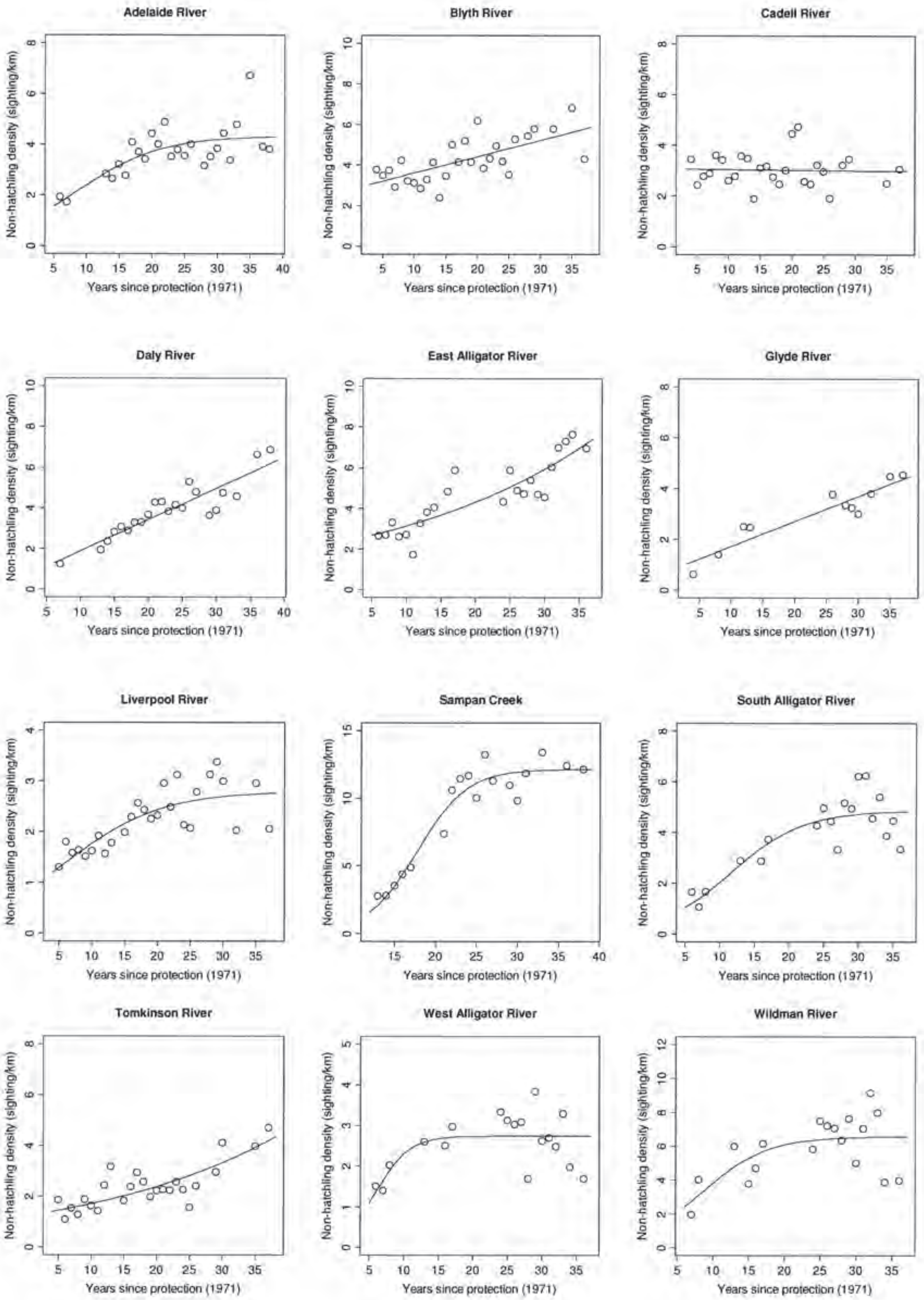


Figure 3. Changes over time in abundance density of non-hatchling (>0.6 m) Saltwater Crocodiles sighted during spotlight surveys in 12 tidal rivers in the Northern Territory, Australia, in 1975-2009. Fitted line is the model selected as best (Table 2).

Table 2. Standard error of the estimate (SEE), Akaike's Information Criterion corrected for small sample (AICc), difference in AICc (Δi), and Akaike weight (wi) for the population growth models of Saltwater Crocodile density in abundance (sightings/km) observed in 12 monitoring rivers in the Northern Territory, Australia, in 1975-2009. We show adjusted coefficient of determination only for the linear model.

River	Model	SEE	r^2	AICc	Δi	wi (%)
Adelaide River	Logistic	0.74		59.72	0	0.45
	Exponential	0.79		61.47	1.75	0.19
	Linear	0.77	0.40	60.17	0.45	0.36
Blyth River	Logistic	0.83		73.15	2.37	0.14
	Exponential	0.82		70.89	0.11	0.42
	Linear	0.82	0.46	70.78	0	0.44
Cadell River	Logistic					
	Exponential	0.66		56.54	<0.01	0.50
	Linear	0.66	<0.01	56.54	0	0.50
Daly River	Logistic	0.62		45.26	4.28	0.08
	Exponential	0.61		42.97	1.99	0.25
	Linear	0.58	0.81	40.98	0	0.67
East Alligator River	Logistic					
	Exponential	0.84		59.53	0	0.54
	Linear	0.84	0.75	59.89	0.35	0.46
Glyde River	Logistic	0.50		22.07	5.39	0.05
	Exponential	0.49		19	2.32	0.23
	Linear	0.44	0.87	16.68	0	0.72
Liverpool River	Logistic	0.38		28.16	0	0.83
	Exponential	0.44		34.23	6.07	0.04
	Linear	0.42	0.48	31.89	3.73	0.13
Mary River	Logistic	1.10		58.78	0	>0.99
	Exponential	2.34		84.42	25.64	<0.01
	Linear	1.94	0.74	77.57	18.78	<0.01
South Alligator River	Logistic	0.83		50.98	0	0.82
	Exponential	1.03		57.68	6.7	0.03
	Linear	0.95	0.59	54.41	3.43	0.15
Tomkinson River	Logistic					
	Exponential	0.54		42.63	0	0.83
	Linear	0.58	0.58	45.85	3.21	0.17
West Alligator River	Logistic	0.59		36.75	0	0.71
	Exponential	0.68		40.07	3.32	0.13
	Linear	0.68	0.07	39.74	2.99	0.16
Wildman River	Logistic	1.53		70.74	0	0.49
	Exponential	1.68		72.47	1.73	0.21
	Linear	1.65	0.21	71.7	0.97	0.30

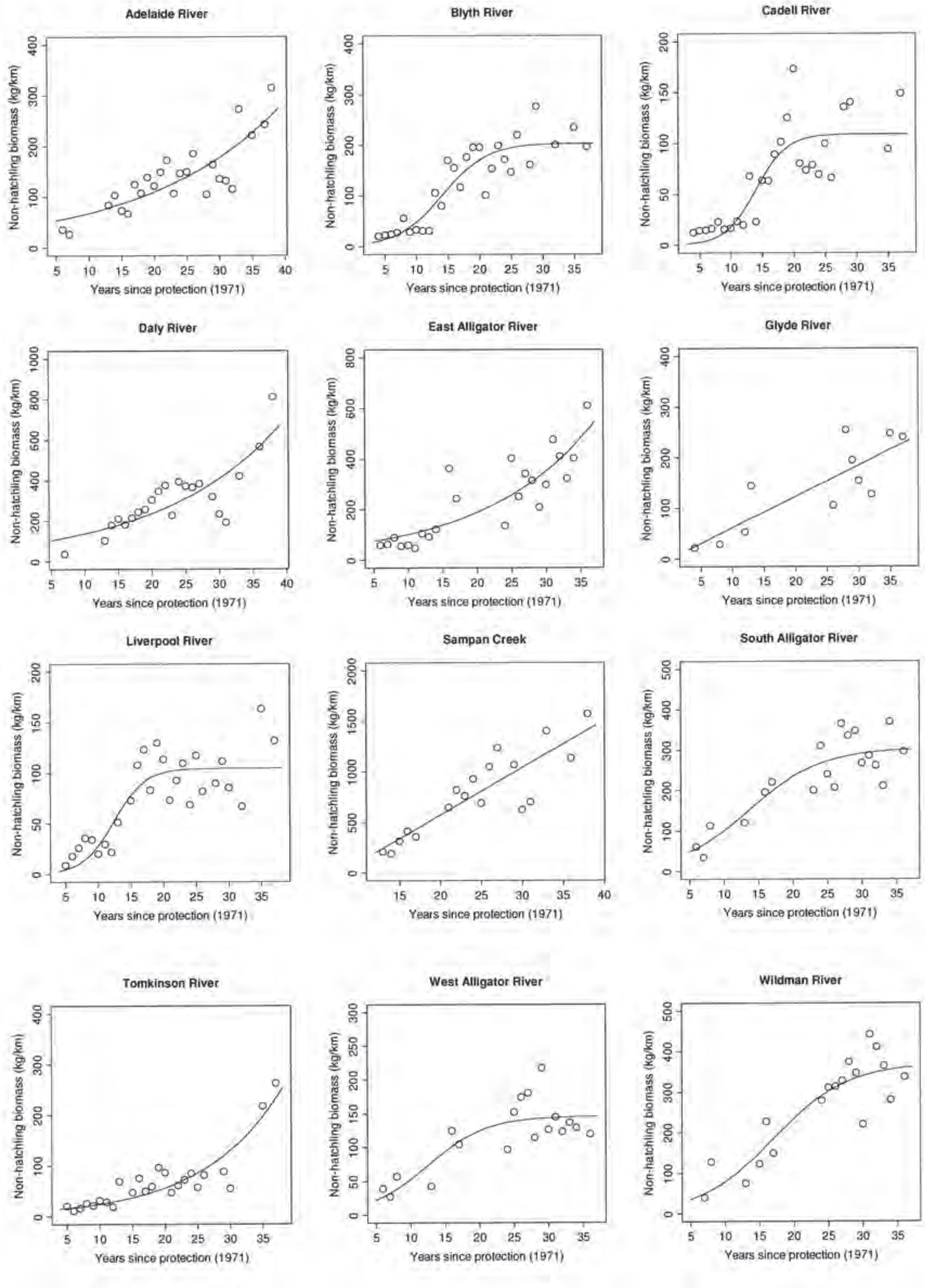


Figure 4. Changes over time in biomass density of non-hatchling (>0.6 m) Saltwater Crocodiles sighted during spotlight surveys in 12 tidal rivers in the Northern Territory, Australia, in 1975-2009. Fitted line is the model selected as best (Table 3).

Table 3. Standard error of the estimate (SEE), Akaike's Information Criterion corrected for small sample (AICc), difference in AICc (Δi), and Akaike weight (wi) for the population growth models of Saltwater Crocodile density in biomass (kg/km) observed in 12 monitoring rivers in the Northern Territory, 1975-2009. We show adjusted coefficient of determination only for the linear model.

River	Model	SEE	r^2	AICc	Δi	wi (%)
Adelaide River	Logistic					
	Exponential	37.80		255.02	0	0.70
	Linear	39.13	0.67	256.76	1.74	0.30
Blyth River	Logistic	34.44		328.06	0	0.96
	Exponential	48.56		340.64	12.58	0.01
	Linear	39.84	0.74	331.32	3.26	0.03
Cadell River	Logistic	27.33		259.12	0	0.79
	Exponential	33.47		268.63	9.51	0.01
	Linear	29.60	0.62	261.98	2.87	0.2
Daly River	Logistic					
	Exponential	96.40		265.98	0	0.74
	Linear	101.30	0.61	268.15	2.17	0.26
East Alligator River	Logistic					
	Exponential	84.19		271.7	0	0.58
	Linear	85.42	0.72	272.37	0.67	0.42
Glyde River	Logistic	53.32		124.62	4.39	0.06
	Exponential	51.01		121.01	0.78	0.38
	Linear	49.23	0.67	120.23	0	0.56
Liverpool River	Logistic	24.07		252.27	0	0.92
	Exponential	29.64		262.05	9.79	0.01
	Linear	27.24	0.58	257.49	5.22	0.07
Mary River	Logistic	217.9		249.34	3.87	0.11
	Exponential	225.6		248.84	3.36	0.14
	Linear	205.5	0.74	245.47	0	0.75
South Alligator River	Logistic	51.44		238.6	0	0.77
	Exponential	61.88		245.91	7.31	0.02
	Linear	55.36	0.68	241.18	2.58	0.21
Tomkinson River	Logistic					
	Exponential	25.60		235.53	0	>0.99
	Linear	35.17	0.63	251.42	15.89	<0.01
West Alligator River	Logistic	31.53		179.75	0	0.76
	Exponential	38.54		185.22	5.47	0.05
	Linear	35.74	0.51	182.51	2.76	0.19
Wildman River	Logistic	57.15		201.16	0	0.55
	Exponential	68.83		206.1	4.95	0.05
	Linear	61.07	0.73	201.79	0.64	0.40

The proportion of small non-hatchlings (<1.8 m) in each river significantly decreased linearly over time in all rivers (Fig. 5). The Daly, East Alligator, West Alligator, and South Alligator Rivers had low proportions of small non-hatchlings relative to most rivers, but proportions were exceptionally low in the Mary River. Peak size classes increased over time (Fig. 6). The highest frequency of the size classes was 1.5 m for 1978 and 1979 combined, 0.9 m for 1984, 2.4 m for 1997, and 2.7 m for 2007 and 2008 combined.

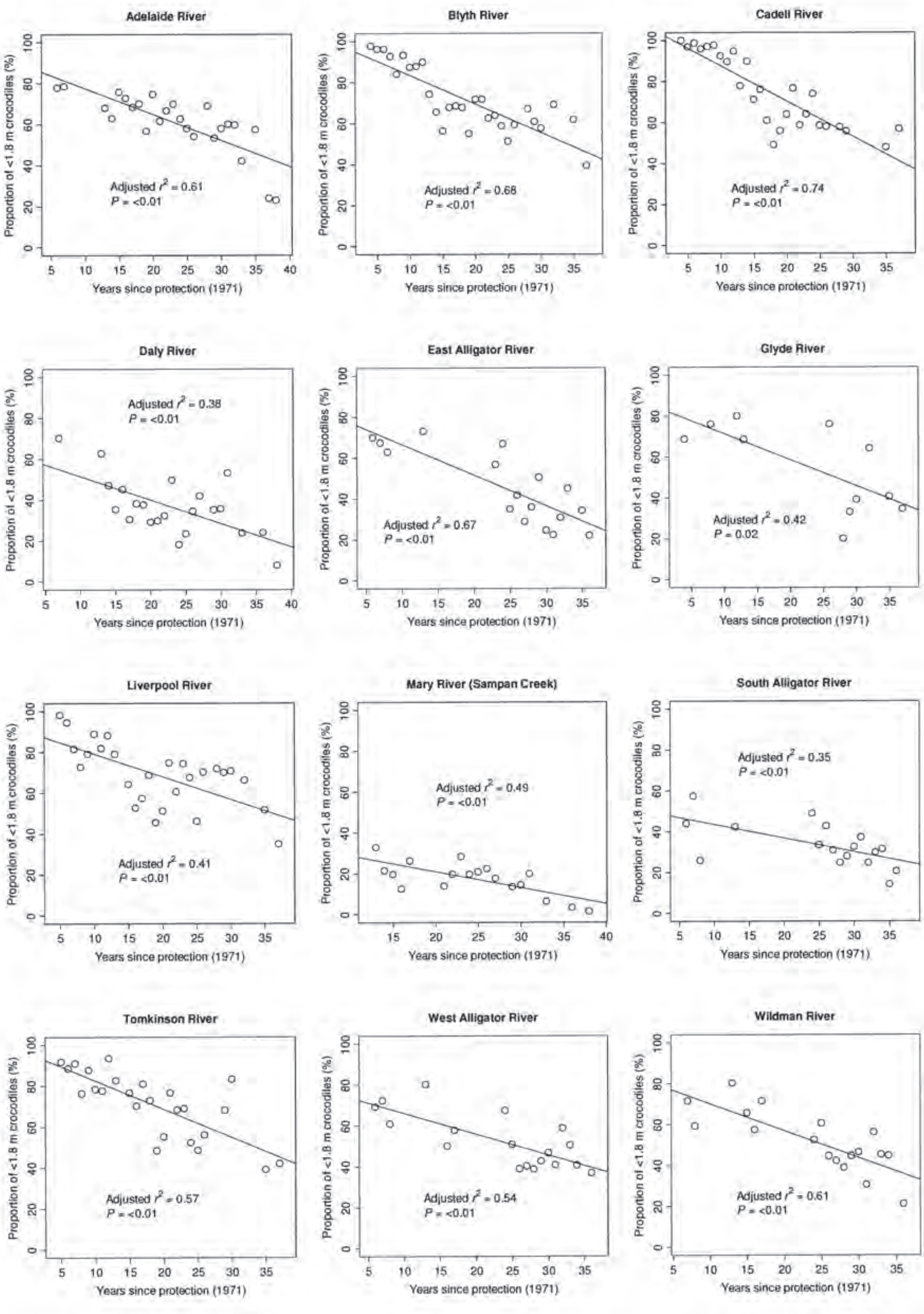


Figure 5. Changes in proportion (%) of small non-hatchling (<1.8 m) Saltwater Crocodiles in 12 tidal rivers in the Northern Territory, 1975-2009.

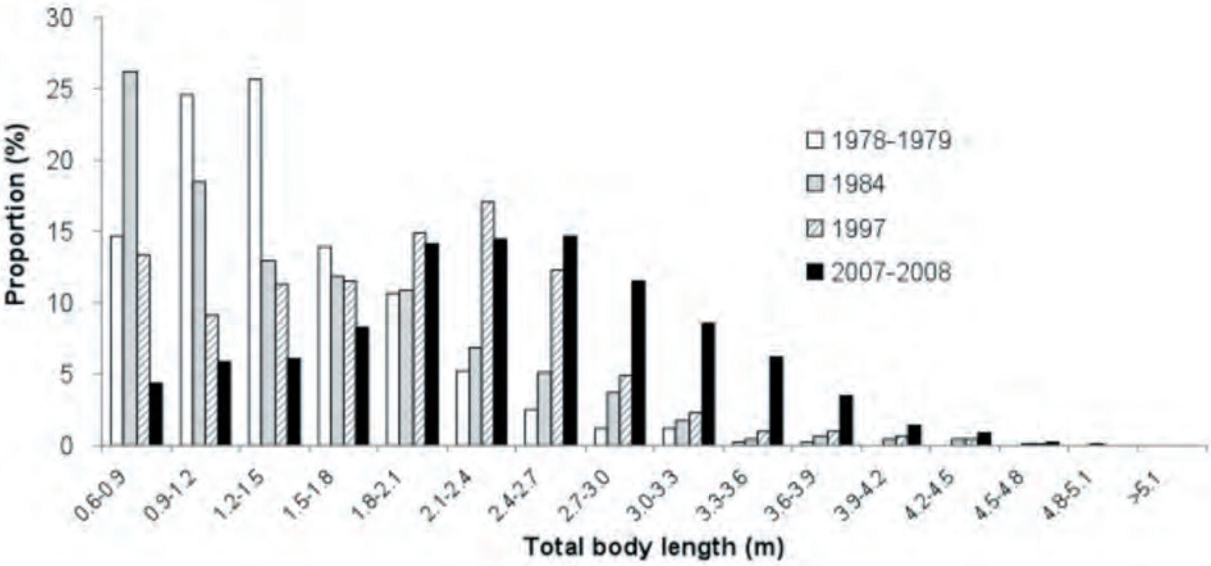


Figure 6. Changes in proportion (%) of Saltwater Crocodiles at each size class from 0.6 m to >5.1 m in 12 monitored rivers combined in the Northern Territory, 1978-1979 (10 rivers in 1978 and 1 river in 1979; no data available for Mary River), 1984, 1997, and 2007-2008 (6 rivers in 2007 and 6 rivers in 2008). The peaks around 2.5 m total body length in 1997 and 2007-2008 reflect a bottle neck of adult-sized females.

When we considered the 12 rivers as one population, the logistic model described the relative abundance data best, suggesting that the recovery of a depleted population of Saltwater Crocodiles in terms of abundance to follows a logistic (asymptotic) pattern rather than a continuing linear or exponential rise (Fig. 7, Table 4). Furthermore, the expected asymptote for the relative abundance density in this population was 5.58 non-hatchlings/km. The abundance density predicted for 2010 was 5.26 non-hatchlings/km (5.73% less than the asymptote). The intrinsic rate of increase (r) estimated from the logistic model was 0.11 (SE= 0.001). This parameter can be interpreted as the instantaneous maximum increase rate achieved in 1971-2010. Finally, the fitted density in 1971 predicts 1.04 non-hatchlings/km.

Similarly, changes in the estimated biomass density over time most strongly supported the logistic model, confirming that the recovery of a depleted population of Saltwater Crocodiles in terms of biomass follows a logistic pattern. Also, the expected asymptote for the relative biomass density in this population is 519.0 kg/km. The biomass density predicted for 2010 was 387.64 kg/km (25.31% less than the asymptote). The intrinsic rate of increase was 0.10 (SE= 0.003). Finally, the fitted density in 1971 predicts 33.21 kg/km, which is likewise an overestimate of the real situation in 1971 due to standardized surveys starting after a large increase in juvenile recruitment.

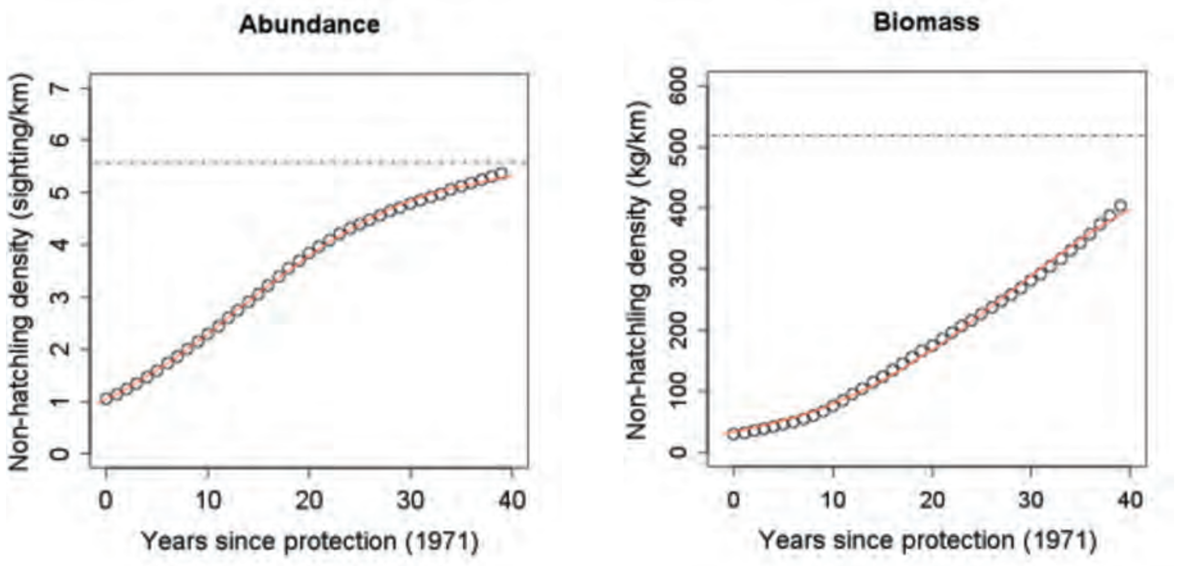


Figure 7. Abundance and biomass densities of non-hatchling (>0.6 m) Saltwater Crocodiles across all monitored sections of all monitored rivers (682 km) in the Northern Territory, Australia, predicted for 1971-2010. Abundance and biomass densities were predicted by the best supported river-specific models (see Tables 2 and 3). The logistic model was supported for the abundance and biomass densities. Broken line is the predicted asymptote.

Table 4. Standard error of the estimate (SEE), Akaike's Information Criterion corrected for small sample (AICc), difference in AICc (Δi), and Akaike weight (wi) for the population growth models of Saltwater Crocodile density in abundance (sightings/km) and biomass (kg/km) predicted for combined monitoring rivers in the Northern Territory, 1971-2010. Adjusted coefficient of determination is shown only for the linear model.

Density	Model	SEE	r^2	AICc	Δi	wi
Abundance	Logistic	0.03		-159.39	0	>0.99
	Exponential	0.45		47.61	206.99	<0.01
	Linear	0.21	0.98	-9.75	149.63	<0.01
Biomass	Logistic	6.65		268.68	0	>0.99
	Exponential	18.57		349.5	80.82	<0.01
	Linear	15.06	0.98	332.745	64.06	<0.01

Discussion

We quantified the changing status of a wild Saltwater Crocodile population over 38 years, as it recovered from severe depletion (1971) to what appears to be almost complete recovery (2009). The initial recovery (1971-1983) occurred under total protection, but with various forms of mortality due to anthropogenic causes such as commercial fishing net (Webb *et al*. 1984). The second phase of recovery (1984-2009) included a managed wild harvest of eggs with no compensation in terms of a return-to-the-wild of raised juveniles. Our results provide compelling evidence that all crocodile uses together were within sustainable levels that did not have detrimental impact on the populations.

Population at the Time of Protection

The logistic model predicted the relative abundance density in 1971 was 1.04 non-hatchlings/km. This estimate is almost certainly an overestimate of the real situation in 1971 and is a bias linked to the standardized surveys beginning in 1975, after there had been a large increase in juvenile recruitment, rather than in 1971 when the recovery started. Extensive interviews with hunters operating in these rivers before protection (Webb *et al*. 1984) suggest the real densities of non-hatchling crocodiles sighted in these rivers by 1971 was appreciably <0.8 non-hatchlings/km, and more like <0.1 non-hatchlings/km.

Population recovery started immediately after protection in 1971, with the first cohort of post-protection hatchlings recruited in 1972. In some remote areas, subject to less intense hunting, it may have started 1-2 years earlier. Populations increased initially by breeding in the rivers, which still contained adults and nesting habitat, and later through dispersal of juveniles (≥2-3 years of age) from such sites into other rivers and parts of rivers where no adults or nesting habitat existed (Webb and Messel 1978a; Messel *et al*. 1981).

These immediate changes in status occurred before the standardized survey program started (1975) and were responsible for the populations being strongly biased towards small juveniles when the standardised surveys started in 1975 to 1984 (Table 1, Figs. 5 and 6, Messel *et al*. 1981). Remote rivers were less intensely harvested than rivers closer to Darwin, and crocodile nesting habitats were largely intact. Rivers closer to Darwin, where the first standardized surveys were conducted later (Table 1), had been harvested more intensely and the available nesting habitat had been greatly reduced by feral water buffalo (Letts *et al*. 1979; Hill and Webb 1982).

Are Crocodiles Approaching a Carrying Capacity?

Our results support claims that the Saltwater Crocodile population in the Northern Territory is approaching an asymptote in abundance (Webb *et al*. 2000; PWSNT 2005, Leach *et al*. 2009), although biomass is still increasing as larger crocodiles grow larger. In some rivers the local population is still increasing in both abundance and biomass, whereas in others abundance appears to be stabilizing. In the population as a whole, abundance and biomass are still increasing slowly. The population increase seems to saturate first in abundance and then biomass, as shown by: 1) the intrinsic rate for abundance (11.13%) being higher than for biomass (9.68%) and 2) the density of abundance in 2010 being closer to the predicted asymptote (5.23% less) than biomass (24.32% less).

These changes have been accompanied by steady changes in the population size-structure, with increases in the numbers of larger crocodiles correlated with decreases in the numbers of juveniles. This pattern was well established before egg harvesting was introduced (Messel *et al*. 1981) and appears to reflect various forms of density-dependent adjustments involving complex interactions between cannibalism, social exclusion, and increased rates of both emigration and mortality (Messel *et al*. 1981; Webb and Manolis 1992). In short, this pattern suggests that the number of crocodiles is not increasing much although their average body size continues to increase.

River-Specific Trends

Our observation, that expected carrying capacity in the rivers in which abundance is stabilizing varied greatly from river to river, is consistent with similar variation in river-specific historical abundance reported by hunters at the time when commercial hunting started in the late 1940s (Webb *et al*. 1984).

The reason different rivers support different densities of crocodiles is not clearly known. Rainfall seasonality, minimum temperature, and the availability of wetlands with favourable vegetation types all exert strong influences (Fukuda *et al*. 2007), affecting, for example, the availability of food, nesting sites, or permanent freshwater (Webb 1991). It is expectation that the rate of increase in both abundance and biomass will ultimately slow to near zero in all rivers in the future at different levels of carrying capacity, although it is difficult to predict when this will happen and most likely it will vary among rivers.

In the case of the Mary River, which now has the highest densities of the largest crocodiles (Webb *et al*. 2000; Fukuda *et al*. 2007), the recovery took place largely through immigration, presumably from the nearby Alligator Rivers. There was negligible known recruitment from local breeding during the 1980s. This river drained an extensive floodplain and was renowned as a recreational fishing site, containing abundant fish stocks (Whitehead *et al*. 1990). Perhaps food availability was responsible for the high densities of crocodiles it sustained. Using a correction factor of 1.5 for relative versus absolute density, the Mary River may well be supporting around 18.2 crocodiles weighing 2355 kg/km.

Extent of Recovery

In the 682 km of mainstream surveyed here (12 rivers), the abundance of crocodiles, when viewed as a single population, predicted for 1975 (4 years after protection) to 2010 increased conservatively from 1.47 to 5.26 crocodiles (>3 times) and from 47.58 kg/km to 387.64 kg/km (>8 times; Fig. 7). Given the situation in 1971 was probably closer to 0.1 crocodiles sighted per kilometer surveyed, as discussed above, the real recovery since protection is likely to have been closer to a >50 times increase in abundance and >100 times increase in biomass.

Correction factors relating relative density indices (crocodiles sighted in surveys) to absolute densities (the real number of crocodiles present) are specific to size and location but appear conservatively to be in the range of 1.5 to 2.0 (Messel *et al*. 1981; Bayliss *et al*. 1986). Hence the real population in the mainstreams of these 12 rivers in 2010 is probably closer to 8-11 crocodiles weighing 600-800 kg/km.

Effects of the Egg Harvest Program

The egg harvest program has not been factored into our population assessments because its influence on the abundance of non-hatchlings (our focus) remains unclear and may be minor as shown by the large increase of the crocodile populations. When the first experimental trial egg harvests were carried out in the wet seasons of 1983-1984 (994 eggs), 1984-1985 (3517 eggs), and 1985-1986 (3470 eggs), no impact on the numbers of small non-hatchlings in the population in the following years could be detected (Webb *et al*. 1989), probably because the survival of hatchlings not removed as eggs increased. Density-dependent survival of hatchlings as shown by Webb and Manolis (1992) may compensate for high mortality rates of eggs due to harvest or natural causes. A mean estimate of 70% of wild eggs is lost each year (Webb *et al*. 1984), mostly to flooding (Webb *et al*. 1977, 1983b). Thus, although the extent of egg harvest has steadily increased over time (commensurate with the increased numbers of adults and nests; <50,000 eggs harvested in 2009-2010 season), and most rivers with nesting habitat have gradually been included in the harvest program (commercial egg harvesting is prohibited in the Kakadu National Park), it may not be greatly affecting trends in non-hatchling densities. However, detailed study on the impact of historical egg harvest should provide a new insight for the management of the Saltwater Crocodile harvest programs.

Conservation and Management of Wild Crocodiles

Saltwater Crocodiles are an important natural resource in the NT for customary use by indigenous people (Lanhupuy 1987), tourism (Ryan 1998; Tremblay 2001a,b), and commercial crocodile farming (Webb and Manolis 1993; Leach *et al*. 2009). The egg harvest program provides landowners with the ability to sell crocodile eggs, creating commercial incentives for them to tolerate large wild populations of crocodiles outside of national parks and protected areas (Webb and Manolis 1993). Saltwater Crocodiles are also serious predators on people and livestock (Webb and Manolis 1989; Caldicott *et al*. 2005). With increasing population of both humans (Australian Bureau of Statistics 2007) and crocodiles in the NT, managing human-crocodile conflict continues to be a priority in the future. Managing the recovery of the wild populations since protection has involved integrating the diverse objectives, perceptions and demands from the public with changing views towards crocodiles (Webb *et al*. 1984, 2000; Leach *et al*. 2009).

The tidal rivers we studied were known to contain high to medium densities of crocodiles historically and today. The degree to which the same trends apply in the many low density rivers, creeks, and around the coastline, is largely unknown. Of particular concern is the degree to which the attainment of an asymptote in the high density tidal rivers, may be stimulating increased dispersal of Saltwater Crocodiles into the low density rivers, and more importantly, into the far upper reaches of rivers, where few Saltwater Crocodiles were encountered in living memory or historical record. There is a mistaken public perception that the freshwater upper reaches of rivers are free from Saltwater Crocodiles and are thus safe for water-based recreational activities, yet individual Saltwater Crocodiles, are increasingly being found in such areas (Letnic and Connors 2006).

Management Inplications

Our results that wild populations of Saltwater Crocodiles have largely increased in number and biomass since protection indicate that ongoing public education and the strategic removal of problem animals, particularly from urban and rural residential areas (Walsh and Whitehead 1993; Nichols and Letnic 2008) are critical. Continuing increase in biomass and decreasing proportion of small individuals in the populations indicate that the proportion of larger crocodiles is increasing, with a corresponding increased capability of attacking people or livestock. There is no mechanism through which swimming in tidal rivers and beaches across the Northern Territory can be made absolutely safe. The management programs should be formulated, being commensurate with the increased size and distribution of the wild crocodile population and the diversity of ways in which they are used by people. In the case of the harvest program, a fundamental management obligation to ensure that the wild population sustained the harvest of eggs and crocodiles to date was met by the survey results we analysed. Ongoing commitment to continual monitoring of the populations, using the standardised survey technique, is important.

Acknowledgements

This paper is an amended version of the article previously published as: Fukuda, Y., Webb, G., Manolis, C., Delaney, R., Letnic, M., Lindner, G., and Whitehead, P. (2011). Recovery of Saltwater crocodiles following unregulated hunting in tidal rivers of the Northern Territory, Australia. Journal of Wildlife Management 75(6): 1253-1266.

This study would not have been possible without the pioneering efforts of Professor Harry Messel of the University of Sydney in the 1970s and 1980s and the hundreds of people, from various institutions, who have subsequently contributed to the crocodile survey programs over nearly 4 decades. We thank the traditional owners of the Indigenous lands for assisting with the surveys and giving permission to survey in their land. We also thank Graham Hall for encouraging us to publish our study, and Keith Saalfeld for providing helpful comments on the manuscript.

Literature Cited

Australian Bureau of Statistics. (2007). Regional Statistics, Northern Territory, 2007. <http://www.abs.gov.au/>. Accessed 25 May 2010.

Bayliss, P., Webb, G.J.W., Whitehead, P.J., Dempsey, K.E. and Smith, A.M.A. (1986). Estimating the abundance of saltwater crocodile, *Crocodylus porosus* Schneider in tidal wetlands of the N.T.: A mark-recapture experiment to correct spotlight counts to absolute numbers and the calibration of helicopter and spotlight counts. Australian Wildlife Research 13: 309-320.

Bayliss, P. (1987). Survey methods and monitoring within crocodile management programs. Pp. 157-175 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons, and the Conservation Commission of the Northern Territory: Chipping Norton.

Burnham, K.P. and Anderson, D.R. (2002). Model Selection and Multi-Model Inference: a Practical Information-Theoretic Approach. Second edition. Springer-Verlag: New York City.

Caldicott, D.G.E., Croser, D., Manolis, C., Webb, G. and Britton, A. (2005). Crocodile attack in Australia: an analysis of its incidence, and review of the pathology and management of crocodilian attacks in general. Wilderness and Environmental Medicine 16: 143-159.

Choquenot, D. and Webb, G.J.W. (1987). A photographic technique for estimating the size of crocodiles seen in spotlight surveys and for quantifying observer bias. Pp. 217-224 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons, and the Conservation Commission of the Northern Territory: Chipping Norton.

Fukuda, Y., Whitehead, P. and Boggs, G. (2007). Broad scale environmental influences on the abundance of saltwater crocodiles, *Crocodylus porosus*, in Australia. Wildlife Research 34: 167-176.

Hill, R. and Webb, G. (1982). Floating grass mats of the Northern Territory floodplains - an endangered habitat? Wetlands 2: 45-50.

Hoetker, G. (2007). The use of logit and probit models in strategic management research: critical issues. Strategic Management Journal 28: 331-343.

Lanhupuy, W. (1987). Australian aboriginal attitude to crocodile management. Pp. 145-147 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons, and the Conservation Commission of the Northern Territory: Chipping Norton.

Leach, G.J., Delaney, R. and Fukuda, Y. (2009). Management Program for the Saltwater Crocodile in the Northern Territory of Australia, 2009-2014. Northern Territory Department of Natural Resources, Environment, The Arts and Sport: Darwin.

Letnic, M. and Connors, G. (2006). Changes in the distribution and abundance of saltwater crocodiles (*Crocodylus porosus*) in the upstream, freshwater reaches of rivers in the Northern Territory, Australia. Wildlife Research 33: 529-538.

Letts, G.A., Bassingthwaighte, A. and De Vos, W.E.L. (1979). Feral Animals in the Northern Territory. Report of the Board of Inquiry to the Northern Territory Legislative Assembly. Northern Territory Government: Darwin.

Lindner, G. (2004). Crocodile management – Kakadu National Park. Pp. 41-51 *in* Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Messel, H., Vorlicek, G.C., Wells, G.A. and Green, W.J. (1981). Monograph 1. Surveys of the Tidal Systems in the Northern Territory of Australia and their Crocodile Populations. The Blyth-Cadell River Systems Study and the Status of *Crocodylus porosus* Populations in the Tidal Waterways of Northern Australia. Pergamon Press: Sydney.

Messel, H., Green, W.J., Vorlicek, G.C. and Wells, A.G. (1982). Monograph 15. Surveys of Tidal River Systems in the Northern Territory of Australia. Work Maps of Tidal Waterways in Northern Australia. Pergamon Press, Sydney, Australia.

Messel, H. and Vorlicek, G.C. (1986). Population dynamics and status of *Crocodylus porosus* in the tidal waterways of northern Australia. Australian Wildlife Research 13: 71-111.

Nichols, T. and Letnic, M. (2008). Problem crocodiles: reducing the risk of attacks by *Crocodylus porosus* in Darwin Harbour, Northern Territory, Australia. Pp. 503-511 *in* Urban Herpetology. Herpetological Conservation Vol. 3, ed. by J.C. Mitchell, R.E. Jung Brown and B. Bartholomew. Society for the Study of Amphibians and Reptiles: Salt Lake City, Utah.

Parks and Wildlife Service of the Northern Territory [PWSNT]. (2005). Management Plan for *Crocodylus porosus* in the Northern Territory. Northern Territory Government: Darwin.

Ryan, C. (1998). Saltwater crocodiles as tourist attractions. Journal of Sustainable Tourism 6: 314-327.

Searcy, A. (1984). In Australian Tropics. Hesperian Press: Perth.

Spiess, A. and Neumeyer, N. (2010). An evaluation of R2 as an inadequate measure for nonlinear models in pharmacological and biochemical research: a Monte Carlo approach. BMC Pharmacology 10:6. <http://www.biomedcentral.com/content/pdf/1471-2210-10-6.pdf>. Accessed 12 December 2010.

Tremblay, P. (2001a). Crocodile tourism in the Top End of the Northern Territory: Summary of the findings. First National Convention on Wildlife Tourism in Australia entitled Wildlife Tourism: Endangered or Sustainable Growth, 28-30 October, Hobart, Australia. <www.wildlifetourism.org.au/2001_conference.htm#proceeding>. Accessed 25 May 2010.

Tremblay, P. (2001b). Alternative frameworks for the management of wildlife resources with multiple uses: Crocodile tourism as a case study. Capitalising on Research - Crocodile. Pp. 339-352 *in* Proceedings of the Eleventh Australian Tourism and Hospitality Research Conference 2001, ed. by C. Pforr and B. Janeczko. Council for Australian University Tourism and Hospitality Education: Canberra.

Walsh, B. and Whitehead, P. (1993). Problem crocodiles (*Crocodylus porosus*) at Nhulunbuy, Northern Territory, Australia: an assessment of relocation as a management strategy. Wildlife Research 20: 127-135.

Webb, G.J.W. (1991). The influence of season on Australian crocodiles. Pp. 125-131 *in* Monsoonal Australia: Landscape, Ecology and Man in the Northern Lowlands, ed. by M.G. Ridpath, C.D. Hayes and M.J.D. Williams. AA Balkema: Rotterdam.

Webb, G.J.W., Bayliss, P.G. and Manolis, S.C. (1989). Population research on crocodiles in the Northern Territory, 1984-86. Pp. 22-59 *in* Crocodiles. Proceedings of the 8th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Webb, G.J.W., Britton, A.R.C., Manolis, S.C., Ottley, B. and Stirrat, S. (2000). The recovery of *Crocodylus porosus* in the Northern Territory of Australia: 1971-1998. Pp. 195-234 *in* Crocodiles. Proceedings of the 15th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Webb, G.J.W., Dillon, M.L., McLean, G.E., Manolis, S.C. and Ottley, B. (1990). Monitoring the recovery of the saltwater crocodile (*Crocodylus porosus*) population in the Northern Territory of Australia. Pp. 329-380 *in* Crocodiles. Proceedings of the 9th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Webb, G. and Manolis, C. (1989). Crocodiles of Australia. Reeds: Sydney, Australia

Webb, G.J.W. and Manolis, S.C. (1992). Monitoring saltwater crocodiles (*Crocodylus porosus*) in the Northern Territory of Australia. Pp. 404-418 *in* Wildlife 2001: Populations, ed. by D.R. McCullough and R.H. Barrett. Elsevier Applied Science: New York City.

Webb, G.J.W. and Manolis, S.C. (1993). Viewpoint: conserving Australia's crocodiles through commercial incentives. Pp. 250-256 *in* Herpetology in Australia, ed. by D. Lunney and D. Ayers. Surrey Beatty & Sons: Chipping Norton.

Webb, G.J.W. and Messel, H. (1978a). Movement and dispersal patterns of *Crocodylus porosus* in some rivers of Arnhem Land, northern Australia. Australian Wildlife Research 5: 263-283.

Webb, G.J.W., Manolis, S.C. and Sack, G.C. (1983a). *Crocodylus johnstoni* and *Crocodylus porosus* coexisting in a tidal river. Australian Wildlife Research 10: 639-650.

Webb, G.J.W., Manolis, S.C., Whitehead, P.J. and Letts, G.A. (1984). A proposal for the transfer of the Australian population of *Crocodylus porosus* Schneider (1801), from Appendix I to Appendix II of C.I.T.E.S. Conservation Commission of the Northern Territory technical report. Northern Territory Government: Darwin, Australia.

Webb, G.J.W. and Messel, H. (1978b). Morphometric analysis of *Crocodylus porosus* from the north coast of Arnhem Land, northern Australia. Australian Journal of Zoology 26: 1-27.

Webb, G.J.W. and Messel, H. (1979). Wariness in *Crocodylus porosus*. Australian Wildlife Research 6: 227-237.

Webb, G.J.W., Messel, H. and Magnusson, W.E. (1977). The nesting biology of *Crocodylus porosus* in Arnhem Land, Northern Australia. Copeia 1977: 238-249.

Webb, G.J.W., Sack, G.C., Buckworth, R. and Manolis, S.C. (1983b). An examination of *Crocodylus porosus* nests in two northern Australian freshwater swamps with an analysis of embryo mortality. Australian Wildlife Research 10: 571-605.

Whitehead, P. J., Wilson, B.A. and Bowman, D.M.J.S. (1990). Conservation of coastal wetlands of the Northern Territory: the Mary River floodplain. Biological Conservation 52: 85-111.

Ranching of *Caiman latirostris* and *Caiman yacare* in Argentina: Where a Problem Becomes a Livelihood

Alejandro Larriera [1], Pablo Siroski [1], Carlos Piña [2,3] and Alba Imhof [1]

[1] Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASPyMA), A. del Valle 8700, Santa Fe, Argentina
[2] CIC y TTP-CONICET, Proyecto Yacaré, Dr. Matteri y España, (3105) Diamante, Entre Ríos, Argentina
[3] Fac. Cs. de la Alimentación, Universidad Nacional de Entre Ríos and Fac. Cs. y Tec., Universidad Autónoma de Entre Ríos, Argentina

Abstract

The sustainable use of wildlife of commercial interest, leading to economic benefit as an incentive for *in-situ* conservation, clearly is nowadays, the realistic approach to conserving natural ecosystems. The local inhabitants usually involved on the ranching program are the employees of the cattle ranches. These "Gauchos" are familiar with the nesting areas, so during the breeding season they are the first ones to find the nests, and when they are properly trained, they also do the harvest of the eggs themselves. The eggs are transported to the ranching station for artificial incubation, but the work of the Gauchos does not end there, as they are also actively involved on research studies, release of yearlings, and monitoring, together with the almost 40 researchers involved in the scientific activities. Certainly caimans are now no longer a problem for the Gauchos and do have a positive value to them. Between the three Provinces working on ranching, there are about 1000 people involved with the projects. They constitute a task force devoted to the protection of the caiman adult population, simply because they are economically incentivized through this relatively new livelihood.

Sustainable Use of Crocodilians

At one time, the conservation of wild crocodilians was pursued exclusively through the creation of wildlife refuges or sanctuaries, the imposition of strict bans on wild harvesting, and the belief that closed-cycle captive breeding was the only rational type of use. At that time commercial utilization of wild populations was regarded almost as the first step on the road to extinction. Subsequently, the concept of sustainability came into being, and in the case of many crocodilian species that were historically exploited, it became evident that rational utilization need not affect the status of the population. It was also evident that the real problem was environmental modification through deforestation, drainage of wetlands, or more recently, intensive agriculture. From that moment, "the enemy becomes a friend" and commercial use was recognised as one of the very few effective tools against habitat loss.

The challenge was to change people's attitudes towards crocodilians, and to give them more "value". Simply telling the public that crocodilians were "good" for the environment was not enough. People needed more tangible rewards. They got these in several ways. The first step was not to deny simple facts: crocodiles are sometimes dangerous and can be a problem, so extensive educational awareness campaigns encouraged people to treat crocodiles with caution and respect.

The idea of "sustainable use" of wild populations was highly controversial in the past, more so than it is today. However, in this case it has provided an economic incentive helping to conserve crocodilian species and their habitats. As a conservation strategy, "sustainable use" is endorsed not only by the IUCN-SSC Crocodile Specialist Group (CSG), but also the world's major conservation bodies including the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on Biological Diversity (CBD) and WWF (G. Webb, pers. comm.).

It is self-evident for many NGOs - and for most scientists and wildlife managers - that sustainable utilization of crocodilians through ranching or hunting, whether alone or combined with other activities, such as ecotourism, does work positively in favour of conservation. Despite the fact that, in general terms, there has always been significant objection to the idea of harvesting wildlife for conservation, and that there are many people who will argue that it doesn't work, actually it has shown to be highly successful in many instances. On the other hand, even those who still harbour hostility towards crocodilians acknowledge their biological and economic importance, and would not wish to see them disappear. Such is the importance of linking conservation with people (Hutton and Child 1989; Hutton and Webb 2002; Hutton *et al*. 2002; G. Webb, pers. comm.).

The Crocodile Specialist Group

The CSG was established in 1971, before CITES came into force with all crocodilian species listed on its appendices (1975).

The formation of the CSG was motivated by conservation concerns about the world's 23 species of crocodilians distributed in some 100 countries. Despite little formal research, it was clear that most species had suffered serious population declines, prompting genuine fears of extinction. The declines were due mainly to excessive and uncontrolled commercial harvesting for the luxury crocodile leather industry.

The CSG today, with a voluntary membership of around 450 scientists, wildlife managers and crocodile industry representatives from 57 countries, can report that 16 crocodilian species appear to be secure from extinction and only 7 species are still at risk (CSG 2012). Paradoxically, none of these have high commercial value.

Management programs involving sustainable use of wild crocodilian populations have demonstrated that conservation goals (recovering a depleted population) can still be achieved while part of the population is being harvested for trade, creating incentives to keep the program going. They have also shown that conservation and commerce can coexist without conflict, despite being motivated by different goals. Most importantly, they have demonstrated that if people and wildlife both benefit from wildlife conservation programs, the programs will have a better chance of internalizing costs and becoming self-supporting in the long-term. Programs that rely on transient donor funding are inherently difficult to sustain because the funding is finite and will eventually be reduced or withdrawn. All the benefits are consistent with the aims and goals of most environmental agreements and organizations (eg CITES, CBD, IUCN, UNEP). They also parallel the goals of the UN Global Compact, created in 2000, which aims to encourage the business world to adopt sustainable and socially responsible policies (G. Webb, pers. comm.).

These management programs provide the luxury leather market with a legal supply of crocodilian skins, with significant ethical credentials. Part of the value of most high fashion handbags sold to customers in Europe today tracks its way back through the supply chain to individual people and families, often in remote areas, who harvested the egg or the crocodilian. It ensures that people at the coalface of crocodilian conservation in the field - whose actions will ultimately determine whether crocodilians and their habitats are retained - become direct beneficiaries of their conservation (G. Webb, pers. comm.).

Ranching *Caiman latirostris* in Argentina

The northern part of Argentina represents the southern-most limit of the distribution of the Broad-snouted Caiman (*Caiman latirostris*) and the Yacare Caiman (*C. yacare*). Both species are distributed in the Provinces of Formosa, Santa Fe, Misiones, Corrientes, Entre Rios, Chaco, Santiago del Estero, Salta and Jujuy, in Argentina, although *C. yacare* occurs in higher densities above the 30o latitude and *C. latirostris* up to the 32o latitude (Medem 1983; Waller and Micucci 1993; Yanosky 1990).

Populations of the *C. latirostris*, at least some years ago, were considered to be seriously depleted, partly due to commercial over-exploitation over the past decades and to the progressive loss of habitat caused by drainage of the marshlands for cattle production. On the other hand, the few remaining adults in the wild were regularly killed by the local inhabitants, sometimes to sell the skin on the illegal market, but also out of fear for the welfare of small animals and children. As fieldwork progressed, a distribution area and a reproductive potentiality bigger than what had been expected were verified (Larriera *et al*. 2008).

During the period of illegal hunting, until the late 1980s, the skin of the Broad-Snouted Caiman was the preferred one, because of its high quality compared with the Yacare caiman, which is much more ossified (Fuchs 2006). In the first studies in the wild, it was believed that the situation of *C. latirostris* was worse than really transpired in the field. This was because the environmental preferences of the species, which inhabits heavily vegetated places, which are difficult for humans to access, whether for hunting or studying, making effective population assessments difficult. On the other hand, *C. yacare* prefers open water environments, giving the impression that they were more common in the places where both species were found. Adequate studies subsequently demonstrated the reality, as the only difference seemed to be that *C. latirostris* was not less frequent, but simply more difficult to locate (Larriera *et al*. 2008).

Ranching of eggs, combined with restocking of the wild population, was considered the safest option to pursue with regard to minimizing the impact on the population. Listed in Appendix I of CITES, international trade in *C. latirostris* products was prohibited until the Argentinean *C. latirostris* ranching proposal was approved at the 10th Conference of the Parties to CITES (Harare, Zimbabwe, 1997), and the population transferred to Appendix II. Initially, ranching was only implemented in Santa Fe Province, but in 2001 it was extended to Formosa Province, and in 2004 to Corrientes Province (Larriera 1990; Larriera 1998; Larriera *et al*. 2008; Ross 1998). *Caiman yacare* was already listed in Appendix II of CITES, so no concessions from CITES were required.

The background for the CITES downlisting was essentially the scientific information generated by the ranching program that began in Santa Fe Province in 1990 (Larriera 1990, 1991, 1993, 1994).

Natural History and the Ranching Program Itself

Crocodilian activity is dependent on ambient temperature. In winter, in the southern limit of its distribution (Santa Fe Province), ambient temperatures fall to 0ºC on some days, so activity is restricted to a few movements between the land (where the animals are exposed to the sun) and the water. From October, crocodilians begin to feed more often, and prepare themselves for the reproductive season. Mating begins in early November, and nest construction from early to mid-December. Females lay their eggs in a mound nest built with vegetation and soil, sometimes far from permanent water. Egg-laying occurs from mid-December to mid-January. Mean clutch size for *C. latirostris* in Argentina is 35 eggs, and the natural incubation period is around 70 days (Larriera and Imhof 2006).

It was estimated that only 30-40% of wild eggs produce hatchlings, with the most common causes of embryonic death being flooding and predation (Larriera and Piña 2000). Average survivorship to one year of age has been estimated at 10%, due to predation and the effects of winter (which starts 2-3 months after hatching at the southern limit). However, survival varies markedly from year to year according to environmental conditions (Larriera and Imhof 2006).

The rationale for the harvest of wild eggs for captive rearing (ranching), is based on consideration of the high natural mortality of embryos and hatchlings and that returning up to 10% of animals hatched at the rearing station will at the very least keep the population stable or allow it to keep growing. The philosophy of the technique is very simple, and consists of "saving" animals under captive conditions, which allows utilisation of some of them for commercial purposes, in order to give economic value to the wetlands where they live.

Through the ranching program egg harvesting is carried out from mid-December to late January. Normally the nests are located by cattle ranch employees, who receive a payment for every marked or harvested egg. During the first years of the work, local inhabitants only identified nests in the wild, and the harvest was carried out by project personnel. But as the work progressed, local people in the field were trained to harvest the eggs themselves, which meant more money for them. The transport of eggs from the nesting areas to where vehicles are waiting is carried out using horses in most cases. Distances vary from a couple of hundred metres up to 15 km (Larriera and Imhof 2006).

The harvest of the eggs is carried out by the "Gauchos" on the basis of the technique proposed by Larriera (1990), and consists of opening the nest to expose the eggs, which are then marked with colour pencils on the top, in order to maintain their relative positions in the incubator as changing these could kill the embryos. The eggs marked in this way are placed in plastic containers together with nest material, thus minimizing the effect of rough movements during transport.

Eggs are transported to the rearing station in Santa Fe City, where they are placed in incubation chambers with 98% humidity and 31.5ºC conditions. At hatching, hatchlings are marked by cutting a sequence of the vertical tail scutes (scales), identifying year and nest number, and then transported to rearing pens where water, temperature and food are controlled (Larriera and Imhof 2006; Larriera *et al*. 2008).

Since its beginning in 1990, the ranching program in Argentina has returned around 30,000 *C. latirostris* yearlings to the wild. The recovery of the wild population has been verified in all the harvest locations, with exceptional increases of 1500% in some of them (Larriera and Imhof 2000; Piña *et al*. 2010; Siroski 2003). It has also been confirmed that 50% of the breeding females in the working areas are animals previously released by the project (Larriera *et al*. 2006).

Conclusions

The local inhabitants usually involved in the project are employees of the cattle ranches, so they are really the cowboys in the field. We in Argentina call them "Gauchos", and their work is basically to control the cows in areas of up to 3000 hectares each. They know their localities very well and are familiar with the nesting areas of the caimans, so during the breeding season they are the first ones to find the nests, and, when properly trained, they also carry out the harvest. These people receive benefits directly from the program through a payment for every egg collected - currently $US1 each. Some of the Gauchos harvest just 2 or 3 nests, amounting to only $US100 to $US200 for the work, but others in more productive areas, and those more motivated, can harvest up to 1000 to 2000 eggs which represents a significant amount of money to them, considering that their salary is around $US400 per month.

Of course, the economic incentive also acts to stop local inhabitants killing caimans and to protect the nesting areas. Because they have an economic incentive to keep the caiman population in good shape, they do not allow anyone to touch the animals in the field, so in practice, they are actively involved in the protection of the wild adults. On the other hand, the Gauchos are also involved in the research work, such as releasing and population monitoring, together with the almost 40 biologists, veterinarians and sociologists involved in the scientific activities.

Certainly caimans are now no longer a problem for the Gauchos and do have a positive value to them. Between the three Provinces involved with ranching programs, there are about 1000 people involved in one way or another, which is more than all the employees of the National Parks, the local government officials, and the national government officials in charge of the enforcement of the laws in the country. In effect, it is a task force devoted to the adult caiman adult protection.

In the last season in Argentina about 30,000 *C. latirostris* and 60,000 *C. yacare* eggs were harvested, which is a major incentive to protect the adults for the local inhabitants in the north of the country. This meant that in those regions where ranching is now carried out, during the last year the local people who live in the field and share the ecosystem with the caimans have received almost $US90,000 through egg payments. Certainly, no-one wants to see the crocodilians vanish now. In fact, they would welcome greater numbers.

Literature Cited

Fuchs, K. (2006). The Crocodile Skin: Important Characteristics in Identifying Crocodilian Species. Chiamaira: Frankfurt am Main, Germany.

Herrera, E. (1999). Comportamiento, conservación y manejo de fauna silvestre: el caso del capibara en Venezuela. Etología 7: 41-46.

Hutton, J. and Child, G. (1989). Crocodile management in Zimbabwe. Pp. 62-79 *in* Crocodiles. Their Ecology, Management and Conservation, ed. by P.M. Hall. IUCN Publications: Gland, Switzerland.

Hutton, J. and Webb, G. (2002). Legal trade snaps back: using the experience of crocodilians to draw lessons on regulation of the wildlife trade. Pp. 1-5 *in* Crocodiles. Proceedings of the 16th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Hutton, J., Ross, J.P. and Webb, G. (2002). Using the market to create incentives for the conservation of crocodilians: a review. Pp. 382-299 *in* Crocodiles. Proceedings of the 16th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

IUCN (1980). Estrategia Mundial para la Conservación. La conservación de los recursos vivos para el logro de un desarrollo sostenido. United Nations: Washington, USA.

IUCN (1991). Cuidar la Tierra: estrategia para el futuro de la vida. IUCN, UNEP and WWF: Gland, Switzerland.

Larriera, A. (1990). A program of monitoring and recovering of caiman populations in Argentina with the aim of management. Pp. 1-5 *in* Crocodiles. Proceedings of the 10th Working Meeting of the IUCN-SSC Crocodile Specialist Group, Vol 2. IUCN: Gland, Switzerland.

Larriera, A. (1991). Cría en granjas: una alternativa de manejo para los caimanes argentinos. (Revisión Bibliográfica). Revista Argentina de Producción Animal 11: 479 484.

Larriera, A. (1993). La conservación y el manejo de *Caiman latirostris* en Santa Fe, Argentina. Pp. 61-69 *in* Anais do 3o Workshop sobre Conservação e Manejo do Jacaré-de-papo-amarelo, ed. by L.M. Verdade, I.U. Packer, M.B. Rocha, F.B. Molina, P.G. Duarte and L.A.B.M. Lula. CIZBAS/ESALQ, Universidade de São Paulo: Piracicaba, SP, Brasil.

Larriera, A. (1994). *Caiman latirostris* ranching program in Santa Fe, Argentina, with the aim of management. Pp. 188-198 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Larriera, A. (1998). The *Caiman latirostris* ranching program in Santa Fe, Argentina. The first commercial rearing. Pp. 379-385 *in* Crocodiles. Proceedings of the 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Larriera, A. and Imhof, A. (2000). Proyecto Yacaré, Santa Fe, Argentina: a sustainable use proposal. Pp. 311-313 *in* Crocodiles: Proceedings of the 15th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Larriera, A. and Imhof, A. (2006). Proyecto Yacaré: Cosecha de huevos para cría en granjas del género *Caiman* en la Argentina. Pp. 51-64 *in* Manejo de Fauna Silvestre en la Argentina. Programas de Uso Sustentable, ed. by M. Bolkovic and D. Ramadori. Dirección de Fauna Silvestre, Secretaría de Ambiente y Desarrollo Sustentable: Buenos Aires.

Larriera A. and Piña, C.I. (2000). *Caiman latirostris* (Broad-snouted Caiman) nest predation: does low rainfall facilitate predator access? Herpetological Natural History 7(1):73-77.

Larriera, A., Siroski, P., Piña, C.I. and Imhof, A. (2006). Sexual maturity of farm-released *Caiman latirostris* (Crocodylia : Alligatoridae) in the wild. Herpetological Review 37: 26-28.

Larriera, A., Imhof, A. and Siroski, P. (2008). Estado actual de los programas de conservación y manejo del género *Caiman* en Argentina. Pp. 141-180 *in* Contribución al Conocimiento del género Caiman de Sudamérica, ed. by J. Castroviejo, J. Ayarzaguena and A. Velasco. Publicaciones Asociacion Amigos de Doñana 18. Seville: Spain.

Medem, F. (1983). Los Crocodylia de Sur América. II. Carrera: Bogotá, Columbia.

Piña, C., Siroski, P., Principe, G. and Simoncini, M. (2010). Population status of *Caiman yacare* and *Caiman latirostris* in North Argentina. Crocodilia 1: 1-5.

Ross, J.P. (1998). Status Survey and Conservation Action Plan: Revised Action Plan for Crocodiles. IUCN: Gland, Switzerland.

Siroski, P.A. (2003). Relevamiento de las poblaciones de caimanes en la región centro y sureste de la Provincia de Formosa. 2002. Informe técnico presentado a la Secretaria de Medio Ambiente de la Nación, Argentina.

Waller, T. and Micucci, P. (1993). Relevamiento de la distribución, hábitats y abundancia de los cocodrílios de la Provincia de Corrientes, Argentina. Pp. 341-385 *in* Zoocría de los Crocodylia. Proceedings of the 1st Regional Meeting of the IUCN-SSC Crocodile Specialist Group. I. Taller sobre zoocría de los crocodylia, Santa Marta, Colombia. IUCN: Gland, Switzerland.

Yanosky, A. (1990). Histoire naturelle du Caiman à museau large (*Caiman latirostris*), un alligatoriné mal connu. Revue Francais d'Aquariologie Herpetologie 17: 19-31.

The Illegal Use of Caimans as Bait for Fishing of Piracatinga, *Calophysus macropterus*, in the Middle Solimões River, Brazil

Botero-Arias, Robinson[1], Miriam Marmontel[2] and Sergio Sobrane Filho[3]

[1] Caiman Research in Conservation and Management Program, Mamirauá Institute for Sustainable Development, Estrada do Bexiga, no 2584 - Bairro Fonte Boa - CEP 69470-000 - Tefé/AM, Brazil (robin@mamiraua.org.br)
[2] Grupo de pesquisa em mamíferos aquáticos amazônicos - GPMAA do Instituto de Desenvolvimento Sustentável Mamirauá, Estrada do Bexiga, no 2584 - Bairro Fonte Boa - CEP 69470-000 - Tefé/AM, Brazil (marmontel@mamiraua.org.br)
[3] Universidade Estadual Paulista Júlio de Mesquita Filho - UNESP, Faculdade de Engenharia de Ilha Solteira, Brazil (sergio.sobranefilho@gmail.com)

Abstract

In the Middle Solimões River the practice of piracatinga (*Calophysus macropterus*) fishing using caimans and dolphins as bait has been recorded. Fishing and selling piracatinga is not an illegal activity, however the use of caimans and dolphins as bait turns this activity into an illegal one. The killing of dolphins for bait has arisen strong emotion by some researchers and especially the media. The absence of systematic data on this activity renders the comprehension and quantification of its effects on natural populations of caimans and dolphins difficult. The Mamiraua Institute has been recording aspects associated with piracatinga`s fishing, supply chain and landing, as well as the use of caimans and dolphins as bait. Our results suggest that Black and Spectacled Caimans are the species regularly used for bait production (67%). The use of pink dolphin as bait was recorded as being incidental and opportunistic. Piracatinga fishing happens year around, with a peak in March and April (40%). Caimans used as bait are sold for $5.00/m. The recent increase of this activity is related to the lack of other economic alternatives and the immediate monetary return it provides.

Rescue of the World's Largest Crocodile: An Effort of Local Government Unit of Bunawan, Agusan del Sur, to Address Human-Crocodile Co-Existence

Mayor Edwin G. Elorde

Municipality of Bunawan, Province of Agusan del Sur, Philippines

The Municipality of Bunawan comprising 10 Barangays is an Agriculture-based Municipality. It has a total land area of 51,218 ha with a population of 35,757 individuals as of census 2007. Some 60% of our lands are devoted to agriculture, such as high value commercial crops, rice and corn production among others. Agusan Marsh and Wildlife Sanctuary, where "Lolong" came from, comprises around 6000 hectares of our total land area. Onother 5 municipalities also contribute a portion of their land areas to the marsh.

The interaction of human and crocodile in the marshland happened long time ago. But then these interactions came to a point wherein crocodiles, especially the large one like "Lolong", already encroached human territory or vice versa. These resulted to series of events where the reptiles already attacked and killed people. Thus, inhabitants retaliated by capturing and killing the 19' crocodile sometime in 2002. Another attacked happened in 2011, where the headless body of a 12-year-old child was recovered.

It is along these lines that LGU-Bunawan acted promptly to rescue and conserve the large crocodile in Agusan Marsh, as well as protect its own people from further attack. Series of resolutions, ordinances and information drives for the affected communities were undertaken for the co-existence of both human and crocodiles. Letter requests to Mr. Sony Dizon (Davao Crocodile Park) and Director Jose Diaz of DENR-NCR and other concerned agencies such as the PAWB among others, were likewise sent in order to assist as well as allow the LGU to rescue the large crocodile. Thus, on 3 September 2011, at around 2300 h, the largest crocodile in the world was rescued, and later named "Lolong" in honor of the late Ernesto "Lolong" Conate, PWRCC certified trapper who died of a heart attack days before "Lolong" was rescued. The rescued reptile was later proclaimed by Guinness World Records as the largest crocodile in captivity. Lolong, a Saltwater Crocodile (*Crocodylus porosus*), measured 6.17 m (20' 3") and weighed 1075 kg. "Lolong" is now situated at the Bunawan Ecopark and Research Center, a safe place for him as well as the other crocodiles in Agusan Marsh. The park has already gathered around 600-800 local and foreign tourists daily, catapulting the Municipality and placing it on the world map, and giving its people a chance to improve their lives through sustainable ecotourism as well as conserve the crocodiles in Agusan Marsh. As the mayor has said that both human and crocodile are created by God, so both must also be protected.

Lolong and Other Dragons: Maximum Size in Crocodiles

Adam R.C. Britton[1], Rom Whitaker[2] and Nik Whitaker[2]

[1] Big Gecko Crocodilian Research, McMinns Lagoon, N.T., Australia (abritton@crocodilian.com)
[2] Madras Crocodile Bank Trust, Mamallapuram, Tamil Nadu, India

Abstract

Accurate, verified data on exceptionally large crocodiles is rare, so when a Saltwater Crocodile (*Crocodylus porosus*) of potentially record-breaking size was captured from Agusan del Sur, Mindanao, in the Philippines in early September 2011, it provided a rare opportunity to collect valuable data on the upper size limit of this species. Morphological data are presented here, and we discuss the relevance of these measurements in the context not only of other large crocodilians, but of hypothetical circumstances that lead to exceptional size in crocodiles.

Introduction

On 3 September 2011 a large male *C. porosus* was captured from Magsagangsanga Creek near Bunawan in the Agusan del Sur Province of Mindanao in the Philippines. It was believed responsible for the death of 12-year-old Rowena Romano, taken from a small dugout canoe at Lake Mihaba in Agusan Marsh on 7 March 2009 (Sistante 2009). It was also blamed in 2011 for the death of a fisherman from Bunawan village (R. Sumillar, pers. comm.). The desire to remove an animal thought most likely to be responsible was considerable. The crocodile that was eventually captured was named after Ernesto "Lolong" Cañete of the Palawan Wildlife Rescue and Conservation Center (PWRCC) who died of a heart attack in late August 2011 shortly before its eventual capture.

Lolong was captured by members of the PWRCC and coordinated by wildlife specialist Ronnie Sumiller using baited steel nooses. The crocodile was so heavy that dozens of local people were needed to haul it to a nearby village where it was subsequently transported by road to holding facilities. Lolong now resides at Bunawan Eco-Park and Research Center.

Media reports of the crocodile's total length ranged from 6.1 to 6.4 m (20 to 21'), and its large size appeared to be corroborated by photographic and video evidence. This attracted interest in verifying these measurements for Guinness World Records, and Natural History New Zealand arranged for one of the authors (AB) to visit Bunawan to do so before witnesses and television cameras. Funding was provided by National Geographic.

Materials and Methods

Capture and Restraint

Lolong was measured in his enclosure at Bunawan Eco-Park on 9 November 2011 at 1400 h local time. Lolong was lying relatively straight on the level concrete floor of his drained pool, with further corrections to straighten his posture possible. Chemical and physical restraint was used to facilitate accurate measurement particularly of the head, to improve safety and welfare. A neuromuscular blocker (Pancuronium bromide @ 2 x 2 mg) was combined with a mild sedative (Diazepam @ 10 mg) to achieve partial immobilization (after Bates *et al*. 2004). Highly conservative doses (0.004 mg/kg for pancuronium bromide, 0.01 mg/kg for diazepam) were used given that Lolong was outside the size range of crocodiles for which either drug had been used previously. Once it was clear that sufficient immobilization had taken place to permit safe handling, further doses were deemed unnecessary. Breathing rate and eye blink response were monitored throughout the procedure.

Chemical induction was achieved after two hours, after which standard physical restraint was employed using a combination of head immobilization using snout ropes, duct tape to secure the jaws, towels to cover the eyes, and physical restraint applied to the limbs and body using a team of five persons. Measurements to the head and body, together with documentation, took approximately one hour after which all physical restraint was carefully removed using established safety protocols. Drugs were allowed to metabolise naturally while the crocodile was under observation, and normal behaviour was observed six hours post injection.

Measurement

Lolong's head, body and tail were straightened prior to measurement. Measurements concentrated on morphological dimensions that would not be influenced by body condition (Fig. 1) and were taken using a steel tape with a millimetre scale. Conversion into other units (eg feet) was done afterwards. The tape was held taut for each measurement, and straight wooden rods held perpendicular to the ground were used as boundary markers for specific measures (eg maximum head width). We followed slightly modified methods previously published for *C. porosus* (Webb and Messel 1978). We used DCL for "head length" to avoid confusing mandible length with "head length" (Whitaker and Whitaker 2008). Skull widths and heights were taken at the maximum points. Snout-pelvis length (SPL; Fig. 1a), to the posterior margin of the hind legs joining the pelvis, was used as a substitute for snout-vent length (SVL) because of the difficulty and welfare considerations associated with rolling such a large crocodile onto its side or back. Previous comparisons (A. Britton, pers. obs.) suggest that SPL and SVL differ by less than 1%.

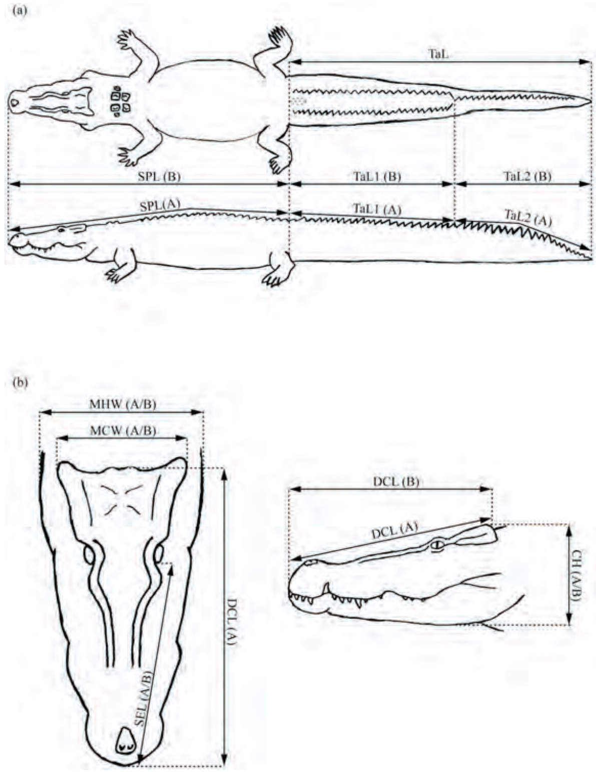


Figure 1. Top-down and profile diagrams of entire crocodile (a) and head (b) illustrating measurements taken using Method A (A) and Method B (B). DCL= dorsal cranial length; SEL= snout-eye length; MHW= maximum head width; MCW= maximum cranial width; IOW= inter-orbital width; CH= cranial height; SPL= snout-pelvis length; TaL= tail length; TaL1= anterior tail length; TaL2= posterior tail length; SPL+TaL1 = snout-scute junction (SSJ); SPL+TaL1+TaL2 = total length (TL).

Two methods for measuring body length were used for comparative purposes. The first ("Method A", Table 1, Fig. 1a) used a steel tape along the dorsal midline from snout tip to tail tip following the slope of the skull and latter part of the tail. The second ("Method B", Table 1, Fig. 1a) used the horizontal distance from snout tip to tail tip exactly parallel to the ground. In practice Method B gave fractionally shorter lengths than Method A (by around 1% in large individuals) and yet Method A is more frequently used (A. Britton and R. Whitaker, pers. obs.) simply because it is more practical especially with large individuals that are difficult to move. Measurements using Method A were preferred as they allow more meaningful comparison with measurements of other large crocodiles. Lolong's tail appeared to be complete.

Table 1. Measurements of Lolong. See "Materials and Methods" for the difference between Method A and Method B. Method A is considered the principal measurement. All measurements are illustrated in Figure 1. All "length" measurements are taken from tip of premaxilla (snout). All "width" measurements are taken at the widest point.

Measurement (mm)	Method A	Method B
Dorsal cranial length (DCL)	700	694
Snout-eye length (SEL)	496	495
Maximum head width (MHW)	450	450
Maximum cranial width (MCW)	228	228
Inter-orbital width (IOW)	84	84
Cranial height (CH)	363	363
Snout-pelvis length (SPL)	2851	2844
Snout-scute junction (SSJ)	4982	4949
Total length (TL)	6170	6095

Lolong's mass was recorded at a truck weighbridge during transport to his captive holding facilities in early September 2011. It was logistically impractical to verify this measurement during our visit, but there is no reason to believe this simple measurement was lacking in rigour.

Results

Using Method A, Lolong's total length (TL) was 6.17 m (20.24') (Table 1) with a dorsal cranial length (DCL) of 700 mm (27.6"). Ratio of DCL to TL is 1:8.8. Snout-pelvis length (SPL) was 2.85 m. Therefore tail length (TaL) was 3.32 m, with TaL to TL ratio of 1:1.9. Snout-scute junction (SSJ) was 4.98 m, therefore we calculated anterior tail length (TaL1) as 2.13 m and posterior tail length (TaL2) as 1.19 m. The ratio TaL2 to TaL is 1:2.8. Measurements using Method B (Table 1) are provided for comparison. All measurements differ by less than 1% between Methods A and B except TL, which differs by 1.2%. Lolong's net mass (accounting for the trailer weight) was 1075 kg (2370 lb).

General body condition based on muscle tone and fat deposits was considered normal for a large wild crocodile. While age could not be determined by physical examination, there were no obvious signs of senescence. Age was estimated subjectively at approximately 50-60 years based on the degree of skull rugosity, health of teeth alveoli, height of dorsal scute keels and overall appearance which can be compared with previous observations and experience. Although the ventral surface was not examined, very little historical scarring was found on the skin, and no limbs, toes or parts of the tail were missing which was considered unusual for such a large wild crocodile. Recent superficial injuries were likely caused by rope abrasion incurred while struggling during capture and transport. All such injuries appeared to be healing normally.

Discussion

At 6.17 m (20.24'), Lolong is at the time of writing the largest wild crocodile ever captured alive and documented. The slightly higher measurement taken by Edwin Elorde shortly after capture (6.4 m, 21') was likely due to the crocodile's posture, the weight of the tail hanging onto the ground from the elevated cart pulling the vertebrae apart enough to add the additional 20 cm length. This underlines the importance of taking length measurements of crocodiles on flat, level ground.

So what about reports of larger crocodiles? These are mostly difficult to verify or come from incomplete specimens (Whitaker and Whitaker 2008). The largest body of evidence comes from skulls residing in museums and personal collections around the world, yet in virtually every case reliable length data from their original owners are lacking. The only resort is to estimate total body length based on known relationships between DCL and TL, yet the problem here is that existing formulae are derived from relatively small crocodiles (Webb and Messel 1978). Such relationships were never intended to be extrapolated to very large specimens. We now know that DCL becomes a smaller proportion of TL with increasing size. The DCL:TL ratio for smaller crocodiles of around 1:7 (Wermuth 1964; Bellairs 1970; Greer 1974) would under-estimate Lolong's length by over a metre because the DCL:TL ratio for large *C. porosus* is closer to 1:9 (Whitaker and Whitaker 2008). On top of this, the shape of the skull of exceptionally large specimens can be quite variable and DCL becomes a less useful indicator of TL.

The largest known *C. porosus* skull has a DCL of 760 mm, making it 8.6% longer than Lolong's skull. If we assume that a DCL:TL ratio of 1:9 is in the right ballpark, TL would be 6.84 m (22.4') which is 11.3% longer than Lolong's TL. The actual length of this specimen has been lost forever, but it seems reasonable to assume that it was a nearly 7 m (almost 23') crocodile. This closely matches a slightly smaller skull from Bhitarkanika in India of DCL 730 mm reported to have come from a 7 m (23') *C. porosus*. Applying the 1:9 ratio to the Bhirtikanika skull gives an estimated TL of 6.6 m (21.7 ft). The truth is unlikely to be far from these figures, and the largest known measured *C. porosus* specimens do not appear to exceed 7 m (23') in length.

The only crocodile larger than Lolong that has been measured and documented was tantalizingly close to a living specimen. Discovered in Obo village on the Fly River in Papua New Guinea (Montague 1983), the recently-killed crocodile's skin plus decapitated head measured 6.2 m (20.3'), possibly an underestimate considering shrinkage of the skin plus an incomplete tail tip, suggesting a TL closer to 6.3 m. The DCL of this crocodile was 720 mm, which at 6.2 m TL would a DCL:TL ratio of 1:8.6, or 1:8.8 considering the likely 6.3 m TL. While not a complete or living specimen, this is still considered the largest *C. porosus* ever measured and documented.

Larger wild crocodiles are based on unverified reports of crocodiles that were apparently never measured. For example: a 7 m plus (over 23') *C. porosus* sighted within the Bhirtarkanika Wildlife Sanctuary in Orissa, India, in 2006 (Whitaker and Whitaker 2008) was a size estimation taken by observers in a boat; a *C. porosus* shot on the Norman River in 1957 was reportedly over 8 m (approx. 26'); a large *C. niloticus* ("Gustave") from Burundi has reached legendary status despite (or because of) never having been captured or measured. A high degree of skepticism for such reports is understandable when bearing in mind the track record of inaccurate or exaggerated size records (Greer 1974; Whitaker and Whitaker 2008).

The only other living captive crocodile that rivals Lolong for length is "Yai" at Samutprakarn Crocodile Farm, Thailand, who was measured in 2000 at 6 m (19.7') with a mass of 1114 kg (2455 lb). It is unknown how much if at all Yai has grown in the last decade. Yai is also the result of artificial captive hybridisation between *C. porosus* and *C. siamensis* (Siamese Crocodile), his size potentially the result of heterosis (or "hybrid vigour") (Shull 1948).

Why are such exceptionally sized crocodiles so rare? It was suggested in an early analysis that males usually stop growing between 3.9 and 6.0 m (12.8 to 19.7') (Webb *et al.* 1978). This range of maximum sizes is influenced by a number of factors such as access to optimal temperatures, access to shelter and basking areas, food availability and quality (Coulson and Hernandez 1983; Dalyrmple 1996; Lang 1987; Webb 1985). Crocodilians are also highly sensitive to stress through social structure and access to resources, all of which affect growth (eg Choudhury and Bustard 1983; Lance 1994; Smith and Marais 1994). Other factors influencing growth include genetics, the health of the adult female, and the incubation environment (Isberg *et al.* 2004; Allsteadt and Lang 1995).

Clearly to achieve maximum size potential, all factors both known and unknown that influence growth need to be optimal. But at what period of life? We know that the greatest proportion of growth occurs in the first 15-25 years to around three quarters of maximum size, although faster growing individuals appear to sustain rapid growth for longer (Webb *et al*. 1978). Therefore it is the fastest growing juveniles that reach the largest adult sizes and grow for longer. In slow-growing individuals, growth rates fall too low to ever achieve maximum size potential and growth essentially stops in older animals (Webb *et al*. 1978; Woodward *et al*. 1995). It is misleading to assume that extremely large crocodiles become that way due to age. For example, the hybrid Yai reached 6 m (19.8') in less than 30 years, and a pure-bred *C. porosus* ("Jaws") at Madras Crocodile Bank reached 5.13 m (16.8') in 38 years. Most wild *C. porosus* take at least 15 years to reach 3.5 m (Webb and Manolis 1989).

To achievement maximum growth potential in the wild, crocodiles need to maximise their access to resources and optimal environmental conditions, and they need to minimise their exposure to stressful factors. Stress in combination with threatening processes (eg. contaminants) can have serious physiological consequences in wild populations (Guillette *et al*. 2000) and at lower levels it seems feasible that stress is capable of more subtle effects such as inhibiting growth rates. One hypothesis is that exceptional size can only be achieved when growing crocodiles do not encounter sources of stress including encounters with humans on a regular basis. Lolong, for example, is likely to have spent most of his life in and around Agusan Marsh, an area with relatively little human traffic and where overall crocodile densities are low (Pontillas 2000). His lack of scarring is unusual in such a large wild crocodile, and suggests limited competition. Under such favourable conditions for a crocodile, individuals that may also have been genetically predisposed for faster growth would have excellent opportunities to thrive and reach exceptional sizes. It is unclear just how important genetic factors are in influencing maximum size in *C. porosus* but it is possible that selection for exceptionally large crocodiles during the extensive and widespread hunting that took place until the 1970s makes such traits extremely rare today.

Acknowledgements

AB thanks the following for the opportunity to visit Bunawan and measure Lolong: Office of the Mayor of Bunawan (Mayor E. Elorde, R. Nuer), Palawan Wildlife Rescue and Conservation Center (including R. Sumiller), Protected Areas and Wildlife Bureau (including M. Lim, Dr. E. Toledo, J. de Leon), Natural History New Zealand (NHNZ), C. Meade, N. Javellana, K. Siney, R. Taylor, B. Maddul, R. Ordona, and the communities Barangay Nueva Era, Barangay San Marcos and Barangay Consuelo. Funding was provided by National Geographic Channel and NHNZ. RW and NW thank the Trustees and Staff at Madras Crocodile Bank Trust for support and assistance. We also thank Brandon Sideleau for providing the artwork. All capture protocols and measurement procedures were carried out according to Australian Government guidelines (DEWHA 2009), and with the permission of Protected Areas and Wildlife Bureau.

Literature Cited

Allsteadt, J. and Lang, J.W. (1995). Incubation temperature affects body size and energy reserves of hatchling American alligators (*Alligator mississippiensis*). Physiological Zoology 68: 76-97.

Bates, L., Webb, G.J.W., Richardson, K.C., Britton, A.R.C., Bar-Lev, J. and S.C. Manolis, C. (2004). "Pancuronium Bromide" - an immobilising agent for crocodiles. Pp. 447-451 *in* Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Bellairs, A. (1970). The Life of Reptiles. Universe Press: USA.

Choudhury, B.C. and Bustard, H.R. (1983). Stunted growth in captive-reared gharial. J. Bombay Nat. Hist. Soc. 80: 423-425.

Coulson, R.A. and Hernandez, T. (1983). Alligator Metabolism: Studies on Chemical Reactions *In Vivo*. Pergamon Press: USA.

Dalrymple, G.H. (1996). Growth of American alligators in the Shark Valley region of Everglades National Park. Copiea 1996: 212-216.

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2009). Code of Practice on the Humane Treatment of Wild and Farmed Australian Crocodiles. DEWHA: Canberra.

Greer, A.E. (1974). On the maximum total length of the saltwater crocodile *Crocodylus porosus*. J. Herpetol. 8: 378-381.

Guillette, L.J. Jr., Crain, D.A., Gunderson, M.P., Kools, S.A.E., Milnes, M.R., Orlando, E.F., Rooney, A.A. and Woodward, A.R. (2000). Alligators and endocrine disrupting contaminants: a current perspective. Amer. Zool. 40(3): 438-452.

Isberg, S., Thomson, P., Nicholas, F., Barker, S. and Moran, C. (2004). Farmed Saltwater Crocodiles: A Genetic Improvement Program. RIRDC: Canberra.

Lance, V.A. (1994). An overview of stress in farmed crocodilians. Pp. 1 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group, Volume 2. IUCN: Gland, Switzerland.

Lang, J.W. (1987). Crocodilian behaviour: Implications for management. Pp. 273-94 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Montague, J.J. (1983). A new size record for the saltwater crocodile (*C. porosus*). Herpetological Review 14: 36-37.

Pontillas, F. (2000). New breeding sites for the Philippine crocodile. Crocodile Specialist Group Newsletter 19: 7-12.

Shull, G.H. (1948). What is “heterosis”? Genetics 33: 439-446.

Sistante, J.C. (2009). Cops seek help in tracking down croc in Agusan Sur, GMA News. URL:http://www.gmanetwork.com/news/story/153560/news/regions/cops-seek-help-in-tracking-down-croc-in-agusan-sur. Accessed: 2012-02-27. (Archived by WebCite® at http://www.webcitation.org/65mW3w696).

Smith, G.A., and Marais, J. (1994). Stress in crocodilians - the impact of nutrition. Pp. 2-33 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group, Vol. 2. IUCN: Gland, Switzerland.

Webb, G.J.W., and Messel, H. (1978). Morphometric analysis of *Crocodylus porosus* from the north coast of Arnhem Land, northern Australia. Australian Journal of Zoology 26: 1-27.

Webb, G.J.W., Messel, H., Crawford, J. and Yerbury, M.J. (1978). Growth rates of *Crocodylus porosus* (Reptilia: Crocodilia) from Arnhem Land, northern Australia. Australian Wildlife Research 5: 385-399.

Webb, G.J.W. (1985). Survey of a pristine population of freshwater crocodiles in the Liverpool River, Arnhem Land, Australia. National Geographic Society Research Report 1979: 841-852.

Webb, G.J.W. and Manolis, S.C. (1989). Crocodiles of Australia. Reed Books: Australia.

Wermuth, H. (1964). Das Verhaltnis zwischen Kopf-, Rumpf- und Schwanzlange bei den rezenten Krokodilen. Senckenbergiana Biologica 45: 369-385.

Whitaker, R. and Whitaker, N. (2008). Who’s got the biggest? Crocodile Specialist Group Newsletter 27(4): 26-30.

Woodward, A.R., White, J.H. and Linda, S.B. (1995). Maximum size of the alligator (*Alligator mississippiensis*). Journal of Herpetology 29: 507-513.

The Behaviour of *Crocodylus porosus* around an Area of High Human Visitation

Hamish A. Campbell, Ross G. Dwyer and Craig E. Franklin

School of Biological Sciences, The University of Queensland, St. Lucia, QLD 4072, Australia

Abstract

Protection of Estuarine Crocodiles (*Crocodylus porosus*) within Australia has allowed the population to steadily grow over the last 35 years. The on-going population recovery presents a paradox for wildlife managers and policy makers; whilst an iconic animal of Australia, a firm tourist attraction and undoubtedly important to ecosystem integrity and health, *C. porosus* poses a significant risk to the public. Knowing the behaviour of adult estuarine crocodiles around sites of frequent human visitation, and estimating the probability by which each specieswill occupy the same locality, may aid in reducing the probability of attacks upon humans. Here, we present the findings from a one year study which used passive acoustic telemetry to identify the behaviour of adult estuarine crocodiles around a shallow riffle zone on the Wenlock River, Queensland; a popular river crossing point, camping area and swimming hole. By combining adult *C. porosus* population estimates with temporal patterns in their movement we were able to predict periods when crocodile-human interaction would be most probable.

Introduction

The frequency of attacks upon humans by the Estuarine Crocodile (*Crocodylus porosus*) has significantly increased across Northern Australia over the last 30 years (Caldicott *et al*. 2005). This has been attributed to the ongoing recovery of the Australian C. porosus population (Fukuda *et al*. 2007; Read *et al*. 2004; Letnic and Connors 2006), combined with increased human visitation and encroachment upon crocodile habitat (Caldicott *et al*. 2005). Humans regularly use areas inhabited by *C. porosus* for recreational purposes making interaction inevitable, and therefore, a primary method of reducing crocodile attacks would be to minimise the periods when humans and estuarine crocodilians are in close proximity. Here we used underwater acoustic telemetry to identify how adult estuarine crocodiles behaved around a shallow water riffle zone (Stones Crossing) located on the Wenlock River, Queensland, Australia. The area is a popular river crossing, camping, fishing and swimming area, and the study aimed to define the variables which defined crocodile presence within this area, and estimate the probability by which crocodiles would be within the immediate vicinity of the riffle zone at any particular time.

Methods

Trapping was undertaken during the month of August 2009 and 2010, along a 50-km stretch of the Wenlock River, Queensland, Australia. A total of 20 traps were deployed in the same location over 3 consecutive years (Fig. 1). A total of 46 adult estuarine crocodiles (>2.5 m total length) were captured. Once captured, the crocodiles were removed from the trap and manually restrained. Body length measurements were taken and a local anaesthetic injected into the area of soft skin and muscle immediately behind the left forelimb. A ventral to dorsal incision (2 cm) was made by scalpel, and using blunt dissection, a pocket was created between the epidermis and the underlying muscle layer immediately below the incision (see Franklin *et al*. 2009 for details). An acoustic transmitter (VR16 VEMCO, Halifax, Canada) was inserted into the pocket, and positioned laterally. The wound was closed by 4 to 6 interrupted dissolvable sutures (Ethicon catgut, NJ, USA). The implanted acoustic transmitters emitted a sonic pulse every 60 s, which was encoded with an ID code unique to the animal. The transmitter had a projected battery life of approximately 7 years.

To detect the presence of the tagged crocodiles within the river, 28 VR2W (VEMCO) acoustic receivers were placed approximately 1-2 km apart throughout a 50-km stretch of the river (Fig. 1). These continually listed out for the acoustic transmitters implanted within the crocodiles. To specifically detect the presence of the tagged crocodiles around the riffle zone two VR2W underwater receivers (VEMCO) were deployed in deep water pools immediately above and below the shallow water riffle zone (N12.38811, E142.17337). This riffle zone was located approximately in the middle of the river section where the crocodiles had been captured and tagged (Fig. 1). Each receiver was attached to a concrete anchor (20 kg) situated ~2 m from the river bank, and the receiver was positioned ~1 m below the water surface at low water. The detection radii for each receiver was determined by towing an activated tag behind a boat in a predetermined pattern around each receiver, and was between 50 and 150 m depending on river geography and bathymetry. At the riffle zone complete coverage was provided for each of the deep pools immediately upstream and downstream. Acoustic monitoring was undertaken from 1 September 2010 through until 31 August 2011.

The effect of tidal cycle upon water depth at the riffle zone was measured by a submerged time-depth recorder (resolution 0.1 m; TDR, Star-Oddi, Iceland).Water depth was measured and recorded every hour throughout the one year study period.

In order to estimate the number of adult crocodiles within a 30 km downriver and 10 km upriver distance of the riffle zone spotlight surveys were undertaken in August 2010 and 2011. All spotlight methodology and population estimates were made following the methodology of Webb *et al.* (1987).

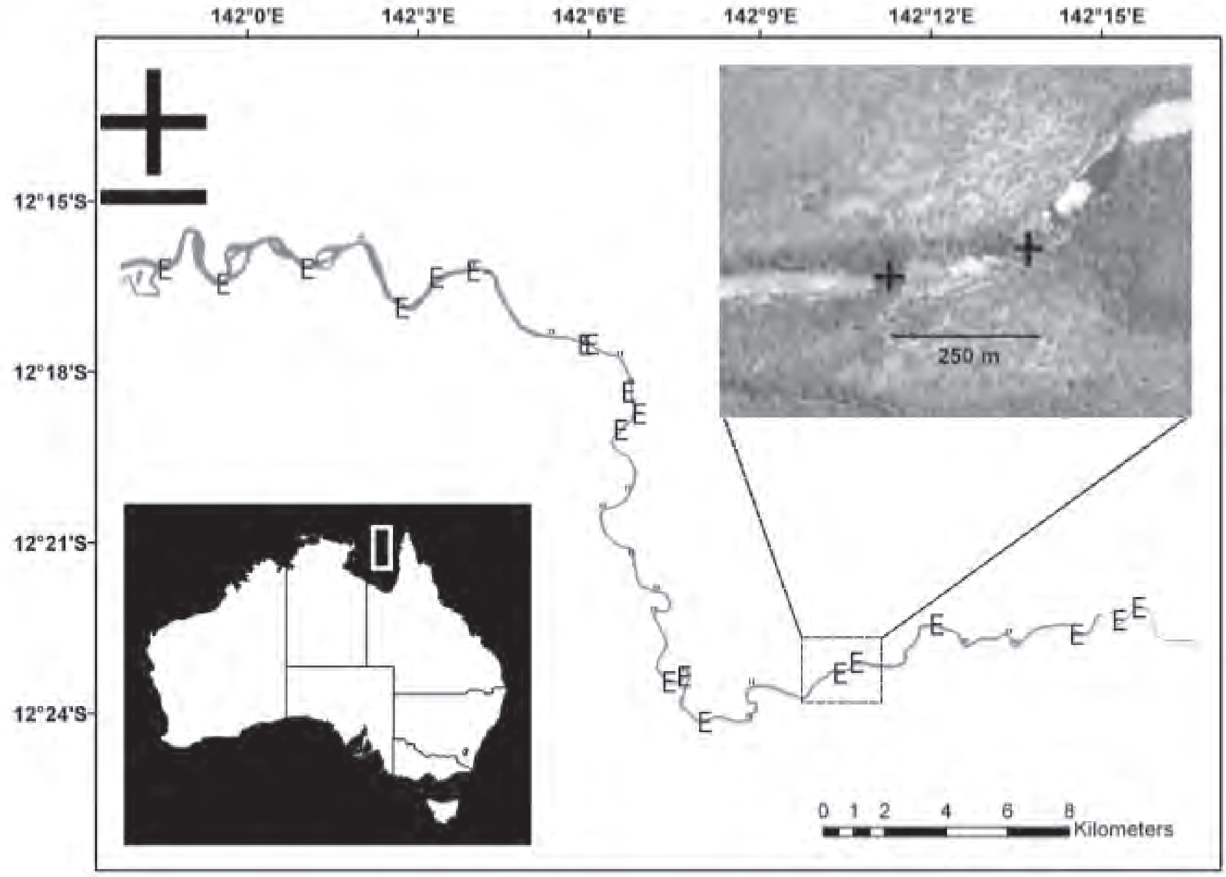


Figure 1. Schematic diagram of the Wenlock River displaying crocodile capture and release locations (black squares) and the location of VR2W underwater listening receivers (black crosses). Inset panels shows study location in Australia (arrow), and overhead image of the shallow water riffle zone (Stones Crossing) with crosses to illustrate the location of each listening station (image supplied by Google Earth©).

Data Analysis

The acoustic transmissions detected upon each of the underwater receivers were used to define periods when the tagged crocodiles arrived and departed the deep pools in the immediate upstream and downstream vicinity of the riffle zone. By comparison of departure and arrival times between the two receivers it was possible to observe the crocodile's movements around and over the riffle zone. All analyses upon the acoustic data were undertaken using the V-track software (written by H.A. Campbell, M.E. Watts and R.G. Dwyer, University of Queensland). These data were then correlated with the tidal, lunar and diel cycles (lunar phase and sunrise and sunset information provided by bureau of meteorology, Australia). The frequency of crocodile movement over the riffle zone was tested for significance against month, hour of the diel cycle, period of the lunar cycle, and hour from the high tide using a one-way ANOVA. P values <0.05 were deemed significant. Probability of crocodile presence within the immediate vicinity of the riffle zone was calculated from the recorded crossing data extrapolated for a projected adult population assessed by spotlight surveys.

Results

Of the 46 adult crocodiles acoustically tagged in the mid to upper section of the Wenlock River in August 2009 and 2010, only 41 were detected to still be within this section of river between September 2010 and August 2011. Out of these 41 adult crocodiles only 12 were recorded in the vicinity of the riffle zone (Table 1). Two of these individuals were captured from the immediate vicinity of the riffle zone, whereas the others were captured and tagged up to 40 km further downstream and 10 km upstream. There was a significant effect of season upon the frequency of crocodile crossings ($F_{1, 10}$ 19.18, $P<0.05$), with a majority of crossings being made between the months of September and December (Fig. 2a). The diel cycle also had a significant effect upon crocodile crossing frequency (F1, 22 32.68, P<0.01), and a majority of the crossings were undertaken during the hours of darkness (Fig. 2b). The phase of the lunar cycle had no significant influence (F1, 2 0.334, P= 0.6) on the frequency by which the tagged crocodiles moved over the riffle (Fig. 2c), but the stage of the tidal cycle did have a significant influence (F1, 4 44.4, P<0.01) upon the frequency of crocodile crossings (Fig. 2d). No crossings were recorded within an hour of the lowest point of the tidal cycle. Upstream movements were focused within 3 hours either side of the high tide, whilst downstream movements were spread more evenly throughout the tidal cycle.

Table 1. Behaviour of acoustically tagged *C. porosus* (mean ± SE) around Stones Crossing between September 2010 and August 2011.

	Upstream	Downstream
Number of crossings	56	60
Number of crocodiles	12	12
Crocodile total length (m)	3.52 ± 0.60	3.52 ± 0.60
Duration of crossing (min)	50.9 ± 1.2	16.9 ± 0.9
Time waiting to cross (h)	9.9 ± 2.5	9.5 ± 5.9

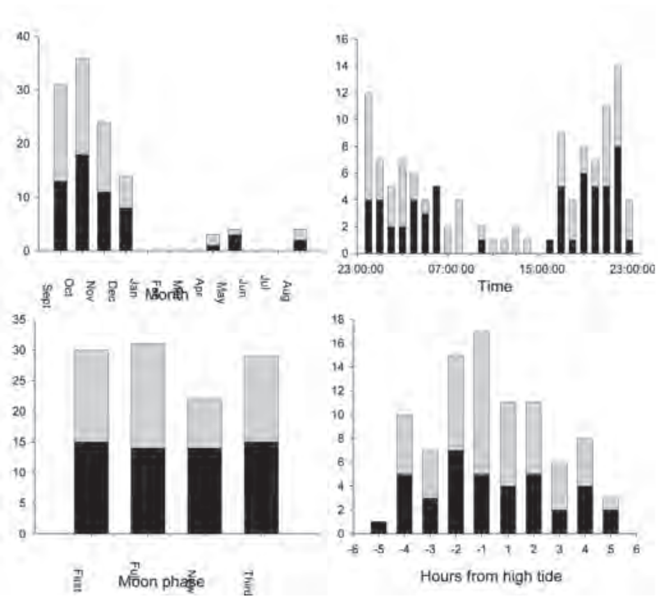


Figure 2. Temporal distribution of riffle zone crossingsundertaken by acoustically tagged *Crocodylus porosus*, separated into downriver (black) and upriver (grey) movements; (a) month of the year, (b) hour of the diel cycle, (c) phase of the lunar cycle, (d) hour pre- and post- high tide.

The acoustic detection data showed that the crocodiles waited for anywhere from 20 min to 36 h in the deep pools in the immediate up and downstream vicinity of the riffle zone prior to crossing (Table 1). The mean length of time that crocodiles would wait in these deep pool areas was similar in duration for upstream or downstream crossings. The time to cross was considerably less than the time the crocodiles spent waiting in the deep pools, and the time to move upstream over the riffle zone took 3-times longer to complete compared to downstream crossings.

The two spotlight surveys undertaken in August 2010 and 2011, counted an adult *C. porosus* population (>2.5 m), within the mid to upper section of the Wenlock River (50 km river length), of 42 and 48 individuals. Combined mark and recapture, helicopter, and boat spotlight surveys have demonstrated that crocodile numbers are underestimated by 35 to 66% from spotlight surveys in mainstream river sections (Bayliss *et al.* 1986). Therefore, we conservatively estimate that the adult crocodile population (>2.5 m) within this section of river to be 100 individuals. Using this population estimate, we calculate that 46% of these individuals were acoustically tagged during the study, with 41% being present between September 2010 and August 2011. Extrapolation of the number of tagged adult crocodiles recorded crossing the riffle zone up to the estimated number of adult crocodiles within the river increased the number of adult crocodiles which crossed over this riffle zone between September 2010 and August 2011 (Table 2). Calculation of the probability of a crocodile being present in the immediate vicinity of this riffle zone, based upon the proposed number of crocodiles crossing over the riffle zone and the average waiting time, showed that there was a higher probability than not of a crocodile (>2.5 m total length) being present (Table 2).

Table 2. Estimates for crocodile presence at Stones Crossing between September 2010 and August 2011. Crossing data were extrapolated up to an adult *C. porosus* population of 100 individuals within the mid to upper section of the Wenlock River.

	Upstream	Downstream
Number of crossings	136	146
Number of crocodiles	29	29
Probability of crocodile presence	0.17	0.21
Probability of crocodile presence between Sep and Dec 2010	0.51	0.65

Discussion

The study findings provide some insight between the behaviour of *C. porosus* around shallow water riffle zones and the incidences of unprovoked attacks upon humans. Firstly, the acoustic tracking data showed that adult Estuarine Crocodiles preferred to cross the shallow riffle area in the dark and on the highest part of the tide, and this resulted in them spending prolonged periods in the immediate vicinity of the riffle zone. These shallow water riffle areas receive a higher proportion of human visitors than other river locations because they form a natural crossing point, are picturesque, good for fishing, and are even considered to be 'safe' swimming locations. The behaviour of humans and estuarine crocodiles around these shallow water riffle areas is conducive with the fact that the majority of crocodile attacks are upon people in the water, wading, or at the water's edge (Caldicott *et al*. 2005). Secondly, the results demonstrated that there was a high probability of a crocodile being in the immediate vicinity of the riffle zone between the months of September to December. These are also the favoured months for camping and fishing within crocodile country, and consequentially, these months have a higher occurrence of human attacks from Estuarine Crocodiles than at other periods of the year (Caldicott *et al*. 2005). Thirdly, 70% of attacks occurred during daylight hours (Caldicott *et al*. 2005). This is most likely a reflection of human activities but may also be a reflection of the crocodile's presence within the close vicinity of riffle zones during daylight hours, as they wait until darkness to cross.

The purpose of the estuarine crocodiles moving across the riffle section is presumably to access habitats along the river. The high frequency of crossings between September and December coincides with the breeding and nesting season (Webb and Manolis 1989), and it is likely that the males increase their range of movement to find mates and the females move to locate nest sites. Previous studies have shown that these months do show the highest annual rate of *C. porosus* spatial movement and trap capture rate (Kay 2004; Walsh and Whitehead 1993). The present study recorded no Estuarine Crocodiles moving over the riffle area between January and March. A possible reason for the absence of *C. porosus* during these months was high flood waters, enabling the crocodiles to travel up and down the river without moving directly over the riffle zone. The very low number of crossings between March and August is perhaps a reflection of the decline in the spatial movement of *C. porosus*.

The tagged estuarine crocodiles in our study showed a preference for crossing the riffle zone during darkness and when the river level was at its highest. These environmental factors would have facilitated a quick crossing with the least amount of exposure for the crocodile. This behaviour suggests wariness by the crocodile, presumably towards humans. Shy behaviour was further demonstrated by the absence of daylight sightings in the vicinity of this riffle zone, even though the acoustic telemetry data confirmed adult estuarine crocodiles were present (H.A. Campbell, pers. obs.). The lack of crocodile attacks at this riffle area, despite the high probability of humans and crocodiles being in the water at reasonably close proximity, supports a theory that Estuarine Crocodiles do not attack humans whenever the opportunity presents itself. Nevertheless, the incidence of human-attacks in Australia by the Estuarine Crocodile demonstrates that this species poses a significant threat to humans. In rivers inhabited by Estuarine Crocodiles we recommend a greater level of awareness around natural weirs and shallow water riffle sections, even if crocodiles have not been recently sighted. Furthermore, we strongly recommend that deeper pools in the vicinity of shallow water riffle zones not be entered and extreme care taken at the water's edge. The shallow waters within the riffle zone may have a low chance of crocodile presence during the hours of daylight, but crocodile presence within these areas will be significantly elevated with the onset of darkness, particularly around the high tide, and between September and December.

Acknowledgements

We thank Barry Lyon and the Mapoon Wild River rangers for collecting the spotlight survey data. The research was funded under the Australian Research Council Linkage Grant scheme. All research was carried out under UQ Australian Animal Committee approval.

Literature Cited

Bayliss, P., Webb, G.J.W., Whitehead, P.J., Dempsey, K. and Smith, A. (1986). Estimating the abundance of saltwater crocodiles, *Crocodylus porosus*, in tidal wetlands of the Northern Territory - a mark-recapture experiment to correct spotlight counts to absolute numbers, and the calibration of helicopter and spotlight counts. Aust. Wild. Res. 13: 309-320.

Caldicott, D.G.E., Croser, D., Manolis, C., Webb, G. and Britton, A. (2005). Crocodile attack in Australia: An analysis of its incidence and review of the pathology and management of crocodilian attacks in general. Wild. Envir. Med. 16: 143-159.

Franklin, C.E., Read, M.A., Kraft, P.G., Liebsch, N., Irwin, S.R. and Campbell, H.A. (2009). Remote monitoring of crocodilians: implantation, attachment and release methods for transmitters and data-loggers. Mar. Fresh. Res. 60(4): 284-292.

Fukuda, Y., Whitehead, P. and Boggs, G. (2007). Broad-scale environmental influences on the abundance of saltwater crocodiles (*Crocodylus porosus*) in Australia. Wild. Res. 34: 167-176.

Kay, W.R. (2004). Movements and home ranges of radio-tracked *Crocodylus porosus* in the Cambridge Gulf Region of Western Australia. Wild. Res. 31: 495-508.

Letnic, M. and Connors, G. (2006). Changes in the distribution and abundance of saltwater crocodiles (*Crocodylus porosus*) in the upstream, freshwater reaches of rivers in the Northern Territory, Australia. Wildl. Res. 33(7): 529-538.

Read, M.A., Miller, J.D., Bell, I.P. and Felton, A. (2004). The distribution and abundance of the estuarine crocodile, *Crocodylus porosus*, in Queensland. Wild. Res. 31: 527-534.

Walsh, B. and Whitehead, P.J. (1993). Problem crocodiles, *Crocodylus porosus*, at Nhulunbuy, Northern Territory - an assessment of relocation as a management strategy. Wildl. Res. 20: 127-135.

Webb, G.J.W. and Manolis, S.C. (1989). Crocodiles of Australia. Reed Books: Frenchs Forest.

Webb, G.J.W., Whitehead, P.J. and Manolis, S.C. (1987) Crocodile management in the Northern Territory of Australia. Pp. 107-124 *in* Wildlife Management: Crocodiles and Alligators, ed. G.J.W. Webb, S.C. Manolis, and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

People's Attitudes towards the Reintroduction of the Philippine Crocodile in Dicatian Lake

Dominic Rodriguez[1], Merlijn van Weerd[1,2], Jan van der Ploeg[1,2], Willem van de Ven[1,2], Samuel Telan[1], Marites Balbas[1] and Jessie Guerrero[1]

[1] Mabuwaya Foundation, Isabela State University, Cabagan, 3328 Isabela, Philippines (Mabuwaya@yahoo.com)
[2] Leiden University, PO Box 9518, 2300 RA Leiden, the Netherlands

Abstract

In July 2009, 50 captive-bred Philippine Crocodiles were reintroduced in Dicatian Lake in the Northern Sierra Madre Natural Park on Luzon. Twenty-two months after this pilot reintroduction we conducted a survey in barangay Dicatian to assess people's perceptions on and attitudes towards the reintroduction of the species. There have been several incidents of crocodiles attacking livestock. However a large majority of the people in the village of 77% still supports the reintroduction of the species in the lake.

Introduction

Reintroducing a species into the wild is one of the most challenging activities for conservationists. The endemic Philippine Crocodile *Crocodylus mindorensis* is categorized as Critically Endangered on the IUCN Red List (IUCN 2012). Hunting, the use of destructive fishing practices and the conversion of freshwater wetlands has led to the disappearance of the species in most parts of the Philippines. The Philippine Crocodile now only survives with certainty in southwestern Mindanao and northern Luzon (van Weerd 2010). The primary objective of the national recovery plan for the Philippine Crocodile is to re-establish Philippine Crocodile populations in the wild (Banks 2005).

The Palawan Wildlife Rescue and Conservation Centre (PWRCC) has successfully bred the species, and now maintains more than 700 individuals in captivity (Ortega 1998). Several areas were identified as potential sites where these animals could be reintroduced into the wild. But antagonistic attitudes of rural communities towards crocodiles have hampered these efforts. People fear that the species will attack children and livestock, and consider restrictions on fishing and farming in areas where crocodiles would be reintroduced illegitimate. For example, local government officials and rural communities opposed the plan to release the species in Manguao Lake on Palawan in 1991 (Ortega 1998). Since then, the idea that rural communities oppose the reintroduction of the Philippine Crocodile has dominated conservation policy in the Philippines (van der Ploeg *et al*. 2011). Recently, the Secretary of the Department of Environment and Natural Resources (DENR), Raul Paje, said that 'there is no mayor anywhere in the Philippines who would allow the release of crocodiles in his municipality.' (AFP 2011).

Since 1999 the Mabuwaya Foundation has worked with local government officials and rural communities to conserve the Philippine Crocodile in the municipality of San Mariano in Isabela Province (van der Ploeg and van Weerd 2006; van der Ploeg *et al*. 2011). These experiences resulted in a project to reintroduce captive-bred Philippine Crocodiles in Dicatian Lake in the Northern Sierra Madre Natural Park. After a series of community consultations, the Dicatian village council and the municipal government declared Dicatian Lake a Philippine Crocodile sanctuary. Fifty captive-bred sub-adult Philippine Crocodiles from PWRCC were reintroduced into Dicatian Lake on 31 July 2009 (van Weerd *et al*. 2010).

The reintroduction took place with the agreement of the community and endorsement of the Local Government Unit of Divilacan and the Protected Area Management Board of the Northern Sierra Madre Natural Park. This paper aims to survey people's attitudes towards the reintroduction of the Philippine Crocodile in Dicatian Lake.

Methods

This study was conducted in barangay Dicatian in May 2011, 22 months after the reintroduction of the 50 captive-bred Philippine Crocodiles. We interviewed 100 respondents from the total population of 328 inhabitants. Using the profile of the barangay, we picked every third person (with a minimum age of 8 years). We interviewed each respondent personally with a structured questionnaire (Appendix 1).

Study Area

Dicatian Lake is located within the Northern Sierra Madre Natural Park (NSMNP), the largest protected area of the Philippines. Barangay Dicatian in the Municipality of Divilacan has a total land area of 3270 hectares. It is bounded in the north by Kabicawan cove, in the south by the Dicatian River, in the East by Divilacan Bay, and in the West by the Sierra

Madre mountain range. The terrain is moderately flat along shorelines and relatively rolling at the southeast portion, and mountainous to very steep sloping towards the west. The flat areas are covered with rice fields and coconut plantations. Most of the land in barangay Dicatian is privately-owned.

A dam in Dicatian Creek was constructed by the Department of Agriculture (DA) and the Local Government Unit (LGU) of Divilacan in 1998 for irrigation purposes. The dam submerged the small creek and part of the forest and created a lake. The surface area of the lake is 14.9 ha and the perimeter is 3601 m. A small Philippine Crocodile population survived in the lake. Accidental killings led to the extinction of the species in the lake in 2005. After a series of community consultations the village council of Dicatian and the municipality of Divilacan declared the lake as a Philippine Crocodile sanctuary on 1 March 2009 followed by the reintroduction of the 50 captive-bred sub-adult Philippine Crocodiles on 31 July 2009.

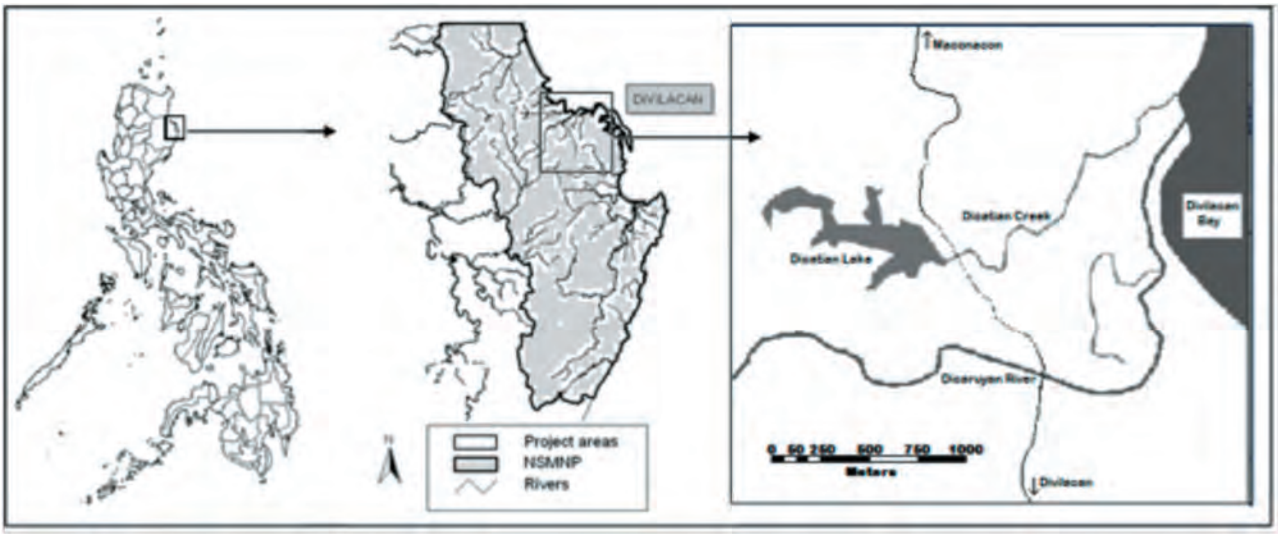


Figure 1. (left) Location of Divilacan within the Philippines and Northern Sierra Madre Natural Park (NSMNP); (right) location of Dicatian Lake and village in Divilacan.

Results

79% of the respondents said that they were informed about the project prior to the reintroduction. Some of the respondents were not around during the community consultations that preceded the reintroduction. 71% agreed with the fact that crocodiles were reintroduced, also 22 months after the reintroduction, but 42% were not aware why the crocodiles were actually reintroduced in the lake.

Forty-eight percent of respondents in barangay Dicatian claim that they have been negatively affected by the reintroduction of the Philippine Crocodile in the lake (Fig. 2). Most of these respondents (30%) refer to crocodile predation on livestock, mainly chicken and ducks. Others claim that the reintroduced animals destroyed their rice fields, or that they are now afraid to go near the lake. 52% of the respondents did not have negative experiences as a result of the crocodile reintroduction.

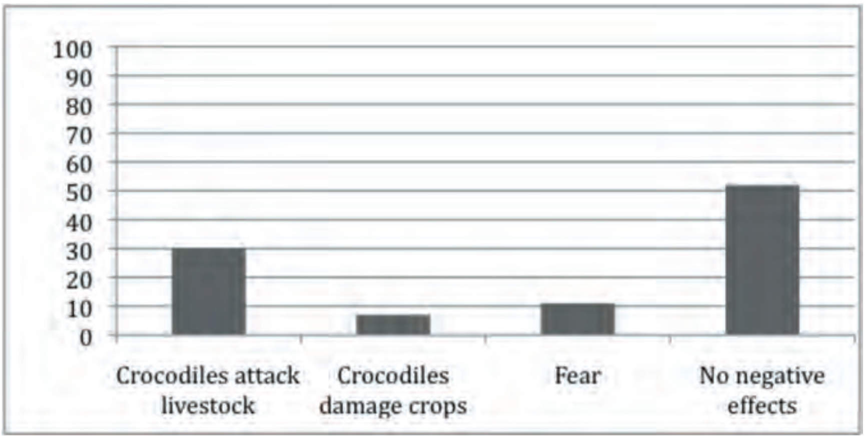


Figure 2. Proportion of respondents affected by the reintroduction of the Philippine Crocodile in Dicatian Lake in terms of livestock predation, damage to crops, fear to go near the lake and no negative effects.

Despite the fact that almost half of the respondents feel they have been impacted negatively, a majority of the respondents (57%) said that they have also benefited from the crocodile reintroduction (Fig. 3). They generally refer to the support by the Mabuwaya Foundation to the community; Mabuwaya assisted the barangay to purchase a generator for general use in the village centre, trained villagers to set up small-scale eco-tourism enterprises and helped individual fishermen with training and gear to shift from fishing in Dicatian lake to fishing at sea or to construct fish ponds. After Super typhoon Megi devastated the coastal area of Isabela Province in October 2010, Mabuwaya started an international aid campaign to help Dicatian and other coastal communities to rebuild infrastructure such as schools and day-care centres.

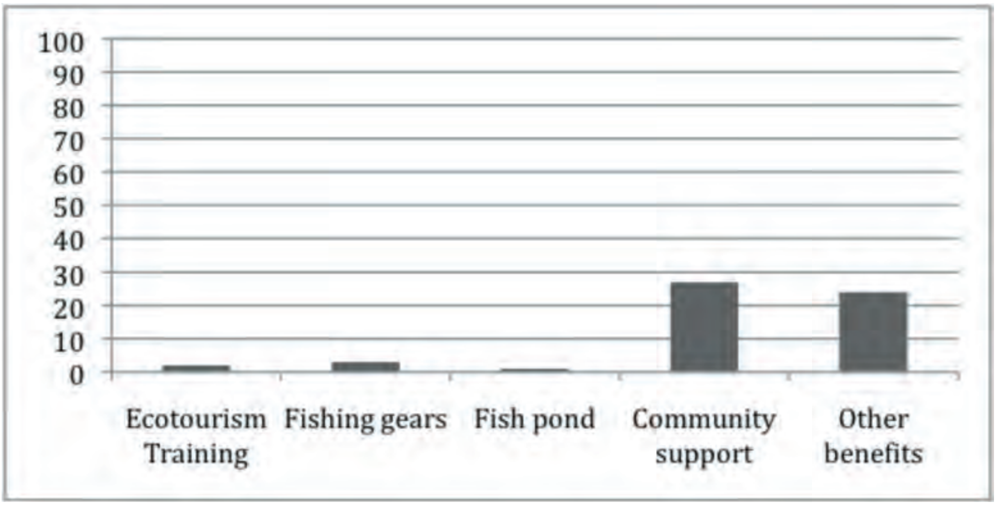


Figure 3. Proportion of respondents that say they benefitted from the reintroduction of the Philippine Crocodile in terms of community and household support.

Crocodile attacks on livestock are widely regarded as the biggest problem by the community (Fig. 4). Other identified problems are the damage crocodiles do to freshly planted ricefields, the fear some people have to approach Dicatian Lake or the fear that their children will be attacked by a crocodile, the damage inflicted to fishnets if crocodiles become entangled in them, crocodiles leaving the lake and the fact that fishing is now prohibited in the Dicatian Lake Philippine Crocodile sanctuary. 37 respondents (37%) do not identify any problem with the crocodiles.

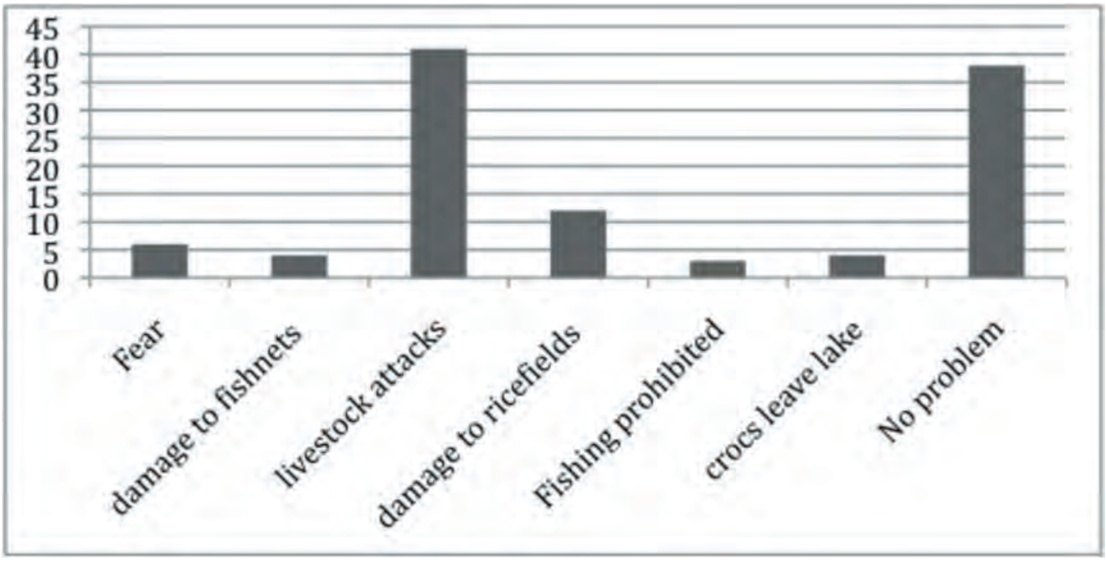


Figure 4. Number of answers to the question: what are the most important problems with the crocodiles in Dicatian? (multiple answers possible).

Many respondents (50) suggest fencing the lake to prevent further attacks on pigs, ducks, chicken and dogs. Other solutions put forward are to remove the crocodiles from the lake (6), provide alternative livelihood assistance to people suffering negative impacts by the crocodiles (6), educate people on the importance of crocodile conservation and on how to avoid problems with crocodiles (5), guard the crocodiles so they will not leave the lake or attack livestock (3) and compensate people for livestock losses (2). 37 respondents do not think the crocodiles form a problem for which solutions are needed (Fig. 5).

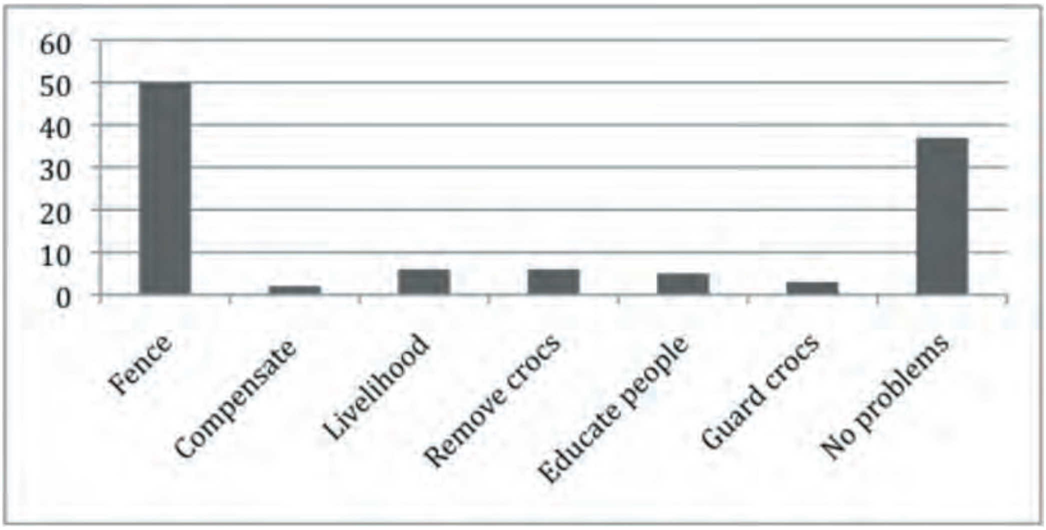


Figure 5. Number of answers to the question: how can we solve the problems with crocodiles in Dicatian Lake?

Discussion

The majority of people in Dicatian (77%) still support the reintroduction of crocodiles in Dicatian Lake but crocodile attacks on livestock do erode local support for the reintroduction. The animals that were released had been in captivity for seven to ten years at PWRCC, where they were fed with chicken and fish. Habituation to people could have caused the crocodiles to come near human settlements and attack livestock. It was observed that most released crocodiles had difficulties in catching their own food, despite the abundance of prey in Dicatian Lake (Mabuwaya Foundation 2009). Farmers and local government officials suggest fencing the lake to minimize crocodile attacks on chicken, ducks and dogs. However, the goal of the reintroduction is to establish a wild Philippine Crocodile population in the Northern Sierra Madre Natural Park, a large protected area (280,000 ha land area) established to conserve free-roaming wildlife. Nevertheless, a partial fence (for example on the dam) could give people a sense of security, and indicate that the concerns of the people are taken seriously. Setting up a compensation scheme or a livestock protection program (for example constructing pig pens and chicken houses so animals are safe at night) are other options to deal with crocodile-livestock conflicts. The finding that many people do not know why crocodiles are released into the wild highlights the need for continuous environmental communication and education.

The findings of this study have important implications for the efforts to re-establish Philippine Crocodile populations in the wild. Antagonistic attitudes towards crocodiles by rural communities and local governments do not form an insurmountable barrier to the reintroduction of the species. With intensive environmental communication and education these negative perceptions and attitudes can be changed into active support for the conservation of the species in the wild. The fact that 50 captive-bred Philippine Crocodiles were reintroduced with full consent of the community and municipal government offers hope that the species can be reintroduced in other areas of its historical range. It remains imperative though to monitor human-crocodile conflicts after reintroduction and to provide solutions to conflicts.

Acknowledgements

We would like to thank all respondents in Dicatian, the community and the Barangay Captain and Council members of Dicatian, Mayor Bulan and the local government unit of Divilacan, Protected Area Superintendant William Savella and Resti Antolin of the Department of Environment and Natural Resources Region II. The Philippine Crocodile reintroduction project in Dicatian and this interview study have been made possible by a Grant provided by the Rufford Foundation.

Literature Cited

Agence France Press (AFP). (2011). Interview with Secretary Paje of the Department of Environment and Natural Resources (DENR). Downloaded from: http://www.google.com/hostednews/afp/article/ALeqM5hpObdw1uHThE2I0KhwXVn48HznkQ?docId=CNG.3f504f40e2fa04f86688eb68b5588ddf.3f1.

Banks, C. (comp.) (2005). National Recovery Plan for the Philippine Crocodile, *Crocodylus mindorensis*. 2nd edition 2005-2008. DENR & RMZG: Quezon City.

Koopmans, F. (2011). Human-Wildlife Conflicts: Implications for the Conservation of the Endangered Philippine Crocodile (*Crocodylus mindorensis*). Unpublished M.Sc. Thesis, Wageningen University, The Netherlands.

Mabuwaya Foundation (2009). One Hundred and One Heartbeats: Towards the Recovery of the Philippine Crocodile in the Wild. Report. Mabuwaya Foundation: Cabagan.

Ortega. V.G. (1998). Philippine crocodile conservation. Comprehensive report. Pp. 101-134 *in* Crocodiles. Proceedings of the 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. UCN: Gland, Switzerland.

van der Ploeg, J., Araño, R.R. and van Weerd, M. (2011). What local people think about crocodiles: challenging environmental policy narratives in the Philippines. Journal of Environment & Development 20(3): 303-328

van Weerd, M. (2010). Philippine Crocodile *Crocodylus mindorensis*. Pp. 71-78 *in* Crocodiles. Status Survey and Conservation Action Plan. Third edition, ed. by S.C. Manolis and C. Stevenson. Crocodile Specialist Group: Darwin.

van Weerd, M., Guerrero, J., Balbas, M., Telan, S., van de Ven, W., Rodriquez, D., Masipiqueña, A., van der Ploeg, J., Antolin, R., Rebong, G. and de Iongh, H. (2010). Reintroduction of captive-bred Philippine crocodiles. Oryx 44(1): 13.

van der Ploeg, J. and van Weerd, M. (2006). A paradigm shift in Philippine crocodile conservation. Pp. 165-186 *in* Crocodiles. Proceedings of the 18th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Appendix 1. Questionnaire on the attitudes of local people after the reintroduction of crocodiles in Dicatian Lake.

1. Name:

2. Sex: Male Female

3. Age:

4. Education:
   - Elementary level / Elementary graduate
   - High school level / High school graduate
   - College level / College graduate

5. Ethnicity: Ilocano Ibanag Agta Kalinga Other ....

6. Livelihood: Farming Fishing Trade Official Other ....

7. Were you informed about the reintroduction of crocodiles in Dicatian Lake? Yes No

8. Did you agree that crocodiles were reintroduced in Dicatian Lake? Yes No

9. Do you know why crocodiles were reintroduced in the lake? Yes No Don't know
   If yes: Why?
   - To protect the species
   - To develop ecotourism
   - Other reason ....

10. Were you negatively affected be the reintroduction of crocodiles? Yes No
   If yes: How?
   - Crocodile attack on livestock
   - Damage to fish net
   - Damage to agriculture
   - Fear
   - Loss of access to the lake (fishing)
   - Other damage ....

11. Have you benefited from the re-introduction of the Philippine crocodile? Yes No
If yes: How? Ecotourism training
Fishing gear
Fish pond
Support to the community
Other ....

12. Who is responsible for the protection of the crocodiles?

DENR	Mabuwaya Foundation	Barangay council
LGU	Bantay Sanktuwaryo	Community
Other	....	

13. What is the most important problem with the reintroduction of crocodiles?

Crocodiles attack people	Crocodiles attack livestock
Crocodiles damage fishnets	Crocodiles damage rice fields
Crocodiles leave the lake	Other ....
People kill crocodiles	

14. How can we solve this problem?

Fence the lake	Remove the crocodiles
Compensate people	Educate people (training)
Provide livelihood support	Disseminate information
Other	

15. What is your overall feeling about the reintroduction of crocodiles in Dicatian Lake?

A Preliminary Analysis of Worldwide Crocodilian Attacks

Brandon Sideleau[1] and Adam Britton[2]

[1] 2900 Bayham Circle, Thousand Oaks, CA 91362, USA (bsideleau@gmail.com)
[2] Big Gecko Crocodilian Research, P.O. Box 1281, Howard Springs, NT 0822, Australia (abritton@crocodilian.com)

Abstract

Attacks on humans by crocodilians have been documented reasonably well in developed countries in the last few decades. Conversely, attacks in developing countries are typically poorly documented despite those countries holding the highest frequencies of crocodilian attacks. Here we present the results of an analysis of over 600 crocodilian attacks worldwide for the period of 2008 through 2011. Attack data were compiled from a number of sources including online media reports, local wildlife officials, crocodilian experts, and relevant recent publications.

Introduction

Human wildlife conflict is a serious and developing issue (Distefano 2008), but understanding and mitigating such conflict requires an understanding of the scale of the problem and the variables involved. This is where databases allowing analysis and interpretation of existing data can have value as a conservation and management tool. For crocodilians this is particularly relevant for developing regions where attacks can be frequent due to water use practices and lack of management (Lamarque *et al*. 2008), and reporting practices from such areas are often incomplete. International media rarely cover attacks in poorer regions, local media may not archive such attacks, government agencies may be wary of reporting and recording data, and misleading impressions about the levels of wildlife conflict can result. Lack of management is often compounded by widespread retaliatory killings of crocodilians (eg Bangka-Belitung Islands in early 2012; Satriawan 2012) that risk local extirpation.

Regions in which crocodilian attacks are common are often those in which crocodilian awareness education is limited and habitat destruction is high, leading to inevitable conflict between humans and crocodilians (eg Sumatra, Borneo). Knowing which regions are experiencing high attack frequencies can guide the implementation of preventative measures such as constructing crocodile-proof barriers along crocodilian-inhabited waterways that are used by humans on a frequent basis, as well as initiating crocodilian education programs and erecting signs warning of crocodilian presence along waterways. An up-to-date attack database can also provide useful information regarding crocodilian presence within areas that have not been surveyed in decades (ie East Nusa Tenggara of Indonesia, Tanintharyi State of Myanmar) and highlight changing attack trends throughout the range of each species over time. Lastly, in addition to procuring useful information regarding human activities associated with attacks, we also gain valuable insights into species-specific differences in attack behaviour on humans, such as those that primarily attack defensively versus those that may regard humans as potential prey.

Materials and Methods

Our database is comprised of four parts: (1) the raw database itself presented within an Excel spreadsheet; (2) a Word document providing detailed descriptions of each attack; (3) an interactive Google Map showing approximate attack locations for every data point; and, 4) a more detailed analysis and comparison of trends within the database. Our aim is to archive this database and provide free access for research, management and educational purposes.

The database of attacks is compiled from a combination of online news reports in different languages, information provided by local wildlife officials/crocodilian experts including existing attack data compilations, and relevant publications. Each attack is reviewed for accuracy, particularly in the case of online news reports where errors and exaggeration may be expected, and entered into the Excel database with as many variables as can be derived from the source. Each attack is also given a broad quality rank depending on its likely veracity, typically depending on the source and whether or not that attack is corroborated by local officials. Each attack is also given a latitude/longtitude coordinate to allow it to be plotted onto a Google Map, the accuracy of which will depend upon the source.

The database is to be presented on a dedicated website which will allow the database to be searched using any of the variables available. The output from each search will be available to view in tabular and text formats, and the relevant data points presented on a Google Map. The ability of the general public to download the raw data is still to be determined but the intention is to prioritize CSG member access to the data.

Results and Discussion

There are some obvious issues with our current database and with obtaining crocodilian attack data in general. First and foremost, there are clear "blind spots" in the data for regions from which attacks are not reported to the media and, in some instances, may go unreported entirely. We also must take into account the veracity of media reports (which constitute the majority of our current database) and the obvious loss of online news records over time, leading to the false impression that attack frequency is increasing at substantial rates. Sensationalism and over-exaggeration within the media are other issues - the circumstances of an attack and the size of the attacking crocodilian are often blown out of proportion.

Despite this, there are clear benefits to the maintenance of such a database. Media will always seek "attack data" for stories on crocodile attack incidents, and controlling the flow of information and directing the way users access it is preferable to a less controlled approach where media may access inaccurate, biased and misleading information and interpretations of such. Loss of attack data are also of concern if any kind of analysis of trends is to be attempted, and such a database can play an important role in archiving these data for future interpretation. There is clearly a need for continual updating of such a database, and the question of what will happen if and when there are no personnel available to continue to update this database are relevant, but by opening the process up to the CSG community it is hoped that contingency measures through multi-user participation will become an option if the database proves to be a valuable asset.

The ability to monitor trends and see unpredictable patterns in attack data provide one of the most important roles for such a database, a role that may not be immediately obvious until the database becomes more complete, but such is the nature of a large amount of data. Our preliminary analysis has been broken down by species and has revealed some interesting information:

Saltwater Crocodile (*Crocodylus porosus*): The analysis suggests that this species is responsible for considerably more attacks on humans than previously believed, likely due to the majority of attacks being reported in different languages or only to local media. The known major conflict regions are Sumatra, East Kalimantan, Timor-Leste (East Timor), Sri Lanka and Bangka-Belitung; a few attacks are also reported annually from East Nusa Tenggara and Sulawesi. The data suggest that in recent years attacks have also been on the rise within the Andaman and Nicobar Islands. Attacks on Little Andaman have been documented (Whitaker 2008), but in recent years attacks within Middle and South Andaman have been on the rise, while attacks within the remote Nicobar Islands may go unreported (Manish Chandi, pers. comm.). It is believed that attacks are also frequent within New Guinea and the Solomon Islands, but reports to the media are infrequent. World Wildlife Fund (WWF) has stated that attacks are also quite common within the Sundarbans of India (The Times of India 2009), yet data regarding these attacks are unavailable. Recent attacks on Lembata Island of East Nusa Tenggara, the Bengkulu Province of Sumatra and West Sulawesi have provided useful information regarding the current distribution of the species, which has been extirpated from much of its former range.

Nile Crocodile (*Crocodylus niloticus*): Data for this species are severely limited by a lack of media reporting from many countries that are known to have high attack frequency (ie Mozambique, Burundi, Malawi, Ethiopia), leading to the false impression that this species is responsible for fewer attacks than *C. porosus*, which we know is not the case. Recent reports from Uganda (Olukya 2012) and Mozambique (Mucari 2012) suggest that only a small fraction of the attacks that occur are reported by the media. In regards to *C. niloticus* attacks we hope that we can work with African crocodile experts to improve the database for the species and increase its utility.

Mugger Crocodile (*Crocodylus palustris*): The database suggests that this species is responsible for the third highest number of reported fatal attacks on humans, behind *C. niloticus* and *C. porosus*. What is interesting is that *C. palustris* attacks rarely involve any consumption of the victim and death is often reported to be a result of drowning after the crocodile drags them under. This is in contrast to both *C. niloticus* and *C. porosus*, which are often reported to consume portions of their victims. This suggests that attacks by *C. palustris* are more likely to be territorial/defensive in nature, rather than predatory. Attacks by *C. palustris* have recently been documented in Maharashtra State (Whitaker 2007) and Gujarat State (Vyas 2010). Gujarat State is the site of the highest number of reported fatalities, but attacks have been documented by the media in most Indian range states in recent years.

American Crocodile (*Crocodylus acutus*): While *C. acutus* is responsible for the highest number of reported attacks within the New World, fatalities are still relatively rare (none reported to the media since October 2010, although 5 fatalities were reported that year). The regions with the highest frequency of *C. acutus* attacks are Mexico, Costa Rica and Panama. Costa Rica holds the highest number of reported fatal attacks, but within the past two years the frequency of attacks has dropped significantly. Attacks have been documented and detailed within both Costa Rica (Bolaños Montero 2011) and Mexico (A.R. Delgado, pers. comm.) in recent years. Information from Panama is limited and attacks may be more frequent there than widely reported (M. Venegas-Anaya, pers. comm.). In addition, no information is available at all from Honduras, which holds a few substantial populations. Like *C. palustris*, attacks by *C. acutus* rarely involve consumption.

Black Caiman (*Melanosuchus niger*): A handful of *M. niger* fatalities have been reported from Brazil within recent years, along with numerous non-fatal attacks. It is known that the species has been responsible for attacks within Guyana (J. Wasilweski, pers. comm.), but we have no data regarding these attacks. The vast majority of attacks by *M. niger* are reported from Amazonas State, Brazil, although fatalities have also been reported from Acre, Rondonia and Amapa. We have no information regarding attacks in Bolivia or French Guiana and only one reported from Peru. Given the remote nature of much of the range of *M. niger* it is likely that many attacks go unreported.

American Alligator (*Alligator mississippiensis*): Attacks by *A. mississippiensis* are recorded by the wildlife departments of each state and are comprehensive. Thus every reported bite is recorded and this has led to high number of minor non-fatal attacks being presented within our database. Many of the reported attacks are provoked and often involve handling; there have been concerns that perhaps such "attacks" should not be logged into the database. Fatal attacks by *A. mississippiensis* are rare (Langley 2005), and at the date of writing there have been no fatal attacks by *A. mississippiensis* recorded since 2007 and only a handful of unprovoked non-fatal attacks are reported every year, mostly within Florida. It would appear that *A. mississippiensis*, while potentially dangerous, does not deserve its occasional reputation of being as dangerous as some of the larger crocodile species or even some of the other New World species (ie *C. acutus* and *M. niger*).

Other Species: Morelet's Crocodile (*C. moreletii*) has been responsible for a surprising number of attacks (and even a couple of fatalities) given its reputation as a relatively non-threatening species. Attacks are most often reported from Tamaulipas State of Mexico, particularly around Tampico and Altamira. This area is heavily populated by humans and appears to hold a reasonably large population of crocodiles. As is the case with most of the other New World species, the fatal attacks rarely involved any consumption, except in the case of small children. The "False Gharial" or Tomistoma (*Tomistoma schlegelii*) was responsible for 3 reported attacks within our study period (all of them fatal.) In all 3 attacks the Tomistoma responsible were very large, and in one case portions of the victim were consumed. Two of these attacks occurred within Central Kalimantan and were well documented in the media, while the third attack took place within the Rokan River of Riau, Sumatra, in 2010. The frequency of attacks on humans by this species is unknown as most attacks by crocodiles within Indonesia are attributed to *C. porosus* unless reason is given to the contrary; they are likely rare. A small number of attacks have also been reported for *Caiman yacare*, *C. crocodilus*, *C. latirostris*, *Crocodylus intermedius*, *C. mindorensis*, *C. siamensis*, and *C. johnstoni*. We have only one fatal attack by a Cuban Crocodile (*C. rhombifer*), occurring within Zapata Swamp in 1995 (T. Ramos, pers. comm.). While considered aggressive, the species is likely too isolated to be responsible for many attacks on humans.

Literature Cited

Bolaños Montero, J.R. (2011). Reflexiones acerca del conflicto entre el hombre (*Homo sapiens*) y el cocodrilo *Crocodylus acutus*. Unpublished manuscript (in Spanish).

Satriawan, I. (2012). Buaya 7 Meter Teror Warga Bangka Kota. Bangka-Tribun News, 26 April 2012 (http://bangka.tribunnews.com/2012/04/26/buaya-7-meter-teror-warga-bangka-kota). Accessed 12 June 2012.

Distefano, E. (2008). Human-Wildlife Conflict Worldwide: Collection of Case Studies, Analysis of Management Strategies and Good Practices. SARD Initiative Report. FAO: Rome.

The Times of India (2009). Frequent tiger, crocodile attacks in Sundarbans villages (27 October 2009).http://articles.timesofindia.indiatimes.com/2009-10-27/flora-fauna/28079828_1_tiger-attacks-royal-bengal-tiger-jamespur. Accessed 12 June 2012.

Lamarque, F., Anderson, J., Chardonnet, P., Fergusson, R., Lagrange, M., Osei-Owusu, Y., Bakker, L., Belemsobgo, U., Beytell, B., Boulet, H., Soto, B. and Tabi Tako-Eta, P. (2008). Human-Wildlife Conflict in Africa: An Overview of Causes, Consequences and Management Strategies. Summary. International Foundation for the Conservation of Wildlife and Food and Agriculture Organization of the United Nations: Rome.

Langley, R.L. (2005). Alligator attacks on humans in the United States. Wilderness and Environmental Medicine 16: 119-124.

Mucari, M. (2012). Mozambique crocodiles kill 47 people. News24, 7 March 2012. (http://www.news24.com/Africa/News/Mozambique-crocodiles-kill-47-people-20120307). Accessed 12 June 2012.

Olukya, G. (2012). Uganda: Crocodile attacks on the rise. The Africa Report, 12 June 2012. (http://www.theafricareport.com/index.php/20120612501813382/east-horn-africa/uganda-crocodile-attacks-on-the-rise-501813382.html).

Vyas, R. (2010). The Muggers (*Crocodylus palustris*) of Vishwamitri River: Past and Present. Herpetology & Environmental Research Project: Vadodara

Whitaker, N. (2007). Survey of Human/Crocodile Conflict in India, Maharashtra State, December 2007. Madras Crocodile Trust: Madras.

Whitaker, N. (2008). Survey of Human/Crocodile Conflict in the Union Territory of the Andaman Islands, Hut Bay, Little Andaman, January 2008. Madras Crocodile Trust: Madras.

Conservation and Management Identifying Individual Gharials to Estimate Population Size, and Determinants of Habitat Use in the Chambal River, India

Tarun Nair[1,2,4], John B. Thorbjarnarson[3†], Patrick Aust[4] and Jagdish Krishnaswamy[1,2,5]

[1]Postgraduate Program in Wildlife Biology and Conservation, Wildlife Conservation Society-India Program, National Centre for Biological Sciences, Bangalore 560065, India (tarunnair1982@gmail.com)
[2]Centre for Wildlife Studies, Bangalore 560070, India
[3]Wildlife Conservation Society, P.O. Box 357520, Gainsville, FL 32635, USA
[4]Gharial Conservation Alliance, Madras Crocodile Bank Trust, P.O. Box 4, Mamallapuram, Tamil Nadu, 603104, India
[5]Centre for Biodiversity and Conservation, Ashoka Trust for Research in Ecology and the Environment, 659, 5th A Main, Hebbal, Bangalore 560024, India
† In Memoriam

Abstract

Gharial (*Gavialis gangeticus*) ecology is poorly understood and reliable population estimates are unavailable. We photographed Gharials to enable individual identification, and recorded ecological and anthropogenic covariates to identify determinants of habitat use. We demonstrate the feasibility of photographic capture-recapture for estimating Gharial abundance in the wild. Our results suggest sandy banks adjacent to deep pools as the most critical factor affecting Gharial habitat-use, and that Gharials have a low threshold of tolerance for anthropogenic disturbance. We suggest identification of Gharial 'hot-spots' and a reassessment of current reintroduction programs based on our results.

Introduction

The Gharial (Gavialis gangeticus Gmelin, 1789), endemic to the Indian sub-continent, was common in the river systems of Pakistan, northern India, Bangladesh, Myanmar, Bhutan and Nepal. However, they are now restricted to only a few, scattered locations in India and Nepal. The Chambal River population is the largest contiguous and most viable population, and has been the focus of conservation and restocking programs. It has however, in recent times, suffered from increasing disturbances from extractive activities and is under severe threat from hydrological modifications. Between 1997 and 2006, the Gharial population reportedly experienced a 58% drop across its range; and its total breeding population was estimated to be less than 200 individuals, resulting in a status change to Critically Endangered (Choudhury *et al*. 2007). In spite of the Gharials' precarious situation, quantitatively robust population estimates have been lacking, and rigorous studies on the Gharial have been limited. The goal of this study was to reliably estimate Gharial populations, and identify factors influencing habitat use by Gharials in the Chambal River.

Methods

Study Area

The study area comprises a 75-km stretch of the Chambal River, within the National Chambal Sanctuary, between 26°32'22"N, 77°45'30"E and 26°48'37"N, 78°10'18"E (Daburpur Ghat and Sukhdyan Pura Ghat, Madhya Pradesh, India), and includes the river mainstream, mid-channel islands, sand-bars, rocky outcrops and adjacent banks. The study area exhibits straight and meandering channels with a sinuosity index (meander ratio) of 1.47; and passes through the flat terrain of the Malwa Plateau with an average gradient of 0.21 m/km (Jain *et al*. 2007). The area lies within the semi-arid zone of northwestern India (Hussain 1999) and the vegetation consists of ravine thorn forest (Champion and Seth 1968). Much of the landscape has been influenced by a long history of human occupation (Kaul 1962). Evergreen riparian vegetation is completely absent, with only sparse groundcover along the severely eroded river banks and adjacent ravine lands (Hussain 1999).

Figure 1. a, b) Location of the study area, in north-central India, along the Rajasthan-Madhya Pradesh border. c) Enlarged map of the study area, showing the 75-km extent of the Chambal River.

In the dry season during the study (February to May 2010), river depth ranged from 0.02 to 18.6 m, while channel width ranged from 44 to 400 m. River discharge levels varied from 75 (February) to 23.9 (May) m^3/s. Sand occupied 29.7% of the shoreline substratum, while gravel, clay-loam and sandstone-rock occupied 16.6%, 20.5% and 33.2% of this stretch respectively. Anthropogenic influences observed during the study period were chiefly in the form of sand-mining, bank-side cultivation, domestic activities like bathing and water collection, gill-net and hook-line fishing, livestock herding, grass-soaking, river crossing and temple fairs.

Field Sampling

The 75-km length of the study area was divided into 30 segments, each measuring 2.5 km, and a rowboat was used to cover this distance in a downstream direction. Four sampling occasions were undertaken between February and May. Each segment was sampled once in February, March, April and May, that is, once in each sampling occasion. Boat survey and stationary bank observations of basking sites were used to collect data. The segments were sampled during periods of maximum basking activity (between 1000 and 1700 h during winter; and between 0630 and 1030 h and 1500 and 1900 h during summer). At each of these basking sites, all basking Gharials were photographed, their location and size-class noted, and basking site characteristics measured. Digiscoping was employed to observe and photograph individual basking Gharials. This was achieved using a 20 - 60x - 80 mm Spotting Scope coupled with a 6 mega pixel digital camera with 3x optical zoom. This was further supported by a 9.1 mega pixel digital camera with 20x optical zoom.

The basic assumptions of closed capture-recapture analysis were met - all individuals had an equal probability of being captured; capture did not affect subsequent recapture; identification marks were not lost; marked and unmarked individuals had the same probability of survival; and geographic and demographic closure.

Habitat variable data like river discharge, water depth, channel width, air and water temperatures, shoreline substratum and presence of basking sites were recorded for each of the 2.5 km segments at a scale of 0.5 km. Anthropogenic activities like sand mining, fishing, bank cultivation, livestock presence, river crossing and miscellaneous activities (bathing, water collection, grass soaking, temple fairs, etc.) were also recorded at the same scale.

Individual Identification and Population Estimation

Individual Gharials were identified by comparing the natural blotches and markings on the lateral scutes of the tail (Singh and Bustard 1976) and also by using additional cues like injuries and scars (Fig. 2; see Nair 2010 for more details). Gharial size-classes were determined by calibrating natural objects or landscape features beforehand, or by setting up measured reference markers at basking sites and then estimating Gharial lengths from photographs using the software 'ImageJ' (Rasband 2007). Individuals <90 cm long were considered to be yearlings, 90-180 cm as juveniles, 180-300 cm as sub-adults, and >300 cm as adults.

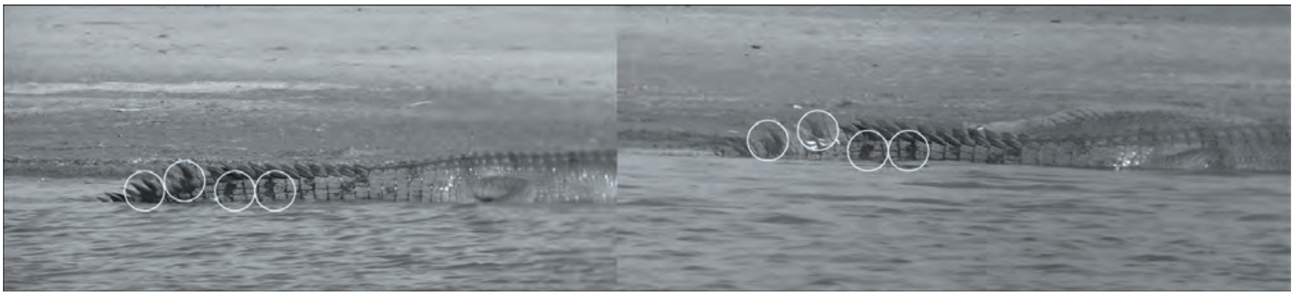


Figure 2. Photo-identification of individual Gharials by comparing the shapes and positions of natural blotches and markings on the lateral scales of the tail.

A standard 'X' matrix (Otis *et al*. 1978) was constructed for identified individuals' inorder to estimate abundance using capture-recapture models. Statistical tests in program CAPTURE (Otis *et al*. 1978; Rexstad and Burnham 1991) supported population closure (z= -1.48, P= 0.069). Closed capture-recapture models were used for abundance estimation in program MARK (White and Burnham 1999). Since individuals may have independent probabilities of being captured on account of their age, size, social status, etc., finite mixture models (Pledger 2000) employing two mixtures of P values, were used to investigate the effects of individual heterogeneity. Here, capture probabilities come from more than one capture probability distribution. There are three parameters with the 2-distribution mixture model - the probability that a given capture probability will come from the first distribution (π), the mean capture probability of the first distribution and the mean capture probability of the second distribution (Pledger 2000).

There was a marked decrease in the intensity of basking, with the progress of the dry-season during the study (Nair 2010). Hence, time was considered an important parameter. Since Gharials are 'thermoconformors', and avoid extreme temperatures (Lang 1987a,b), the number of captures of basking animals are expected to vary from winter to summer. Individual heterogeneity was also considered important since there are differences in accessibility to basking sites, due to social hierarchies; differences in individual responses to disturbances and individual thermal behaviour is known to vary, influenced by a range of internal (age, nutritional status, etc.) and external (social mileau, climate, etc.) factors. (Lang 1987a).

The Akaike Information Criterion (AIC) index of model fit was used for model selection. The model with the lowest AICc score was considered the most parsimonious (Burnham and Anderson 1998). Models with ΔAICc <2 were considered good models (see Table 2), since these models are best supported by the data, while models with ΔAICc between 3 and 7 have moderate support and those greater than 7-10 are relatively poor (Anderson and Burnham 1999; Burnham and Anderson 2002). Estimates of the derived parameters (Burnham and Anderson 2004), from models with good and moderate support (ΔAICc <7), were model averaged in program MARK, to produce an estimate which is conditional on the results from the above selected models.

Effects of habitat and anthropogenic variables

Changes in river discharge and in air and water temperatures during the study were plotted using box-and-whiskers plots. Water depth and channel width were recorded at 0.5-km intervals along the length of the river. In addition, depth measurements were taken at 10-m intervals along the width of the river. Kriging was employed in a Geographical Information System to interpolate these depth measurements. We used scatter plots to ascertain the correlation between various human activities and Gharial encounter rates.

To identify factors affecting the encounter rates of Gharials in each of the segments, we used Classification and Regression Trees (CART) (Breiman 1984). Models with the lowest Residual Mean Deviance and number of terminal nodes (tree complexity) were used, as measures of model selection. Encounter rates were modelled as a function of all habitat and anthropogenic variables. From these, only extent of shoreline substratum, channel width, mean channel depth and the extent of sandstone-rock shoreline substrate were used in the actual tree construction. Numbers at terminal nodes indicate mean Gharial encounter rates influenced by that particular parameter.

Over 80% of our data set consisted of zero-values, that is, a large number of zero Gharial encounters (Fig. 3). These are referred to as 'zero-inflated' data. The zeros of the dataset are treated as Bernoulli outcomes with a probability p0 for the proportion of zeroes in the data, while the non-zeros are treated as having a Poisson distribution.

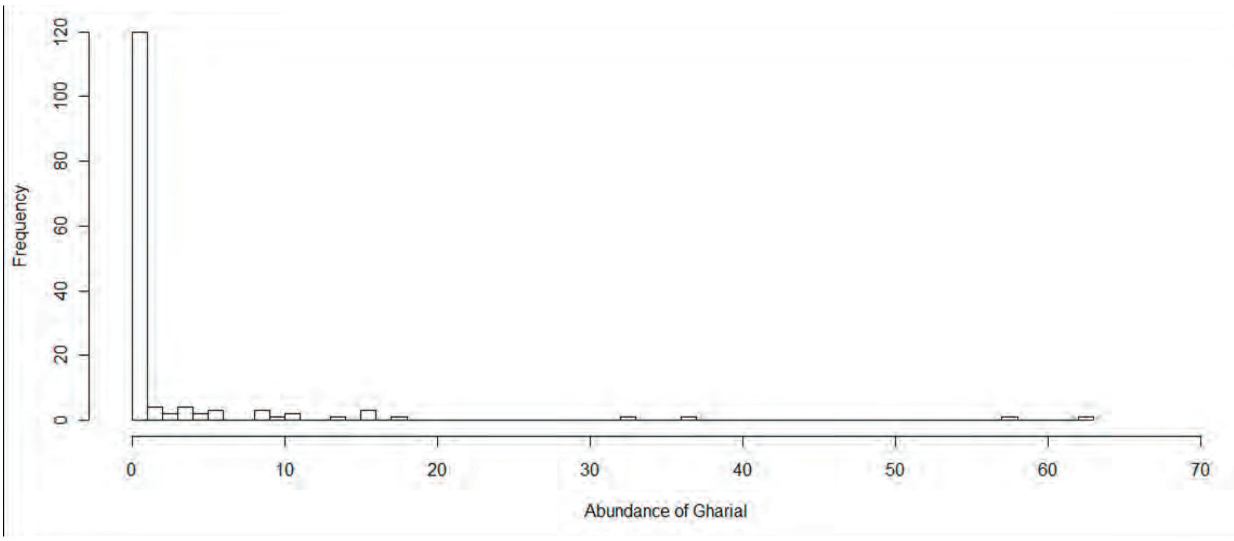


Figure 3. Zero-inflated nature of Gharial encounter rates (abundance).

We used Bayesian spatial count regression models for analyzing the effects of ecological covariates and spatial adjacency on encounter-rates.

For site (i),
Gharial count [i] ~ Intercept + slope * basking site [i] + spatial effect term[i], OR
Gharial count [i] ~ Intercept + slope * depth [i] + spatial effect term[i]

We compared Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) models, and to these we assumed a Conditional Auto-Regressive (CAR) normal distribution as an uninformative prior distribution for spatial random effects. Deviance was compared for model selection. All statistical analyses were conducted using the software R 2.11.1 (R Development Core Team 2010) and WinBUGS (Spiegelhalter *et al*. 2007). For Bayesian analyses, 10,0000 Markov chain Monte Carlo simulations were carried out and a burn-in period of 10,000 iterations was discarded for each model.

Results

Abundance Estimate

Four hundred captures (332 unique photographs; 159 only left sides, 134 only right sides and 39 both sides) were obtained from the total sampling effort. Capture histories were constructed separately for either side since most captures were obtained of only one side and the side with most captures (left) was used in the analysis (Table 1). Individuals photographed from both sides were also used.

Table 1. Summary statistics for photographic capture-recapture data (left-side only + both sides) of 198 Gharials (114 adults, 37 sub-adults and 47 juveniles) sampled in National Chambal Sanctuary during February-May 2010.

Sampling Occasion	1	2	3	4
Animals caught at occasion	52	69	61	66
Newly caught at occasion	52	61	46	39
Re-caught at occasion	0	8	15	27
Total caught at end of occasion	52	113	159	198

Closed population models and three groups (adults, sub-adults and juveniles), were employed in Program MARK for abundance estimation. Finite mixture models employing two mixtures of P values were used to investigate the effects of individual heterogeneity. Models were selected using the Akaike Information Criterion (AIC) index of model fit (Table 2). Capture probability (p) and recapture probability (c) were modelled as p= c, since the study design did not modify Gharial behaviour across the four occasions, ie, no behavioural effects. Capture probability (p) and recapture probability (c) were modelled either as varying over time (t), constant over time (.), varying across mixtures (g), or varying across both mixtures and time (g+t). The heterogeneity parameter, ie, probability of mixture (pi) and population size (N) were modelled across mixtures (g), to compute independent estimates for adults, sub-adults and juveniles.

Table 2. Model selection by program MARK for Gharial capture-recapture data from the National Chambal Sanctuary during February-May 2010, using AICc, Δ AICc, AICc Weight, Model Likelihood and Number of parameters (k). Heterogeneity parameter, ie, probability of mixture (pi); varying across mixtures (g); varying over time (t); constant over time (.)

Model	AICc	Δ AICc	AICc Weight	Model Likelihood	k
{pi(g), p(g+t)=c(g+t), N(g)}	-482.8165	0.0000	0.38051	1.0000	15
{pi(g), pa(t)= ca(t), pb(t)=cb(t), N(g)}	-482.6898	0.1267	0.35715	0.9386	14
{pi(g), p(.)= c(.), N(g)}	-481.3976	1.4189	0.18718	0.4919	4
{pi(g), p(t)= c(t), N(g)}	-478.5194	4.2971	0.04439	0.1166	7
{pi(g), p(g)= c(g), N(g)}	-477.5535	5.2630	0.02739	0.0720	6
{pi(g), p(g+t), c(g+t), N(g)}	-473.1566	9.6599	0.00304	0.0080	39
{pi(g), pa(g+t)=ca(g+t),pb(g+t)=cb(g+t), N(g)}	-468.8527	13.9638	0.00035	0.0010	30

Models with good and moderate support (ΔAICc <7), were model averaged, to produce an estimate which is conditional on the results of the selected models. Abundance estimates from the most parsimonious models (low ΔAICc) exert most influence to the final estimate. The standard error (SE) of the model averaged estimate is a function of the SE from each model and the extent of compatibility between model-specific estimates (Conn *et al*. 2006). The 'top' model estimated 231±32 adult, 83±23 sub-adult and 89±19 juvenile Gharials respectively, while the weighted average estimated 220±28 adult, 76±16 sub-adult and 93±16 juvenile Gharials respectively.

Determinants of habitat use

Gharial encounter rates and site occupancy are expected to be influenced by seasonality of river discharge and temperature, both of which showed marked changes across the duration of the study. Ambient air and water temperature increased from February to May, and river flow and discharge showed a decrease from 75 m^3/sec to 23.9 m^3/sec during this period.

Scatter plots were used to ascertain the correlation between various human activities and Gharial encounter rates. In the following example (Fig. 4), I have used data from a single occasion for representation. On the X-axis is the proportion of a segment used by various human activities, and on the Y-axis is the Gharial encounter rate within those segments. We see that all these recorded human activities negatively influence Gharial encounter rates, which were always clumped at zero or near-zero values of disturbance.

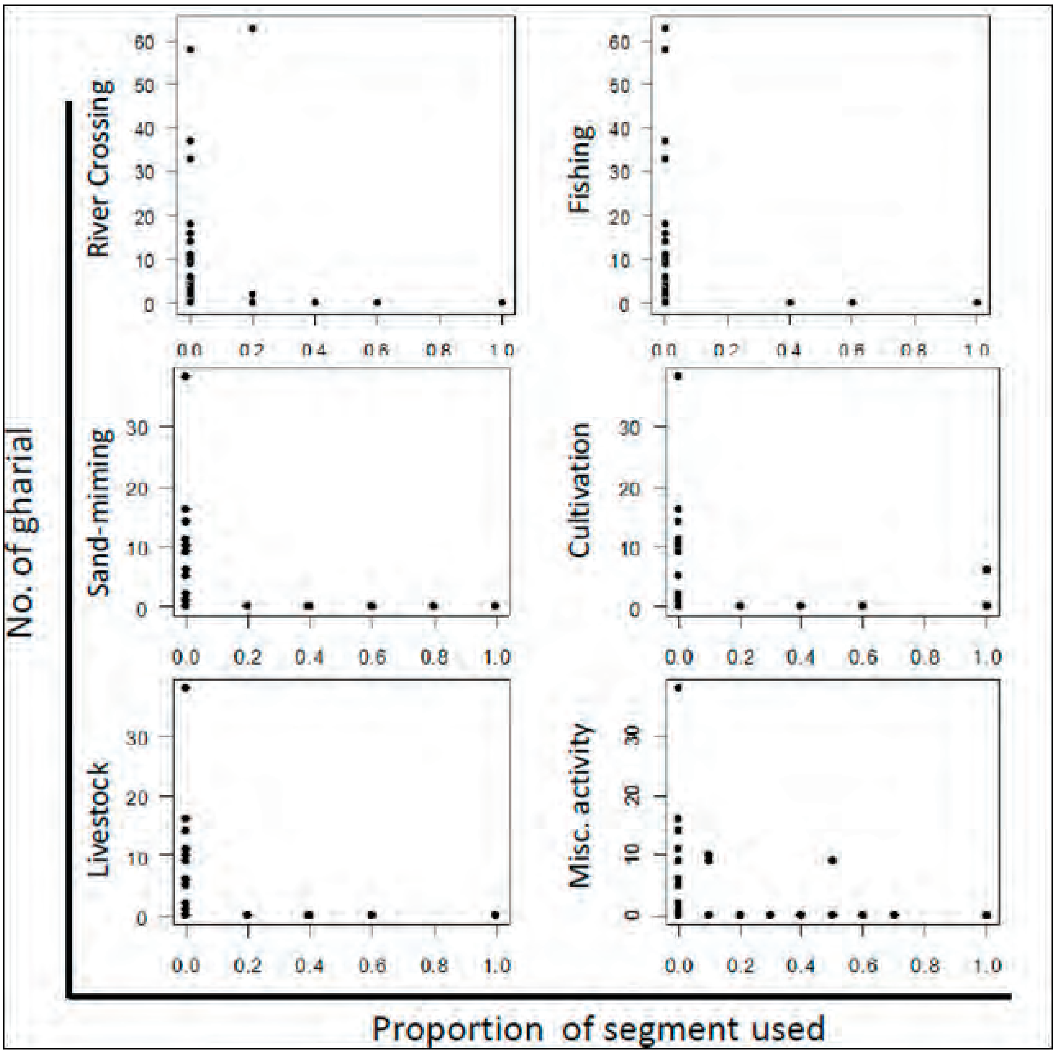


Figure 4. Scatterplots illustrating the correlation between various human activities and Gharial encounter rates.

Classification and Regression Trees were used to identify factors affecting Gharial encounter rates in each of the segments. The following regression tree (Fig. 5) describes the variation in Gharial encounter rates for one occasion. This was the best tree model based on lowest residual mean deviance and number of terminal nodes. Here, heterogeneity within data is hierarchically partitioned such that variation within data is reduced to the extent possible at each split. The influence of a particular parameter on mean Gharial encounter rates is indicated by the numbers (in boxes) at the terminal nodes. In this regression tree the first split at the 'basking sites' demonstrates that the availability of suitable basking sites (sand banks) was the most important parameter. Further, subject to the availability of suitable basking sites, and that it covered more than 50% of that particular segment, 'mean channel depth' greater than 1.45 m emerged as the next most important parameter influencing Gharial encounter rates. The next most influential parameter is complimentary to the availability of suitable basking sites, ie, rock-sandstone bank (unfavourable basking site) covers less than 5% of that particular segment.

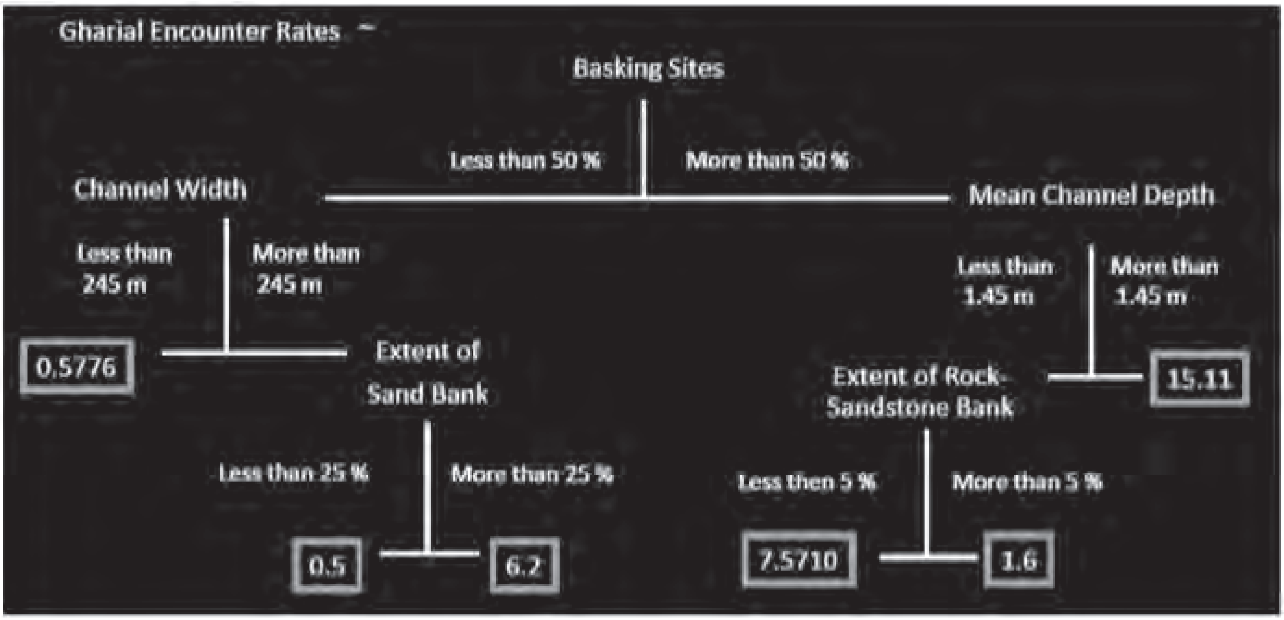


Figure 5. Classification and Regression Tree illustrating the influence of various parameters on Gharial encounter rates in one sampling occasion.

Gharial habitat use positively influenced by presence of basking sites and river depth. Spatial random effect parameter value was low. Zero-inflated Poisson Models were selected over Zero-inflated Negative Binomial Models based on Deviance Information Criteria (Table 3).

Table 3. Parameter estimates for the Zero-Inflated Poisson (ZIP) and Zero-Inflated Negative Binomial (ZINB) models for Gharial encounter rates and habitat usage influenced by basking site and channel depth.

Model	Intercept (beta1)	Slope (beta2)	Spatial Variance (1/tau)	Deviance
~ basking site + spatial effect	Mean (SD) and credible interval	Mean (SD) and credible interval	Mean (SD)	Mean (SD)
ZIP	0.25 (0.47)	1.75 (0.47)	2.1 (0.80)	250 (10.07)
ZINB	0.29 (0.48)	1.73 (0.48)	2.385 (0.95)	250.9 (10.22)
~ channel depth + spatial effect	Mean (SD) ande credible interval	Mean (SD) and credible interval	Mean (SD)	Mean (SD)
ZIP	0.31 (0.60)	0.92 (0.88)	0.85 (0.40)	304.2 (14.82)
ZINB	0.55 (0.54)	0.90 (0.70)	1.09 (0.47)	312.1 (12.61)

Discussion

Population estimation

Our study demonstrates the feasibility of individual identification combined with capture-recapture models to estimate population sizes. Our results also suggest sandy banks adjacent to deep pools as the most critical factor affecting Gharial habitat use, and that Gharials have a low threshold of tolerance for human disturbance.

Our top model estimated 231±32 adult, 83±23 sub-adult and 89±19 juvenile Gharials, while the weighted average estimated 220±28 adults, 76±16 sub-adults and 93±16 juveniles, for our 75-km study area. In comparison, a 2009 survey based on total counts (Bhadoria, Luikham and Sharma, unpubl. data), reported 102 adults, 49 sub-adults and 33 juveniles for a 109-km stretch of the NCS, within which our 75-km study area falls. Based on these values, we estimate absolute densities of adult, sub-adult and juvenile Gharials at 3.08±0.43, 1.11±0.3 and 1.19±0.25 per km. respectively (top model), and 2.93±0.37, 1.01±0.21 and 1.24±0.21 per km. respectively (weighted average). On the other hand, Bhadoria, Luikham & Sharma (unpubl.) estimate densities at 0.94, 0.45 and 0.30 adult, sub-adult and juvenile Gharials per km respectively. Although not accurate or precise, we suggest, on the basis of our 'top' model, a detection probability based correction factor of 3.27, 2.47 and 3.97, to relative abundance estimates of adult, sub-adult and juvenile Gharials, respectively, obtained from boat-based daytime surveys, until such time that better correction factors can be derived.

Conventional crocodilian boat surveys, that rely on total or eyeshine counts, have been shown to underestimate population sizes because of size-related wariness, submergence and concealment bias (Bayliss *et al*. 1986; Hutton and Woolhouse 1989). This, together with the fact that captive-reared Gharial have been released on an ongoing basis in many Indian rivers, has made it difficult to assess the true status of Gharial based on existing population counts (Choudhury *et al*. 2007). Photographic identification of individual Gharial offers several advantages employed within the sampling framework of capture-recapture for estimating detection probabilities and population size. It will also enable regular monitoring of their critically endangered populations. Photo-identification has the advantages of being a non-invasive technique, with fewer economic and logistic constraints of capture, handling, capture and post-capture stress, tracking, altered behaviour and the demand for large sample sizes.

We are also of the opinion that without determining the current status of Gharials, highly intensive strategies like egg-collection and rear-and-release programs, on the basis of underestimates of population sizes are unwarranted and divert valuable conservation resources away from field-based protection measures, which are essential in the face of threats like sand-mining, fishing and bank-side cultivation. Moreover, Gharial reintroductions are poorly monitored, have low success rates (Ballouard *et al*. 2010) and have never re-established viable breeding populations in areas where they were locally extirpated, for all the currently recognised breeding sites had surviving populations when the restocking programmes were initiated (Choudhury *et al*. 2007). Future conservation and management efforts should be based on periodic and rigorous monitoring of demographic and reproductive parameters of Gharial populations and we suggest a reassessment of all reintroduction and restocking programs.

Habitat use

Reduced discharge and water level can mean a reduction in the extent of available habitat, in terms of preferred water depth. Decreasing water levels, through the dry season, was expected to cause increased clustering of individuals, within the deeper sections of the river. However, this did not manifest during the course of this study, probably because the dry season - reduced flow pattern had already set in at the start of the study and the clustering of Gharials observed on all four occasions was an artefact of Gharial response to reduced flow regimes.

The human influences recorded in this study - sand-mining, livestock herding/grazing, bankside cultivation, fishing, river-crossing, and miscellaneous activities, all had a negative impact on habitat use by Gharials. It is possible that mere human presence rather than a particular activity at the land-water interface is the source of disturbance. Gharials displayed a low threshold of tolerance for disturbance and will avoid them. This strengthens the case for having inviolate areas and also for strengthening protection regimes.

Gharial encounter rates and habitat usage were higher in areas where large, undisturbed, sandy banks were adjacent to deep pool sections. While the preference to sandy banks has been attributed to the ease of movement and better basking conditions, deep pools offer suitable refuges from threats (Hussain 2009) and are also known to offer more stable temperature regimes.

The ability to identify, quantify and map the limiting factors for a species will enable the prediction of long-term changes in the behavioural responses and population dynamics of the species, and will also allow the prioritization of conservation areas. For effective conservation and management of Gharials within their natural habitats, it is important to be able to assess species distribution and abundance, and the influence of habitat attributes and human disturbances on them. This is vital to make management recommendations, assess the success and validity of conservation measures, and design future conservation strategies for this critically endangered and charismatic crocodilian.

Acknowledgements

This study was funded by the Department of Science and Technology, Government of India. We thank our respective affiliate organisations for academic and logistic support. We thank the Rajasthan, Madhya Pradesh and Uttar Pradesh Forest Departments for research permissions. Krishnapriya Tamma, Rajeev Tomar, Rakesh Vyas, Rakesh Singh, Ram Awatar, Kaptan Singh, Jagdish, Rajveer and Shyam Singh for field and logistical support; Romulus Whitaker, Jeffrey Lang, Ajith Kumar, Srinivas Vaidyanathan, Nachiket Kelkar, Varun Goswami, Umesh Srinivasan, Nishant M.S.,Devcharan Jathanna and Barry Noon for all the discussions and critical inputs at different stages of the study.

Literature Cited

Anderson, D. and Burnham, K. (1999). General strategies for the analysis of ringing data. BirdStudy 46: S1, S261-S270.

Ballouard, J.M., Priol, P., Oison, J., Ciliberti, A. and Cadi, A. (2010). Does reintroduction stabilize the population of the critically endangered gharial (*Gavialis gangeticus*, Gavialidae) in Chitwan National Park, Nepal? Aquatic Conservation: Marine and Freshwater Ecosystems 20: 756-761.

Bayliss, P., Webb, G.J., Whitehead, P.J., Dempsey, K. and Smith, A. (1986). Estimating the abundance of saltwater crocodiles, *Crocodylus porosus* Schneider, in tidal wetlands of the northern territory - a mark-recapture experiment to correct spotlight counts to absolute numbers, and the calibration of helicopter and spotlight counts. Australian Wildlife Research 13: 309-320.

Breiman, L., Friedman, J.H., Olshen, R.A. and Stone, C.J. (1984). Classification and Regression Trees. Wadsworth: Belmont.

Burnham, K.P. and Anderson, D.R. (1998). Model Selection and Inference: A Practical Information Theoretic Approach. Springer: New York.

Burnham, K.P. and Anderson, D.R. (2002). Model Selection and MultimodelInference: a Practical Information-Theoretic Approach. 2nd Edition. Springer: New York.

Burnham, K.P. and Anderson, D.R. (2004). Model selection: understanding AIC and multimodel inference, with contrasts to BIC. Sociological Methods and Research 33: 261-304.

Champion, H.G. and Seth, S.K. (1968). A Revised Survey of the Forest Types of India. Manager of Publication: Delhi.

Choudhury, B.C., Singh, L.A.K., Rao, R.J., Basu, D., Sharma, R.K., Hussain, S.A., Andrews,H.V., Whitaker, N., Whitaker, R., Lenin, J., Maskey,T., Cadi, A., Rashid, S.M.A., Choudhury, A.A., Dahal, B., Ko, U.W.K., Thorbjarnarson, J. and Ross, J.P. (2007). *Gavialis gangeticus*. In IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 22 November 2009.

Conn, P.B., Arthur, A.D., Bailey, L.L. and Singleton G.R. (2006). Estimating the abundance of mouse populations of known size: promises and pitfalls of new methods. Ecological Applications 16(2): 829-837.

Hussain, S.A. (1999). Reproductive success, hatchling survival and rate of increase of gharial *Gavialis gangeticus* in National Chambal Sanctuary, India. Biological Conservation 87: 261-268.

Hussain, S.A. (2009). Basking site and water depth selection by gharial *Gavialis gangeticus* Gmelin 1789 (Crocodylia, Reptilia) in National Chambal Sanctuary, India and its implication for river conservation. Aquatic Conservation-Marine and Freshwater Ecosystems 19: 127-133.

Hutton, J.M. and Woolhouse, M.E.J. (1989). Mark-recapture to assess factors affecting the proportion of a Nile crocodile population seen during spotlight counts at Ngezi, Zimbabwe, and the use of spotlight counts to monitor crocodile abundance. Journal of Applied Ecology 26: 381-395.

Jain, S.K., Agarwal, P.K. and Singh, V.P. (2007). Hydrology and Water Resources of India - Volume 57 of Water Science and Technology Library - Tributaries of Yamuna River. Springer.

Kaul, O.N. (1962). Management of Chambal ravines in Rajasthan. Indian Forester 88: 725-730.

Lang, J.W. (1987a). Crocodilian behaviour: implications for management. Pp. 273-294 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Lang J.W. (1987b). Crocodile thermal selection. Pp. 301-317 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Nair, T (2010). Ecological and Anthropogenic Covariates Influencing Gharial *Gavialis gangeticus* distribution and habitat use in Chambal River, India. M.Sc. thesis, National Centre for Biological Sciences, Tata Institute of Fundamental Research, India.

Otis, D.L., Burnham, K.P., White, G.C. and Anderson, D.R. (1978). Statistical-inference from capture data on closed animal populations. Wildlife Monographs 62: 7-135.

Pledger, S. (2000). Unified maximum likelihood estimates for closed models using mixtures. Biometrics 56: 434-442.

R Development Core Team (2010). R: A language and environment for statistical computing. R Foundation for Statistical Computing: Vienna, Austria.

Rasband, W.S. (2007). ImageJ, National Institutes of Health, Bethesda, MD (available at http://rsb.info.nih.gov/ij/).

Rexstad, E.A. and Burnham, K.P. (1991). Users Guide for Interactive Program CAPTURE. Colorado Cooperative Wildlife Research Unit, Colorado State University: Colorado, USA.

Singh, L.A.K. and Bustard, H.R. (1976). A method to identify individual young Gharial (*Gavialis gangeticus*). British Journal of Herpetology 5: 669-671.

Spiegelhalter, D.J., Thomas, A., Best, N. and Lunn, D. (2007). Win-BUGS. Version 1.4.3 User Manual. MRC Biostatistics Unit: Cambridge, UK.

White, G.C. and Burnham, K.P. (1999). Program MARK: survival estimation from populations of marked animals. Bird Study 46: 120-138.

Gharial Conservation Initiatives in Nepal

Sabita Malla[1], Narendra Man Babu Pradhan[2], Ghana Shyam Gurung[2] and Bed Bahadur Khadka[2]

[1] WWF Nepal, Baluwatar, Kathmandu, Nepal
[2] Chitwan National Park, Chitwan, Nepal

Abstract

Gharial Conservation Initiatives in Nepal is a joint undertaking of WWF Nepal and Department of National Park and Wildlife Conservation, Nepal, funded by "Lacoste". This project has played an instrumental role in bringing about positive impact in Gharial conservation and management in Nepal. Aspects related to long-term gharial conservation has been discussed in this paper. The capacity of 20 wildlife technicians and park staff has been enhanced in scientific monitoring and captive management of Gharials. *Ex-situ* facilities have been improved in Kasara Gharial Breeding Centre at Chitwan National Park. A fish farm has been constructed to supply live fish to Gharials in captivity. Systematic studies have been carried out to establish baseline data with respect to population in wild; quantification of habitat occupancy and threat co-variates. Massive conservation education and outreach program conducted in 27 different locations of Chitwan was influential in changing local people's attitude towards Gharial conservation. Support for 10 fish farms and skilled development training provided to 100 fish-dependent communities as alternative livelihood options in buffer zone areas has helped reducing pressure in Gharial habitats. The population in wild has received pro-active protection with the implementation of smart river rangers' concept in both the Rapti and Narayani Rivers.

Introduction

The Gharial (*Gavialis gangeticus*), belonging to the family Gavialidae, is one of the most threatened of all crocodilian species (GCA 2008). It once thrived in all the major river systems of the Indian sub-continent, spanning from Indus in Pakistan across the Gangetic floodplain to Irrawaddy in Myanmar. Now, it is presumed to be extinct from Bangladesh, Bhutan, Myanmar and Pakistan (Behura and Singh 1978; Maskey 1989). Its distribution is limited only to 2% of its historical range with as few as 200 breeding adults remaining in the wild (Whitaker *et al*. 1974). This represent a 96% decline in the population of this species since 1940s (GSRP 2011). Realizing its grim situation, the Gharial was upgraded from endangered to critically endangered in IUCN's Red Data List in 2007, and is listed in Appendix I of CITES.

In Nepal, the species almost reached the extinction stage during the 1970s. It was revived through captive rearing and restocking program with the establishment of Gharial Conservation Breeding Centre (GCBC) at Kasara, Chitwan National Park in 1978. Since 1992, 861 Gharials have been released in different river systems of Nepal but the wild population hasn't stabilized. Though captive rearing program has been successful; restocking program is very much questionable (WWF 2011) and has only contributed to stop complete extinction in the wild. Presently, the only existing populations are sparsely distributed in the Narayani, Rapti, Babai and Karnali Rivers. In all these river systems, the Gharial faces a grim situation primarily due to tremendous pressure on its food and habitat. Activities like overfishing, use of gill nets, river poisoning, sand mining, and dam construction have together contributed to its periled situation (Maskey 1989; Ballouard and Cadi 2005; Thapalia *et al*. 2009).

Against this backdrop, WWF Nepal in collaboration with Department of National Park and Wildlife Conservation envisioned a project with the long-term goal of "Conserving wild and released gharial population and their habitats by addressing existing threats both through *ex-situ* and *in-situ* approaches". This project has been possible through the generous support of "Lacoste" through Fonds De Dotation Pour La Biodiversite (FDB)'s Save Your Logo Progam (SYL). This project is a 3-year project and receives total funding of 75,000 Euros per annum. It was launched on 7 April 2010 and will continue until 2013. The project so far has been able to accomplish the following objectives.

Objectives

- To establish baseline data on status (population size, density, size classification, adult sex-ratio)and distribution of the species
- To assess the factors governing Gharial presence and quantify threat covariates
- To upgrade the *ex-situ* facilities of the Gharial Conservation Breeding Centre, Kasara
- To build the capacity of the park rangers and wildlife technicians in captive management and scientific monitoring of Gharials.
- To make local communities and the public aware of the plight of Gharials through conservation education and outreach programs
- To integrate favourable measures for Gharial conservation in the management of protected areas
- To collaborate with GCA and reinforce Gharial conservation in Nepal

Study Area

Chitwan National Park: Rapti and Narayani River

The Rapti River forms the northern boundary of Chitwan National Park (CNP). It originates in Mahabharat range and flows for about 120 km before reaching the Narayani River (Smythies 1941; Shankar 1984). It is fed by ground water and springs and hence it does not dry even during the low flow period.

The Narayani River forms the northwestern boundary of CNP. It originates in the Himalayas and is formed by the confluence of the Kaligandaki and Trishuli Rivers. It flows southwest for 30 km from a gorge in Mahabharat range to the confluence with the Rapti River. It then flows for about 25 km while reaching Tribeni and in due course joins the Ganges River in Hajipur, India.

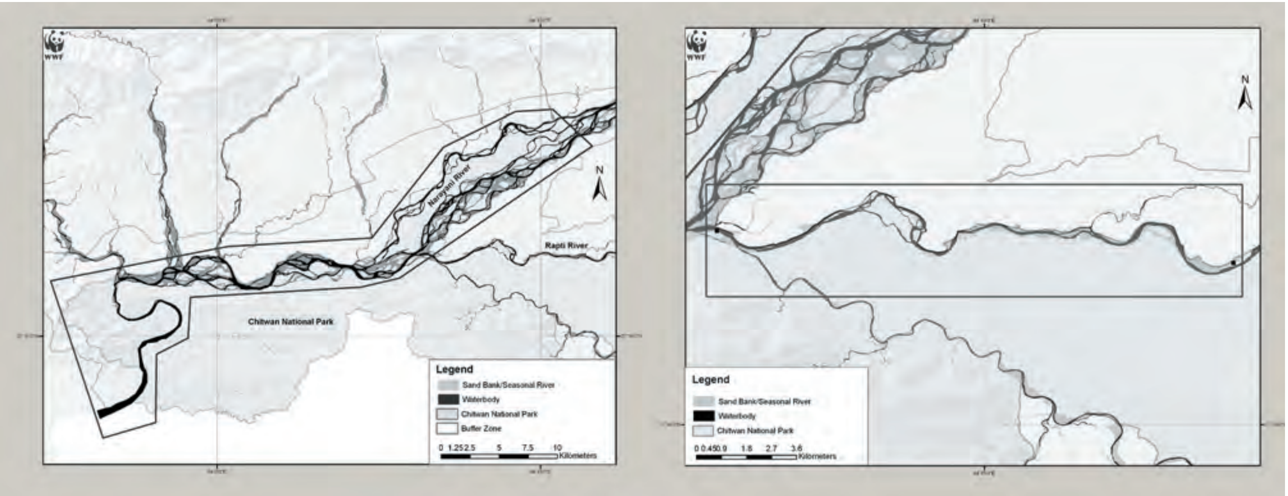


Figure 1. Rapti River (left) and Naryani River (right).

Bardia National Park: Karnali and Babai Rivers

The Karnali River is one of the longest rivers (507 km) in Nepal. It has its origin in the perpetually snow-covered Himalayan mountains [Mansarovar and Rakchas (Demon) Lake]. It receives much snow-fed rivers such as Mugu Karnali and Humla Karnali at the Himalayan belt. On reaching Chisapani the river makes spectacular gorge and diverges into two channels, Karnali in the west and Geruwa in the east. The Geruwa River forms the western boundary of Bardia National Park and flows approximately for 37 km between Chisapani and Kothiaghat.

The Babai River is a tributary of the Karnali River and joins it about 50 km downstream from the Nepal-India border. It originates from a low mountain in Churias at Dang district and flows northwest parallel to the Bheri River. After entering Chepang it remains untouched and locked in from either side of the rivers by mountain ridges. It flows for about 40 km from Chepang to Parewaodar giving a complete scenic beauty to the Babai valley named after the river.

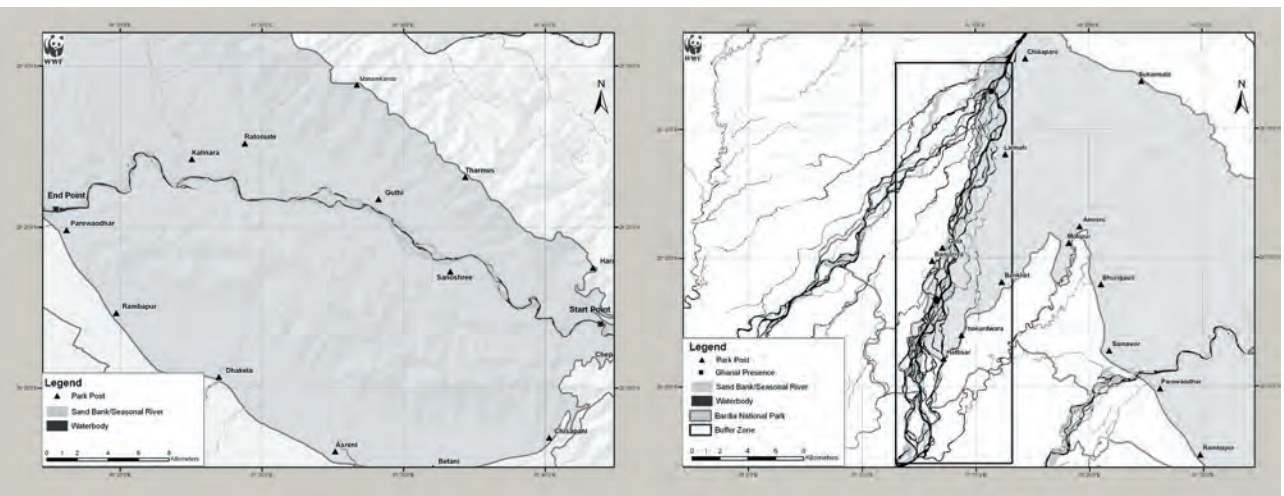


Figure 2: Karnali River (left) and Babai River (right).

Objective 1: To establish baseline data on status (population size, density, size classification, adult sex-ratio) and spatial distribution of the species.

Methods: Basking sites in Nepalese river systems are devoid of vegetation which could have otherwise hindered sighting of Gharial. Thus, with visibility bias being almost negligible, total counts of basking Gharial was adopted for estimating population size, with an assumption that all Gharial would come out to bask during the survey season (winter months, late February to early March). The major drawback of this method is that it does not take into account detection probabilities. However, to check the variation in the count and to ensure greater detectibility, sampling effort was increased to three times for each of the river segments surveyed. The river segments were identified on the basis of past studies (Khadka *et al*. 2008) and divided into segments based on the approximate distribution of river length and ease of field logistics.

Table 1. Survey data for 19 February 2011 (Day 1), 20 February 2011 (Day 2) and 21 February (Day 3) in CNP. Numbers in brackets indicate relative densities (ind./km) of the maximum sightings.

River	Segment	km	Day 1	Day 2	Day 3
Rapti	Itcharni-Kasara (1)	25.04	16	18	20
	Kasara-Rapti Narayani confluence (2)	20.27	10	12	9
	Reu River		0	3	0
	Buddhirapti (7)	7.38			
	Total	78.07	26	33 (0.42)	29
Narayani	Sikrauli-Amaltari- East (3)	25.38	16	23	19
	Sikrauli-Amaltari-West (4)	26.78	3	9	10
	Amaltari-Bagwan (5)	20.47	2	2	4
	Bagwan-Triveni (6)	22.04	11	14	8
	Total	94.67	32	48 (0.51)	41
Karnali	Chispani-Kothiaghat (1)	37.00	1	1	4 (0.11)
Babai	Chepang-Guthi (1)	21.5			
	Guthi-Parewaodar (2)	18.5			
	Total	40.0	14	17 (0.43)	9
Koshi	Chatara-Koshi Barrage (1)	39.00	0	0	0

Field personnel were divided into groups of 4 people (2 trained observers and two boatmen). Each team reached the starting point of each segments and started the survey around 15-30 minutes after sunrise (correlating with the time of maximum basking activity) and continued till the segment ended. Each segment was completed in approximately 2-3 hours. Therefore, each team started and completed in almost the same time period of the day. Observers were equipped with Nikor binoculars (10 x 50), Garmin GPS and standard data sheets. Two observers with binoculars scanned either side of the river banks looking for Gharials and recording data on every direct sightings while the two other people paddled the boat. Size-classes were determined by calibrating natural objects/features and by setting up measured reference markers (placing a 3 m stick) at basking sites. Total Gharial body length was measured from head to tip of the tail (Bustard and Singh 1977). Individuals <90 cm long were considered to be yearlings, 90-180 cm as juveniles, 181-300 cm as sub-adults, and >300 cm as adults (Nair 2010). Similarly, only adult animals were "sexed", with males being distinguished from females by the presence of a ghara.

Results: Population Estimate: Of the three consecutive surveys, the highest count was recorded on Day 2 in the Rapti, Narayani and Babai Rivers, while in Karnali it was Day 3 that was the highest; these maximum counts were considered for population estimation. Based upon the results of three different replicates, population size was estimated as 102 ± 6 (Koshi 0; Karnali 4; Babai 17; Narayani 48; Rapti 33; Table 1). No Gharial were recorded in the Koshi River, despite the release of 10 Gharials in 2010.

Density: The Gharial population density in all of the surveyed river systems of Nepal was low as compared to Chambal River (Table 1).

Size Distribution: Most (36%) animals sighted were in the sub-adult category, with adults and juveniles comprising similar proportions (29%) each. Surprisingly there were 5 yearlings (5%) also recorded (Table 2).

Table 2. Size distribution of Gharial sighted in Nepalese river systems.

River	>300 cm	181-300 cm	90-180 cm	<90 cm
Rapti	6	10	17	0
Narayani	16	17	10	5
Babai	7	8	2	0
Karnali	1	2	1	0
Nepal	30	37	30	5

Sex Ratio: Based on Gharial considered to be adults, the sex ratio was biased towards females in all rivers surveyed [Rapti 1.0 (N= 6), Narayani 0.88 (N= 16), Babai 0.71 (N= 7), Karnali 1.0 (N= 1), all 0.87 (N= 30); expressed as proportion of females].

Spatial Distribution: Gharial distribution was mapped using Arc GIS 9.3.Gharials were not uniformly distributed across the segments and also within the segments species showed concentration at few selected locations.

In the Narayani River, Segment 3 (Sikrauli to Amaltari East) had the highest concentration (23 animals), followed by Segment 6 (Bagwan to Tribeni) with 14 individuals. In both of these segments 2 Gharial hotspots were confirmed; Khoriyamuhan, where as many as 20 individuals were seen, and Velauji area at which11 individuals were recorded.

In the Rapti River, Gharials were more uniformly distributed compared to other river segments. Segment 1 (Itcharni-Kasara) had the highest number of gharials (20), and Dudhaura Charhara was identified as a Gharial hotspot with 12 individuals.

Similarly, in the Babai River Gharials were mostly localized in three locations - Chepang, Guthi, Kalinara and Parewaodar. Very few sightings of Gharial in the Karnali River were recorded from Helipad and Lalmati area.

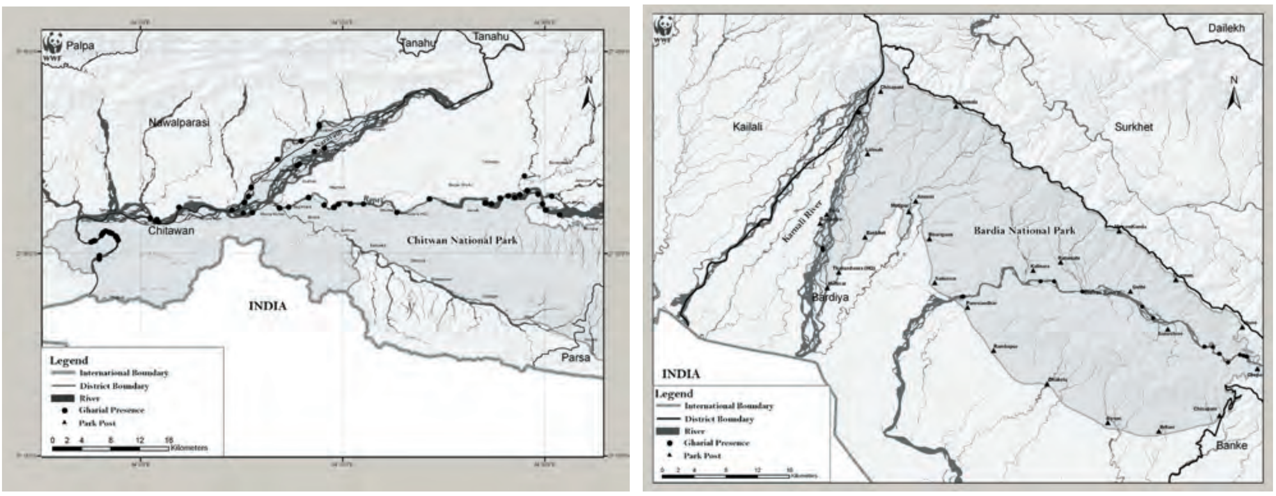


Figure 3. Spatial distribution of Gharial in Chitwan (left) and Bardia (right) National Parks.

Discussion: We found significant difference in Gharial sightings in the rivers across three replicates (ANOVA, F= 2.634, p<0.05) therefore indicating a single survey is not sufficient to provide reliable information on population status. During a countrywide survey of Gharial in 2008 the estimated population was 81 individuals (DNPWC 2008). Going back to the release data since the last count of 2008, DNPWC re-introduced 70 more Gharial in the Rapti, Koshi, Karnali and Babai Rivers but the population increase is only 21%. In the best case scenarios if all the released Gharial had survived since 2008 the population would have increased by 86%. Similarly, since 1991-2011, DNPWC released 761 Gharials in different river systems of Nepal. However, the surviving population is only 13.4% of the total released population. This clearly indicates that the re-stocking program in Nepal is not meeting the long-term species conservation goal in the wild and therefore warrants efforts to understand the problem in the wild and address them accordingly. Size-class distribution of Gharial in the wild in Nepal is the product of Gharial surviving from different released years. Adult males and females surviving in the Rapti, Narayani and Babai Rivers are the ones released prior to 1997. The presence of few yearlings also suggests that a nest or two might have gone undetected during collection, and producing hatchlings in the wild.

Objective 2: To assess the factors governing gharial presence and quantify threat covariates

Methods: To assess the factors governing Gharial presence, habitat variables (water flow, river stage, river width, presence/absence of sand bank and river confluence) was recorded every 500 m in the Rapti and Narayani Rivers. Similarly, food availability (prey weight) was quantified every 5 km by throwing hand-net 3 times in the river. Water samples were collected every 5 km along the entire Rapti and Narayani Rivers, and were tested for parameters viz: pH, EC, turbidity, TDS, BOD, COD, DO, nitrogen and phosphorous content. Water samples were tested at ENPHO (Environment and Public Health Organization) and WETC (Water Engineering Training Centre) laboratory.

Disturbance (fishing, sand mining, stone quarrying, human intensity, boat intensity, washing, bathing and cattle grazing) was recorded every 500 m. Similarly, Gharial presence-absence data was collected at every 500 m.

Table 3. Variables quantified for assessing habitat quality requirements.

	Variables	Measured	Equipment	Covariates
1	Stage height-river level (m)	every 500 m	Staff gauge	Change in river level
2	Channel width (m)	every 500 m	Range finder	Mean channel width
3	Presence of sand bank (+/-)	every 500 m	Soil texture tests	clay, loam, sand, gravel, rock
4	Height of sand bank (m)	every 500 m	Ocular estimation	
5	Water flow (m/s)	every 5 km	Floating method	
7	Fish (prey) weight (g)	every 5 km	Hand net, balance	
8	Presence of river confluence (+/-)	every 500 m	-	
9	Temperature	every 5 km	Thermometer	
10	pH	every 5 km	pH meter	
11	Turbidity (NTU)	every 5 km	Turbidity meter	
12	TDS	every 5 km	TDS meter	
13	Electrical conductivity (EC us/cm)	every 5 km	Conductivity meter	
14	Nitrate (mg/L)	every 5 km	UV-VIS Spectrophotometer	
15	Total Phosphorous (mg/L)	every 5 km	UV-VIS Spectrophotometer	
16	Dissolved oxygen (DO mg/L)	every 5 km	Iodometric Titration	
17	Biochemical oxygen demand (BOD)	every 5 km	5 days incubation	
18	Chemical oxygen demand (COD)	every 5 km	Open Reflux Method	

Factors governing Gharial presence: Stepwise regression analysis was carried out to compare the factors governing gharial presence. Of the different parameters entered (Sand bank, Sand bank height, River width, River level, Water flow, River confluence, Cumulative Disturbance Index and Prey weight) three factors that positively influenced the distribution are sand bank ($t= 3.7$, $p<0.01$) prey weight($t= 3.1$, $p<0.05$) and river confluence ($t= 3.1$, $p<0.05$).

Habitat occupancy: Program Presence version 2 (Hines 2006) was used to model the habitat occupancy of Gharials by fitting the detection/non-detection data (MacKenzie 2005) with the above mentioned parameters as covariates. The model with the lowest AIC was selected over the other models that explained the most variability. The model that incorporated sand bank, river confluence and cumulative disturbance was the best performing model to describe habitat occupancy by Gharials in Rapti and Narayani Rivers. Using the top model with lowest ΔAIC=419, and AIC weight (w) of 1, the Gharial habitat occupancy pattern in the Rapti and Narayani Rivers ranged from 0.052 (SE= 0.028) to 0.81 (SE= 0.035).

Table 4. Probability of occupancy (PSI) estimates generated with covariates with sand bank, river confluence and cumulative disturbance (each of the 40 segments was 5 km).

Segment	PSI	SE	95% Conf. Interval	Segment	PSI	SE	95% Conf. Interval
1	0.0956	0.028	0.052 - 0.166	19	0.2779	0.049	0.192 - 0.383
2	0.1008	0.026	0.059 - 0.165	20	0.4656	0.077	0.321 - 0.615
3	0.1062	0.028	0.061 - 0.176	21	0.4996	0.027	0.446 - 0.552
4	0.1752	0.034	0.117 - 0.252	22	0.2274	0.042	0.154 - 0.321
5	0.2998	0.029	0.245 - 0.360	23	0.2783	0.038	0.208 - 0.360
6	0.6097	0.027	0.555 - 0.661	24	0.5112	0.057	0.399 - 0.621
7	0.153	0.038	0.091 - 0.244	25	0.1567	0.029	0.106 - 0.223
8	0.7558	0.035	0.679 - 0.818	26	0.3122	0.026	0.262 - 0.366
9	0.3969	0.036	0.327 - 0.471	27	0.7244	0.032	0.657 - 0.782
10	0.5214	0.068	0.388 - 0.651	28	0.5697	0.037	0.495 - 0.640
11	0.4664	0.034	0.403 - 0.530	29	0.2225	0.035	0.160 - 0.300
12	0.47	0.031	0.403 - 0.537	30	0.5919	0.058	0.474 - 0.699
13	0.4261	0.035	0.366 - 0.488	31	0.5991	0.042	0.513 - 0.678
14	0.6339	0.039	0.561 - 0.701	32	0.5071	0.022	0.462 - 0.551
15	0.4011	0.039	0.327 - 0.479	33	0.7693	0.046	0.665 - 0.848
16	0.6872	0.039	0.604 - 0.759	34	0.8949	0.029	0.820 - 0.940
17	0.7531	0.031	0.686 - 0.809	35	0.6713	0.023	0.624 - 0.715
18	0.6131	0.03	0.552 - 0.670	36	0.4187	0.018	0.382 - 0.455

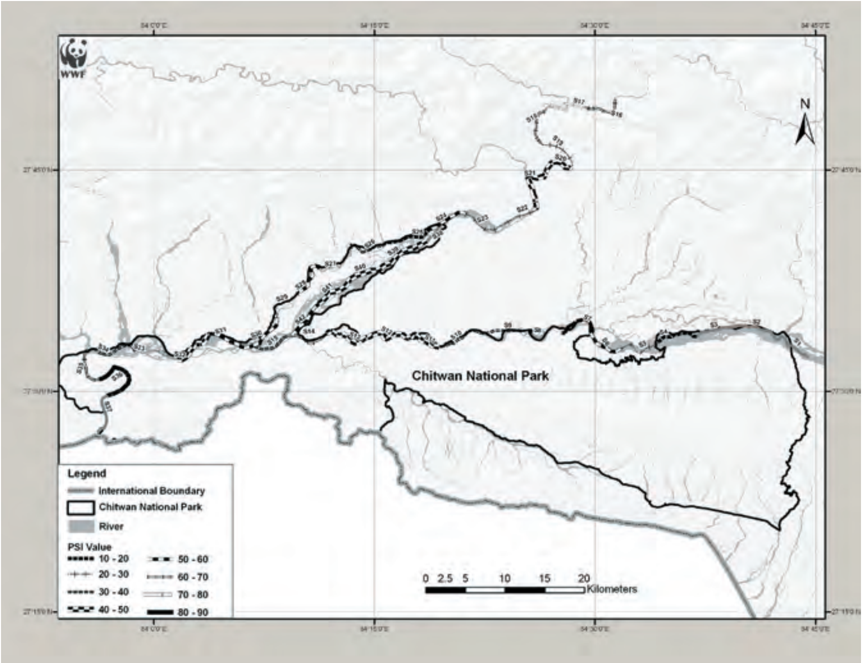


Figure 4. Gharial habitat occupancy in Chitwan NP based on PSI values generated through occupancy modeling.

Water Quality Test: Of the 40 water samples from 40 different stations in the Rapti and Narayani Rivers, only samples from 2 stations (nearby Brikuti Paper Mill area and Tuborg Beer Factory) were below the minimum standard prescribed for aquatic fauna. Although Bhrikuti Paper Mill and Tuborg Beer Factory claim to have Boiler Wet Subscriber Treatment Plants, the results indicated that the plants were non-functional during the research period. All parameters from the remaining 38 stations met the requirements (Table 5).

Table 5. Water quality results from 40 stations. Bhrikuti Paper Mill and Tuborg Beer Factory were below minimum standards.

	Location	Temp. (˚C)	pH	TDS (ppm)	Turb. (NTU)	EC (us/cm)	Nitrate (mg/L)	Phosph. (mg/L)	DO (mg/L)	BOD	COD
1	Pokhara Buspark	7	8.4	219	1.1	270	0.5	<0.1	9.6	0.4	6.5
2	Bhirkuti Paper Factory	22	7.4	628	205	788	3.5	0.4	3	240	2325
3	Shivnagar	17	8.4	8	1	250	0.8	<0.1	7.4	0.3	10
4	Pitauji Ghat	17	8.5	220	1.7	258	0.6	<0.1	8.8	0.3	13.5
5	Tuborg Beer Factory	17	7.4	1479	243.7	1761	8.9	53.7	0	525	2950
6	Sikrauli Ghat	19	8.5	223	1	255	0.8	<0.1	9	0.2	13.5
7	Kujauli	17	8.9	217	1.3	278	0.6	<0.1	9.5	1	8
8	Divyapuri	17	8.8	213	1.3	356	0.8	<0.1	12.7	0.4	6.5
9	Gohi tappu	17	8.3	211	2	385	<0.2	<0.1	9.5	0.9	13
10	Island Jungle Resort	19.5	8.5	201	2	262	0.57	0.02	7.1	0.5	3
11	Amaltari	20.5	8.8	197	2	258	0.45	0.01	8.2	1.7	7
12	Temple Tiger Ghat	19.5	8.7	203	3	267	0.69	<0.01	4.9	1.4	7
13	Nandapur	19.5	8.5	207	3	266	0.42	<0.01	5.8	1	3
14	Seri	16	8.5	212	2	270	0.57	<0.01	6.4	1.2	7
15	Tamaspur	18.1	8.5	208	3	267	0.5	<0.01	7.2	1.1	4
16	Bagwan	20	8.6	207	3	268	0.48	<0.01	8.5	0.76	3
17	Velauji	18	8.5	210	4	267	0.47	<0.01	7.6	1.1	6
18	Velauji	19.8	8.5	213	3	266	0.57	<0.01	7.2	1.3	4
19	Tribeni	19.5	8.4	214	2	267	0.69	<0.01	6.9	1.7	9
20	Lothar Machan	22	8.2	169	2	214	1.6	<0.01	6.2	0.42	1
21	Dubi Chowk	22	8.5	169	3	232	1.3	<0.01	7.1	1.2	4
22	Kumratha	22	8.6	181	3	226	1	<0.01	7.9	0.53	1

Table 5 cont'd. Water quality results from 40 stations. Bhrikuti paper mill and Tuborg beer factory were below minimum standards.

	Location	Temp. (˚C)	pH	TDS (ppm)	Turb. (NTU)	EC (us/cm)	Nitrate (mg/L)	Phosph. (mg/L)	DO (mg/L)	BOD	COD
23	Itcherni	21	8.5	176	4	211	0.2	<0.01	11.4	1	2
24	Patnaghat	21.2	8.5	188	3	230	0.3	<0.01	10.2	0.76	5
25	Badrani	21	8.2	316	3	398	3.1	<0.01	7.8	1.1	7
26	Charara Ghat	20.1	8.2	218	5	300	0.65	<0.01	8.9	1.3	7
27	Jarneli	21.5	9.9	236	4	292	0.23	<0.01	9.2	1.7	6
28	Kasara	20	9.8	204	5	282	0.36	<0.01	10.7	2.2	6
29	Kasara Ghat	22	8.2	244	3	297	0.31	<0.01	6.5	1.2	6
30	Dhurba	22	8.3	246	2	306	0.29	<0.01	7.5	1.4	6
31	Sukranagar	22	8.3	250	2	302	0.32	<0.01	7.4	1.3	9
32	Budhanagar	18	8.2	248	3	297	0.41	<0.01	6.5	1.4	7
33	Meghauli Ghat	17	8.1	243	3	287	0.56	<0.01	9.5	4.4	9
34	Laukhani	20.4	8.3	247	4	296	0.54	<0.01	9.7	2.06	18
35	Jalbire	19.7	8.3	169	2	230	0.76	<0.01	8.5	1.2	10
36	Near Seti Confluence	19	8.4	174	3	218	1	<0.01	7.9	2.2	7
37	Dasdhunga	19.8	8.4	174	2	216	0.68	<0.01	3.1	1.3	12
38	Poultry Farm Area	17	8.4	165	3	215	0.7	<0.01	3	1.5	10
39	Chitwan Diary	17.1	8.4	171	3	219	0.8	<0.01	8.7	1.6	7
40	Devghat	17	8.4	180	3	228	0.68	<0.01	7.9	1.3	5

Threat Quantification: Both the Rapti and Narayani Rivers suffer tremendous pressure from various disturbances (Table 6). Of the total river surveyed (Rapti, 68.5 km; Narayani 108.5 km), the available habitat ("no" to "low level" of disturbance) for Gharial was 25 km in the Rapti and 47.5 km in the Narayani. The fishing methods used in the Rapti and Narayani Rivers were assessed and quantified. Likewise, the entire river segment studied was mapped based on the disturbance intensity (cumulative disturbance per segment) i.e no disturbance to high disturbance zone (Fig. 5).

Table 6. Threat quantification in the Rapti and Narayani Rivers.

River	km	Fishing	Sand Mining	Stone Quarry	Boat Intensity	Washing	Bathing/ Swimming	Cattle Grazing
Rapti	68.5	1.85	0.219	0.190	0.70	1.07	3.59	4.25
Narayani	108.5	0.61	0.13	0.36	1.07	0.99	1.00	2.19

Table 7. Fishing frequency (per day) in the Rapti and Narayani Rivers.

River	Rapti	Narayani
Arrow fishing	31	0
Baiting	1	13
Electric current	9	0
Gill net	44	35
Hand net	42	18

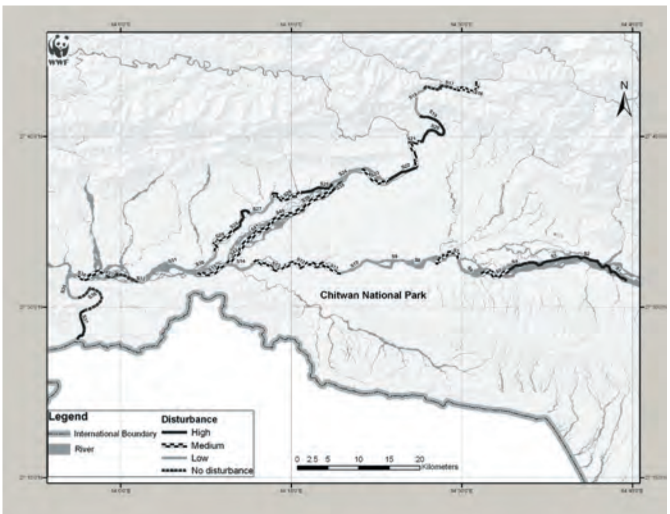


Figure 5. Disturbance intensity map for the Rapti and Narayani Rivers, 2011.

Discussion: Gharials were found to occupy river stretch with zero to very low level of disturbance, fine sand banks, especially deep pools with river confluence and greater prey availability. Water pollution level indicated only at the source point of Bhrikuti Paper Mill and Tuborg Beer Factory suggests that the water replenishing capacity is high in the Narayani River. The other fact that cannot be ruled out is the water load that could have diluted the effects in the river.

Objective 3: To upgrade the ex-situ facilities of Gharial Conservation Breeding Centre (GCBC), Kasara

As a part of upgrading *ex-situ* facilities in GCBC, two adult breeding pools have been constructed. These additional breeding pools have helped reduce overcrowding of the adults. Similarly, lab room has been renovated with a major objective of having fully equipped infrastructure within the breeding centre. It has been equipped with lab accessories such as laptop, camera, weighing machines, data loggers, pH meters, TDS meters, thermometers, etc. for record-keeping and management of captive Gharials. Likewise, a fish farm has been constructed adjacent to breeding pool with the purpose of raising finger size fish and feeding live fish to the Gharial in captivity. One of the predictions about captive-raised Gharial is that the hunting instinct/capability are diminished due to the dead fish (easy prey) provided thereby lowering the survival rates in the wild.

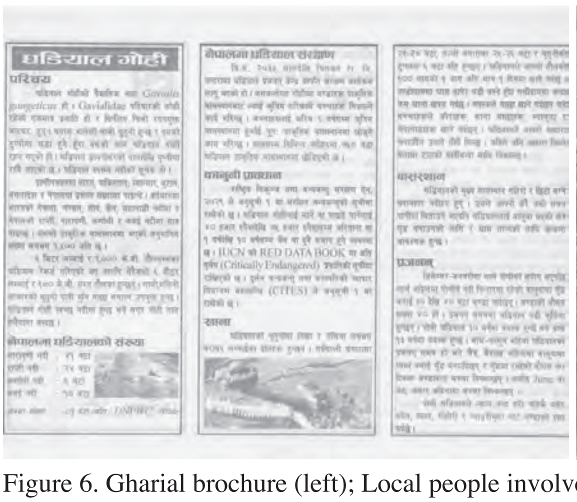
Objective 4: To build the capacity of the park rangers and wildlife technicians in captive management and scientific monitoring of Gharials.

Acknowledging the strong urgency of the skilled human resource to aid in conserving the critically endangered Gharials, WWF Nepal organized 4 days of training for 20 park rangers and wildlife technicians on various aspects of Gharial conservation, biology, captive management and monitoring techniques. The participants comprised of 10 rangers from Chitwan National Park and Shuklaphanta Wildlife Reserve and 10 wildlife technicians from National Trust for Nature Conservation. The major objective of the program was to develop manpower specifically for captive management research and regular monitoring of Gharial in Nepal. Since then, this trained manpower has been mobilized in various Gharial conservation and monitoring programs in Nepal.

As per the request of Government of Bhutan, WWF Nepal in co-ordination with DNPWC organized a 4-day short training course on "captive management of Gharials" to 5 staff of Gharial Conservation Farm, Gedo Forest Division, and Bhutan. Presently, Gharial Conservation Farm is performing better in terms of increasing the survival rates of Gharials and the government is planning for the restocking program in near future.

Objective 5: To aware the local communities and the publics on the plight of Gharials through conservation education and outreach programs

One of the major project emphases has always been on conservation education and outreach program. Gharial conservation education materials viz leaflets and brochures were prepared both in Nepali and English scripts (Fig. 6). The target groups reached out were local people around Gharial habitats, school students, eco-club members, hoteliers, nature guides and tourists. Brochure, "Gearing up for the Gharial" was also sent to various network offices around the world and is also available through WWF Nepal's resource centre. Electronic form of the brochure has been useful in reaching out to both national and international audiences.


घडियाल गोही

परिचय

नेपालमा घडियालको संख्या

Figure 6. Gharial brochure (left); Local people involvement in Gharial Conservation Outreach Program (right).

Massive conservation outreach programs were successfully undertaken in 23 VDC (Village Development Committee) of Chitwan and Nawalparasi districts ensuring the participation of Bote, Majhi and Mushar communities (these are the river dependent communities). A total of 806 people from fishing community, 2000+ people from local community and 1200+people from buffer zone communities were directly sensitized in Gharial conservation. In the same way, Chitwan National Park being one of the most visited tourist center in Nepal, interactive workshop on gharial was organized for tourism entrepreneurs in Sauraha. A total of 26 nature guides and 49 hoteliers showed active participation and committed to raise their voices for Gharials.

Objective 6: To integrate favourable measures for Gharial conservation in the management of protected areas

Preparation of Gharial Conservation Action Plan (2012-2016)

Gharials still face a host of threats in the wild. Despite being 20 times more endangered than the tiger, the species conservation yet is not guided by any policy document in the country. Therefore it was realized that the country hold a strong guiding document with set vision, goal and strategies that identifies the highest priority conservation actions in their habitat for overall management of the species. Therefore, the task of Gharial Conservation Action Plan (GCAP) was also a top priority of this project and a team of experts are currently preparing the plan.

Preparations of the river management plan for critical Gharial habitats

Rivers have always been no man's property and protecting the rivers has always been a major challenge in Nepal. There are thousands of fishing communities living around rivers whose livelihood has been entirely dependent upon fishing. But, rather than traditional fishing, it is the commercial fishing, boating, sand mining, boulder extraction, dam construction and river diversion that are causing serious threat to Gharial habitat. Therefore, alike the need for species action plan at a national level, the local stakeholders strongly believed that unless, the two major river systems (Rapti and Narayani) in Chitwan National Park are managed properly and urgently, there is little hope for the survival of Gharials and other freshwater species in Nepal.

So through several round of discussions with the local stakeholders, consensus was reached that given the stake to the locals for managing rivers, they would support to managing river resources. This need has called for the "River Management Plan for Rapti and Narayani Rivers" and is also under development process. River management plan is expected to clearly spell out the stakeholders, resources to be managed and strategies for management.

Objective 7: To collaborate with GCA and reinforce gharial conservation in Nepal

GCA Collaboration

GCA's role to Nepal has been particularly important for providing scientific information and timely feedbacks on the project initiatives especially focused on scientific research and captive management. GCA's support to Nepalese officials in providing hands on training on captive management, scientific monitoring, capture and rescue techniques proved crucial in capacitating the park rangers, wildlife technicians and smart river rangers through similar kind of training organized in Nepal. Also, crocodile rescue techniques learnt in Crocodile Bank, Chennai has been implemented both in Rapti and Narayani Rivers and was possible to save the lives of three Gharials entangled in the gill nets in the Narayani River.

Reinforcing Gharial conservation in Nepal

- Formation of River Management and Gharial Conservation Sub-Committee: With increased awareness in gharial conservation, Bufferzone User Committee (BZMC), Chitwan, which is the legal body for managing buffer zone resources, has taken an important step to institutionalize the river management program. There are now altogether 5 River Management and Gharial Conservation Sub-committees in Rapti and Narayani Rivers.
- Mobilization of Smart River Rangers: At least 5-7 river-dependent communities (Bote, Majhi and Mushars) under each River Management and Gharial Conservation Sub-committees have been trained as "Smart River Rangers" to systematically monitor Gharial population and patrol the rivers. There are 5 teams of smart river rangers each assigned to patrol their respective river segments (ie two segments in Rapti and 3 in Narayani). Each of the team has 5 members comprising of two surveyors, two boatmen and one game scout. Game scout is officially appointed by Chitwan National Park to accompany the team in every month's patrol and monitoring operation. The team surveys their respective river segment 1-2 times a month and collect data on gharial status and illegal activities. The team also has the authority to warn the illegal fishermen and seize the fishing nets in the river. (Fig. 7). This team has been monitoring Gharial population in the Rapti and Narayani Rivers since October 2011. The team's effort in monthly patrol has been useful in keeping a track of Gharial population in each river segments. Similarly, it has been instrumental in minimizing and keeping a check on illegal activities in rivers, reducing the use of gill nets, reduction in reported cases of entangling of Gharials and timely rescue. This year 3 Gharials entangled in the nets were successfully rescued by smart river rangers and park staff. From October, 2011 to May, 2012 smart river rangers had 581 sightings of Gharial in 5 river segments.

Altogether 119 gill nets were seized and burnt by smart river rangers leading to decline in the usage of gill nets in the latter months. Likewise, 11 people using electro-fishing were punished. Similarly, there has also been decline with sand mining, stone quarrying and other illegal activities in the river.

Figure 7. Smart River Rangers Team patrolling the river.

- Livelihood support for river dependent communities: Altogether 10 community fish farms have been supported through the project in different parts of bufferzone area of Chitwan National Park. The objective of providing support to community fish farm is to lower the fishing pressure in the rivers by targeting fishing communities who compete for the same fish resources. The strategic locations for community fish farms were selected based on the intensity of fishing problem in the area. Of these 4 community fish farms are constructed in Amaltari area, 2 in Laukhani, 1 in Rajahar and 3 in Jagatpur. Likewise skilled development training such as tailoring, driving, cookery, handicraft making was provided to 100 river-dependent communities in Amaltari, Bagwan and Laukhani areas of Chitwan.
- Gharial Restocking program in CNP: With the initiation of smart river rangers program, rivers within CNP are considered better protected from disturbances; so gharial restocking program was rejuvenated. A total of 100 captive Gharials (19 males, 81 females) were released into different section of Rapti River between January and April 2012 (Fig. 8). These released individuals comprised of animals hatched in the period 1997-2006. All the Gharials were measured, sexed and marked by scute cutting for easier identification of the animals. Animals were loaded into a ventilated wooden box of size (20 x 30 x 180 cm) and transported to the enclosure near by GCBC. Enclosure made of *Narenga* spp. were good enough for fish to come and would allow Gharials to get acclimatized before finally breaking the enclosure and escaping into the natural habitat. At present there are 582 gharials in captivity at GCBC, and 861 captive-reared Gharials have been released as of April 2012 in different river systems of Nepal.

Figure 8. Gharial released in enclousure at Rapti River.

Figure 9. Gharial being rescued in the Narayani River.

Major Project Outcomes

- Gharial Conservation Action Plan developed
- River Management Plan for Rapti and Narayani Rivers developed
- *Ex-situ* conservation measures (2 Adult Breeding pool, lab, fish farm, visitor centre) upgraded in Kasara, Chitwan National Park
- Formation of River Management and Gharial Conservation Sub-Committee
- Capacity building and mobilization of river-dependent communities(Bote, Majhi, Mushar) as smart river rangers in patrolling rivers and monitoring gharial population
- Gharial rescue nets prepared and handed over to the Smart River Rangers team
- Alternative livelihood opportunities in the form of community fish farm and skill development training provided to river-dependent communities

Measurable Project Impact

- Increase in number of Gharial nests in the wild: In 2010, the year of project initiation, there were only 4 nests found in the Rapti and Narayani Rivers, which increased to 9 in 2011. This year it has increased to 11 and this increasing trend is the result of continuous monitoring of the population and strict protection of the river segments.
- Increased capacity of the captive breeding centre: Gharial breeding centre facilities are improved with the construction of two new breeding pools, lab, fish farm and enhanced visitor centre. 2012 was the year with the highest number of gharials in the history of GCBC; it supported 682 gharials of which 100 were released in Rapti River. Other indicators for increased capacity of the captive breeding centre is the "hatchling survival %" which shows an rising trend in the survival percentage of gharial after one year of age.
- Increased in Conservation Fee: Gharial Conservation Breeding centre started collecting entry fees since 2006; but till 2009 the revenue collected was very minimum (NRs 866,660). It almost doubled in the year 2010 reaching NRs 1,465,880 and has been increasing rapidly. Still one quarter of the year is left for this year's closing and more national and international tourist is expected.
- Successful rescue of entangled Gharials: This year 3 Gharials entangled in the nets were successfully captured and rescued with the help of the nets provided to the Smart River Rangers group. All 3 Gharials were finally released back into their natural habitat.
- Increased interest of Media in highlighting Gharial conservation: Local as well as national journalists are found to have increased interest in the species, they are documenting most of the project initiatives to bring about mass awareness both at local and national level.

Conclusions

Increase in nests number in the wild has brought optimistic hope in the future of this critically endangered Gharial. Similarly, the proposed telemetry study is expected to provide light into the fate of Gharial restocking program in Nepal. The ongoing species action plan is anticipated to get attention from all levels of stakeholders; from policy makers to decision makers and implementers in the field. River Management Plan shall provide guideline to usage of river resources, increased ownership taken by the river-dependent communities and control on usage and exploitation by commercial users. There has been growing awareness in local people about Gharial conservation and they are known to take pro-active measures. Smart river rangers program has been very successful and is able to minimize fishing incidences while keeping a check on other illegal activities in the river. Improvement in captive facility in the park has positive impact in the survival of gharials, better space management and increased number of tourists contributing to greater conservation fees for GCBC management. River-dependent communities have readily accepted the livelihood opportunities provided through the project. They have been supporting the conservation initiatives and are committed for long term conservation of critically endangered Gharial.

Literature Cited

Ballouard, J.M. and Cadi. A. (2005). Gharial Conservation in Royal Chitwan National Park, Nepal.

Burnham, K.P. and Anderson, D.R. (2002). Model selection and multi-model inference. Second edition. Springer-Verlag: New York.

GCA (Gharial Conservation Alliance) (2008). International Gharial Recovery Action Plan. http://www.Gharialconservation.org/PDF/GRAP.pdf.

GSRP (2011). Gharial Species Recovery Plan, Janauary, 2011. Workshop Convened by the Gharial Conservation Alliance, Delhi, 22-24 June 2009.

Hines, J.E. (2006). Presence 2 - software to estimate patch occupancy and related parameters. USGS-PWRC.

Khadka, B.B. (2010). Gharial hatching status in 2010, Chitwan National Park, Nepal. Crocodile Specialist Group Newsletter. 29(3).

Khadka, B.B. (2011). Gharial and Mugger monitoring in the Narayani and Rapti Rivers of Chitwan National Park, November 2010. Crocodile Specialist Group Newsletter 30(1).

Khadka, M., Thapaliya, B.P. and Kafley, H. (2008). Gharial Crocodile Monitoring in Nepal. A Report Submitted to WWF Nepal and Department of National Parks and Wildlife. Conservation, Kathmandu, Nepal.

Mackenzie, D.I. (2005). What are the issues with presence-absence data for wildlife managers? Journal of Wildlife Management 69: 849-860.

Maskey, T.M. (1989). Movement and survival of captive reared gharial (*Gavialis gangeticus*) in the Narayani River, Nepal. Unpublished Ph.D. thesis, University of Florida, USA.

Nair, T. (2010). Ecological and anthropogenic covariates influencing Gharial *Gavialis gangeticus* distribution and habitat use in Chambal River, India. Unpublished M.Sc. Thesis, National Centre for Biological Sciences, Tata Institute of Fundamental Research, Bangalore.

Thapaliya, B.P., Khadaka, M. and Kafley, H. (2009). Population Status and Distribution of Gharial in Nepal. The Initiation 3: 1-11.

Whitaker, R., Rajamani, V., Basu, D. and Balakrishnan, V. (1974). Preliminary Survey of the Gharial, *Gavialis gangeticus*. Madras Snake Park Trust Report. pp 1-16.

WWF Nepal (2011). Population Status and Distribution of Gharial in Nepal. WWF Nepal: Kathmandu.

A Newly Founded Non-profit Organisation Focused on Contributing Towards the Better Understanding and Conservation of Tomistoma (*Tomistoma schlegelii*)

Anthony K. Pine

The Tomistoma Fund, 1965 Chicago Ave. Suite A, Riverside, CA 92507, USA

Abstract

The Tomistoma Fund is an established 501(c)3 public charity founded in May, 2011, to further promote funding and collaboration of efforts towards the research, conservation, and management of wild Tomistoma (*Tomistoma schlegelii*). As an endangered species in the IUCN Red List, there is an immediate need to further our scientific understanding of the species current geographic distribution, ecology, reproductive biology, behaviour, and diet in order to pursue future conservation and management efforts. The objective of this organization is to help facilitate Tomistoma research projects and initiatives in the aforementioned, but not limited to, fields of study. Equal in importance, our organization aims to promote local and international education and awareness for the species through literature and public presentations. As a newly founded organization, we do reverently request any possible guidance and supervision from organizations already developed towards Tomistoma research and conservation.

The Management of American Alligators in Louisiana, USA: A History, Review and Update

Ruth M. Elsey[1] and Noel Kinler[2]

[1] Louisiana Department of Wildlife and Fisheries, Rockefeller Wildlife Refuge, 5476 Grand Chenier Highway, Grand Chenier, Louisiana 70643, USA
[2] Louisiana Department of Wildlife and Fisheries, 2415 Darnall Road, New Iberia, Louisiana 70560, USA

Abstract

The American Alligator (*Alligator mississippiensis*) occurs in the southeastern United States and management programs exist in most states. Alligators are utilized in Louisiana and are managed as a renewable natural resource. Wild alligators are harvested in a controlled manner using strict guidelines and strong oversight at the state and federal level. Quotas are based on sound scientific survey methods to estimate regional population levels, and harvest levels set proportionally to estimated population levels in each locale. Alligator eggs are also harvested commercially on many wetlands, which avoids high natural mortality. The eggs are then hatched on licensed commercial alligator farms, and alligators raised for their valuable leather and meat. Mandatory release of juvenile alligators to properties from which eggs were harvested ensures future recruitment. This sustained use management regime benefits the landowner, alligator farmer, alligator trapper, and other industry personnel and promotes preservations of wetlands, due to the economic incentive of maintaining quality alligator habitat. Problem or nuisance alligators are relocated or harvested by licensed trappers to avoid human-alligator conflict. These programs have grown in magnitude since their inception and modification made with time as needed. This paper reviews the history, development, and current status of management of alligators in Louisiana.

Introduction

The Louisiana Department of Wildlife and Fisheries (hereafter Department or LDWF) manages the American Alligator (*Alligator mississippiensis*) as a commercial, renewable natural resource. The Department's sustained use program is one of the world's most recognizable examples of a wildlife conservation success story. Louisiana's program has been used as a model for managing various crocodilian species throughout the world. Since the inception of the Department's program in 1972, over 836,000 wild alligators have been harvested, over 6.8 million alligator eggs have been collected, and over 4.1 million farm-raised alligators have been sold bringing in millions of dollars of revenue to landowners, trappers and farmers. Conservative estimates have valued these resources at over $US802,000,000, providing significant, direct economic benefit to Louisiana. The management and sustained use of this resource as a conservation tool has been documented in detail (Joanen *et al*. 1997).

This report provides a historical perspective; outlines the basis and philosophy of the Department's management program; reviews the federal Government's oversight and approval role for management of the alligator in the USA; discusses wild, farm, and nuisance alligator programs; briefly lists research activities; and reviews the revenue and briefly discusses expenditure information associated with the management program and the Louisiana Alligator Resource Fund. This paper serves to review the research and management that led to the development of a sustained use program, and how the management program in Louisiana has been adapted over the last 40 years. In particular, emphasis will be placed on changes made to the program since our last similar update at the 17th working meeting of the Crocodile Specialist Group (Elsey and Kinler 2004); some portions of that document are duplicated herein for introductory purposes.

Historical Perspective

Alligators have been used commercially for their valuable leather since the 1800s (Stevenson 1904). The history of trade in alligator hides has been outlined in detail (Joanen and McNease 1991). This harvest was generally unregulated throughout the 1900s, until a gradual population decline resulted in severely reduced harvests in the early 1950s. In 1962, the alligator season in Louisiana was closed, and research studies, focusing on basic life history factors were undertaken which led to development of a biologically sound management program. Studies included reproductive biology and nesting ecology, as well as telemetry, habitat preferences, and movement patterns of adult and juvenile alligators (Joanen 1969; Joanen and McNease 1970; 1972; McNease and Joanen 1974). Of tremendous importance was the establishment of a rigorous survey method to estimate and monitor population trends (McNease and Joanen 1978).

Aerial surveys of coastal alligator nests were initiated in 1970. Longitudinal north-south lines were flown along the entire coast of Louisiana. A total of 51 census lines were used, with 28 lines at 3.8˚ intervals in the three southwestern parishes, and 23 lines at 7.5˚ intervals in the remaining coastal parishes (McNease and Joanen 1978), for a sampling intensity of 0.76% of 1.3 million ha (3.2 million acres) of alligator habitat (excluding 0.4 million ha categorized as salt marsh).

From 1962 through August 1972, alligators were totally protected. During this time a myriad of state and federal laws regulating harvest distribution and allocation of take, methods of harvest and possession, transportation and export of live alligators, alligator skins and their products was enacted. Similarly, in 1970 the Louisiana legislature recognized that the alligator's value, age at sexual maturity, and vulnerability to hunting required unique consideration and passed legislation providing for a closely regulated experimental commercial harvest (Joanen and McNease 1981).

The goals of the Department's alligator program are to manage and conserve Louisiana's alligators as part of the state's wetland ecosystem, provide benefits to the species, its habitat and the other species of fish and wildlife associated with alligators. The basic philosophy was to develop a sustained use management program which, through regulated harvest, would provide long term benefits to the survival of the species, maintain its habitats, and provide significant economic benefits to the citizens of the state. Since Louisiana's coastal alligator habitats are primarily privately owned (approximately 81%), our sustained use management program provides direct economic benefit and incentive to private landowners, and alligator hunters who lease land, to protect the alligator and to protect, maintain, and enhance the alligator's wetland habitats. One of the most critical components of the management program was to develop the complex set of regulations which required individual applications for each property to be considered for tag allocation, landowner permission, proof of ownership and detailed review of habitat quality related to alligator abundance, all of which combined to equitably distribute the harvest in relation to population levels.

Initial Wild Harvests

In 1970, the Louisiana State Legislature (Act 550) gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana (Joanen and McNease 1991). After the initial surveys were conducted in 1970 and 1971, the LDWF developed a system of hunter applications, licenses, tags, etc., to initiate an experimental harvest of wild alligators, and distribute the take according to population levels. Based on field research and the telemetry studies, a harvest conducted in autumn (when nesting female alligators are in the remote interior marsh with new hatchlings at nest sites) would select the take for adult males, or immature alligators of either sex. During the period of total protection (1962-1971) alligator populations increased quickly and by 1972 the Department was ready to initiate its new sustained use management program.

In September 1972, the experimental alligator harvest was conducted in Cameron Parish, Louisiana. A total of 1350 alligators (80.3% males) were taken by 59 trappers in 13 days. A detailed analysis of the harvest was reported (Palmisano *et al*. 1973) and in 1973, Vermilion Parish was also included in the harvest, which was increased to 19 days. In that year, 2921 alligators were taken by 107 hunters. The program expanded with time, and Calcasieu Parish was also hunted in 1975. As nest surveys continued to show rising population trends, all coastal parishes were hunted starting in 1979; and by 1981 the harvest was expanded statewide. The wild harvest program has gradually increased over time to the point where approximately 30,000-35,000 wild alligators are harvested annually.

The quota for the total numbers of alligators to be allowed for harvest (how many CITES tags to be issued to landowners/trappers) is related to the population of alligator estimated to occur on each piece of property. The alligator nest count by aerial transect gives an estimate of the total population, based on the theory that a certain proportion of the entire population consists of nesting females. Population trends are monitored closely each year by the estimated coastal nest counts seen on aerial survey.

Transect lines (and therefore nest counts) are categorized into marsh types, based on the vegetative types present. Certain "indicator" species of plants, depending on their salinity tolerances occur in different marsh zones. The marsh types are fresh, intermediate, brackish, and saline with increasing salinity levels in each zone. Very little (if any) alligator nesting occurs in salt (saline) marsh.

Transect lines are also categorized by location of the parishes (counties) in Louisiana. Tag allotments are determined for each parish, by marsh type. For example, in 2003 in Cameron Parish, one tag was allocated for each 90 acres of fresh marsh, while 170 acres of brackish marsh were needed to qualify for one CITES tag. In the western portion of Vermilion Parish, high nesting rates were seen, and thus only 75 acres of intermediate or brackish marsh were needed to qualify for one CITES tag in 2003. Poorer habitat and lower nesting rates led to a quota of only one tag per 500 acres of brackish marsh in St. Bernard Parish. Each year the nesting surveys and prior year's harvest results are closely examined by biological staff to determine the tag allocations for each region. The very best quality habitat with the highest nesting density had a CITES tag allocated for only 55 acres of this quality habitat in 2011.

Oversight by the US Fish and Wildlife Service

Five years after Louisiana closed the alligator harvest season, the alligator was listed on the federal *Endangered Species Act* in 1967. At this time the alligator was considered an endangered species throughout its range. In March of 1974, Louisiana petitioned the Secretary of the Interior, requesting that populations of the alligator in Louisiana be removed from the list of threatened and endangered species in Cameron, Vermilion and Calcasieu Parishes. In subsequent years, similar petitions sought to reclassify the alligator, first in 9 additional coastal parishes in 1978 and then statewide in 1981. Each of these petitions was based on results of detailed scientific study and the demonstrated success of the early harvest programs. The development of these early management and wild alligator harvest programs have been described in detail previously, outlining the inventory methods, population surveys, establishment of harvest recommendations, and validation of hides taken (Palmisano *et al*. 1973; Joanen and McNease 1981, 1987a).

Export of alligator skins and products out of the United States is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, which became effective in 1975, regulates the international trade in protected species; its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. The US Fish and Wildlife Service (USFWS) administers CITES requirements and controls for the USA. The species covered by CITES are listed on one of three Appendices, according to the degree of protection needed. Currently, the alligator is listed on Appendix II of CITES, because of its similarity of appearance to other crocodilians that are truly endangered or threatened.

In order to fulfill CITES requirements, the USFWS through a series of rulemakings, has developed a complex set of requirements with which the individual states, including Louisiana, must comply in order to be granted export approval for harvested alligators skins and products. The most critical component in these requirements is that the Department must certify, on an annual basis, that the harvest programs we administer will not be detrimental to the survival of the species. The "non-detriment" finding is predicated on our assessment of the current condition of the alligator population, including trends, population estimates or indices, data on total harvest, harvest distribution and habitat suitability evaluation. Additionally, the management program must provide for a rigorously controlled harvest with calculated harvest level objectives. All alligators and eggs harvested must be taken from specifically identified properties and all hides individually tagged (with approved, serially marked CITES export tags furnished by the USFWS). The USFWS requires strict accountability for each tag allocated to the harvester, requiring that all unused tags are returned at the close of the season.

Wild Alligator Management and Harvest Program Expansion

Beginning in 1970, when the Louisiana State Legislature gave the Department of Wildlife and Fisheries full authority to regulate the alligator season in Louisiana, the Department has annually inventoried alligator nest production throughout coastal Louisiana in order to assess the status of alligator populations. Results of annual alligator nest surveys are compiled to provide estimates of nest density (acres per nest) by parish and by habitat type (brackish, intermediate, or fresh). Private and publicly owned lands [state and federal refuges, and state owned WMAs (Wildlife Management Areas)] are compiled separately.

As the experimental harvests proved successful and the program gradually became larger, nesting surveys were intensified to ensure the harvest did not cause any detriment to the wild alligator population. Additional "B" transect lines were added in 1981 (McNease *et al*. 1994) at midpoints between the established lines to increase sampling intensity to a total of 106 lines. In 1999, another series of "C" lines were added (now 143 transect lines). The survey takes some 9 days and costs approximately $US60,000 annually.

With expansion of the program beyond the coastal marsh zone, other habitat types (cypress-tupelo swamp, northern lakes, dewatered marsh, transitional/deteriorating marsh) also have tag quotas. Further refinement of the analysis in recent years has even led to some parishes being subdivided into east and west zones; or even divided in thirds (east, middle and west).

To avoid large fluctuations in annual tag quotas due to weather-induced changes one year's nesting effort, the tag quota was changed to being based on the average of the most recent 5-year surveys in approximately 1992. Other factors such as size classes harvested in the prior year, sex ratios harvested, regional "nuisance" alligator complaints, etc., are all considered when carefully establishing harvest quotas for each area.

"Bonus" Tag Implementation

As the wild harvest program in Louisiana readily appeared to be sustainable, it was adapted again in 1999 to make use of the more plentiful alligators in the 4-5' size classes (122-183 cm). Starting in 1999, trappers were issued an additional quantity of "bonus" tags to be used on alligators less than 183 cm in length. The number of "bonus" tags issued was 10% of the trapper's regular quota. For example, a trapper whose normal CITES tag quota is 21 would also have been issued 2 bonus tags to be used on smaller alligators. The "regular" tags may be used on alligator of any size. A trapper who qualified for 43 regular tags would have been issued 4 "bonus" tags. Some 3200-4400 bonus tags have been issued annually since 1999; the average size was initially approximately 5'9" (175 cm) to 5'10" (178 cm). Fortunately these hides were generally much larger than the hides from the average farm-raised alligators in Louisiana which average 3.69-3.81' (112-117 cm) total length at that time. Thus the two markets had little (if any) overlap. The "bonus tag" program was well received by landowners and trappers initially, but when the economic recession led to lower demand and lower prices (especially for smaller hides) there was less interest in this component of the program. Over time, compliance also became an issue, with some trappers not abiding by the voluntary use of bonus tags on alligators less than 6' in length. Thus, the bonus tag program was suspended after the September 2008 season; and was not implemented in September 2009 or thereafter.

Processing Improvements and Hide Quality

The wild alligator harvest initially was limited to a few major land companies who hired local citizens to trap their quota, and trappers who harvested alligators from family owned land. Trappers would skin their own alligators, and sell the salted hides to buyers at local auctions. Alligator meat was sometimes used for home consumption. As the wild harvest expanded, centralized processing sheds were established by dealers. Trappers bring their lot of hides to the shed, or dealers transport alligator carcasses from rural collecting points to the processing shed in refrigerated trucks. The alligator meat has become a secondary source of revenue to benefit to landowner and dealer. Refinements in the alligator skinning procedure and care of the hide have been developed to try to minimize damages in transport, skinning, and storage, to maintain and improve the quality of the raw hide.

Recent changes by the Department have been enacted to attempt to spread the harvest out over several weeks of the thirty day season, as a limited number of experienced and skilled alligator skinners are available for this seasonal work. These include opening the wild season on a Wednesday (beginning in 1998) so some trappers will complete their tag allocation before the opening weekend, when more trappers can begin harvesting efforts unconstrained by work obligations. Additionally, two distinct harvest zones were established in 2007, with the East Zone season opening on the last Wednesday of August in each year, and the West Zone opening on the first Wednesday in September of each year. The wild harvest in Louisiana has developed into a multi-million dollar source of income for the state's landowners and trappers.

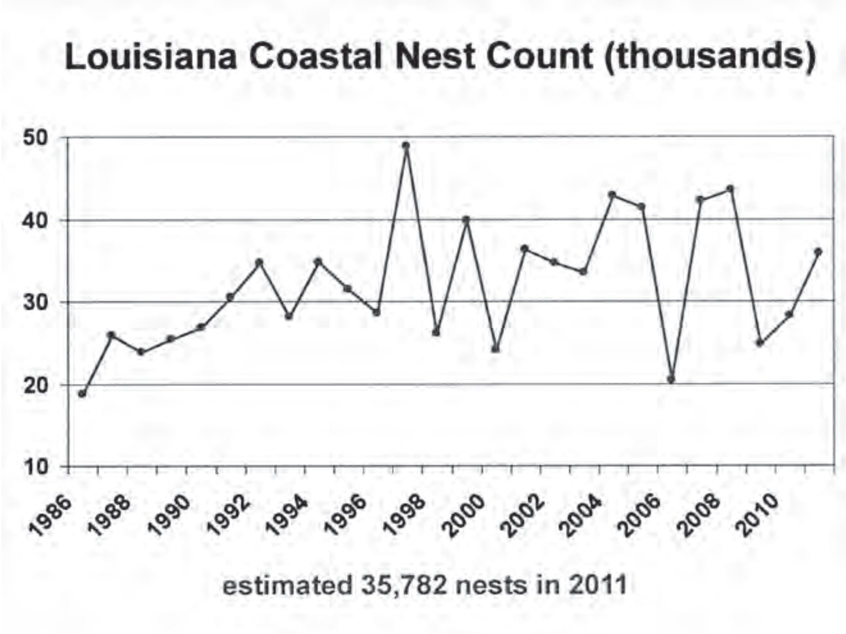
Survey Methods and Intensity; Establishment of Harvest Quotas

The vegetative type lines used to determine CITES tag quotas for wild alligators (and alligator egg quotas for ranching, see below) were initially delineated in 1968 (Chabreck *et al*. 1968). Numerous environmental factors such as salt water intrusion, wetlands erosion, etc. cause changes in marsh types over time. The vegetative type surveys were flown approximately every ten years (1978, 1988, 1997 and then 2001) to document the changes and adjust quotas accordingly. Recent efforts have been made to fly this survey more frequently (perhaps every five years) to closely monitor the critical problems of wetlands loss, saltwater intrusion, and marsh deterioration in coastal Louisiana.

Evaluating each trapper's family property or land owned by large private corporations and determining the quantity of various marsh types on the wetlands is very labor intensive. One piece of property may have divided interest ownership as the property was passed down from generation to generation. Property descriptions are obtained from tax assessor's offices in each parish to determine exact locations and boundaries for each piece of property. Maps of vegetative/marsh types and ownership are compared to calculate how many acres of each marsh type exist on each piece of property to be evaluated for CITES tag issuance. Until recently this has been done "by hand", an extremely labor intensive process considering the magnitude of the alligator habitat and number of commercial hunters in Louisiana.

A computer based GIS/ArcView system was initiated around the year 2000 to develop digital files of each landowner's property, with superimposed vegetative type delineations. This program now allows LDWF biologists to more easily incorporate the new marsh types or vegetative changes when new surveys are flown.

In June/July of each year, over 4000 km of transects are flown by helicopter, surveying 122,000 acres of wetland habitat. The sampling intensity covers approximately 3.4% of 2.3 million acres of private coastal wetlands, and 6.9% of some 622,000 acres of public coastal wetlands (up to 14.3% of some publicly owned wetlands are intensively surveyed). During the most recent summer survey, in 2011 we estimated that 35,782 alligator nests were present in the coastal marsh habitats, up from the 28,168 nests estimated in 2010. Although coastal habitats have significantly recovered from the devastating hurricanes in 2005 and 2008, nest production remained below average as drought conditions affected some coastal parishes during spring and summer 2010 and 2011.

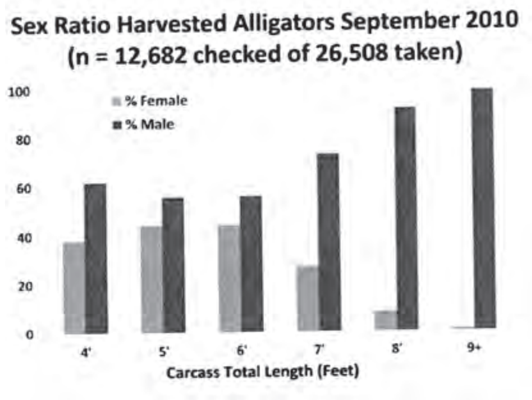


Nest density and alligator population estimates are combined with a detailed review of harvest parameters and a general assessment of environmental factors observed during each survey to determine final harvest level objectives. Over 50 individual alligator harvest quotas are developed annually in order to distribute the harvest in relation to alligator abundance in the various habitats across the state. As mentioned above, in the best habitat one alligator is harvested per 55 acres, while in the poorer habitats one alligator is harvested per 500 acres.

Alligator hunters annually submit a description of the property on which they have permission to hunt. The Department's biological staff assesses the habitat quantity and quality and determines the number of alligators that can be harvested by each hunter each year. This methodology ensures that alligators are harvested in proportion to their population levels and that the harvest will not negatively impact populations at any location, which is paramount for the "finding of no detriment" required by the USFWS for the harvest program. The currently approved quota system represents an allowable wild alligator harvest, which coupled with the state authorized wild alligator egg harvest program (see below) represents a level of population utilization currently unparalleled in the world of crocodilian management.

Under this sustained use alligator program, over 868,000 wild alligators have been harvested since 1972. The annual harvest takes place in September to specifically target the adult males and immature segments of the alligator population. Adult females, which typically inhabit interior marshes in September, would be more susceptible to harvest if the season was scheduled during the spring or summer. Careful evaluation of habitat parameters and ecological impacts can influence quotas established by Department biologists; for example severe drought led to lowered harvest quotas in 1996 and 2000. A combination of hurricane damage from the 2005 hurricanes and drought in 2006 led to accordingly decreased quotas in 2006. Minor adjustments such as delay in opening dates, temporary season closure, or season extensions have been made in emergency situations such as the catastrophic hurricanes in 2005 and 2008; to ensure the resource is used wisely.

In 2009 harvest was severely reduced due to worldwide economic recession which lowered price and demand for farm-raised and wild alligators. In 2010, demand and price for wild harvested alligators increased as the economic recovery began in Europe, Asia and in the United States). During the 2010 wild season, a total of 26,508 alligators were harvested by 2248 licensed alligator hunters. The sex ratio of over 12,000 of these alligators was 70.32% male. Alligators harvested averaged 7.5' in length, with an estimated value of $US5.3 million.



In 2011, as prices and demand for hides increased somewhat, trappers participated to a larger extent and 32,213 alligators were harvested by 2964 licensed trappers.

Each year the alligator program staff works closely with landowners and alligator hunters to provide assistance regarding alligator management on their respective properties. We have provided numerous habitat base maps to landowners for their use in participation of both the wild and alligator egg harvest programs. Harvest reports summarizing average lengths and size class frequency distribution of harvested alligators are available upon request.

Additional "Recreational" Harvest Opportunities

In recent years the LDWF has put tremendous effort into allowing additional "lottery" hunts for recreational alligator hunting on state-owned WMAs and public lakes, and allowed for some smaller properties to qualify for a single CITES tag. When hide prices are lower, some commercial trappers may be more inclined to host "sport" or "trophy" hunters as a means to gain additional revenue. The number of "sport" licenses sold (the majority are non-Louisiana residents) averaged 142 per year from 2005-2009, and increased to 197 in 2010 and increased again to 374 licenses issued in 2011.

Bar-coded CITES Tags

In order to streamline the alligator hide inspection process for validation prior to in-state tanning or export, the LDWF worked closely with the USFWS and manufacturers to develop, test, and implement the use of bar codes on CITES tags. This was started during 2008 and has proven to minimize the human errors associated with data entry errors (transposition of numbers or incorrect recording of numbers on paper documents) during mandatory hide inspections. Some technical difficulties were encountered as expected as this new technology was initiated, but over time various scanners have been tested and reliable models selected for use.

Farming/Ranching Program

Early alligator farms in Louisiana were generally small, family owned operations; and often run more as a hobby/curiosity than a commercial enterprise. Extensive studies done by Department biologists showed alligators could be efficiently cultured and grown in captivity (Joanen and McNease 1987b). To encourage a possible new industry, the initial few farmers were supplied hatchlings from eggs collected from state-owned lands, and incubated and hatched by Department personnel. A program was established wherein farmers would receive hatchlings from the LDWF for 10 years; by which time some of their first hatchlings received would be sexually mature and the farmer would then obtain eggs from his own captive breeders. As time passed, the captive breeding proved to be less economical than ranching of wild eggs, and the requirement to maintain captive breeders was eliminated.

Hatchling alligators fared well in heated "controlled environmental chambers" or sheds in captivity and could reach market size in 1-2 years. Soon the demand for hatchlings for this new industry could not be met from agency resources. The LDWF then developed guidelines and strict quotas (similar to how wild harvest quotas are determined) whereby potential ranchers might obtain eggs from suitable private wetlands, which historically have been shown to support substantial populations of alligators. Egg "ranching" (collection of alligator eggs from the wild) proved more economical and successful than captive breeding; and egg collections from privatively owned wetlands were first permitted, on a limited basis, in 1986.

Releases to the Wild - "Head Start" Alligators

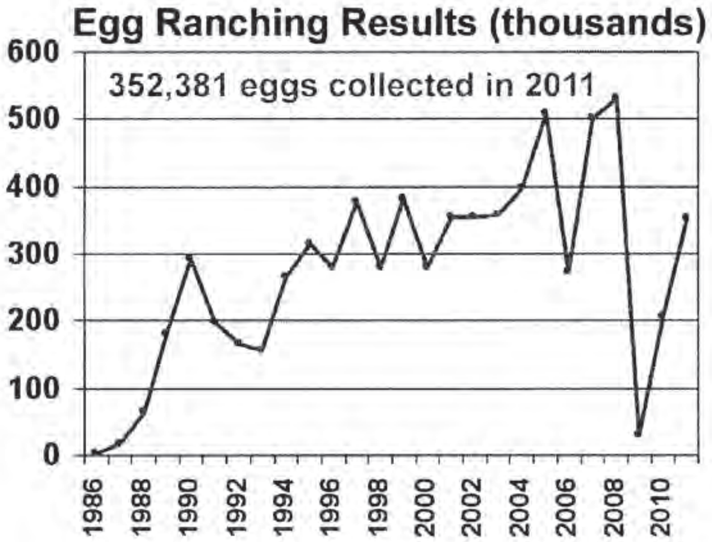
Louisiana's alligator ranching program increased dramatically between 1986 and 1990 and has been described in detail (Elsey *et al*. 2001). To ensure wild alligators were not depleted as a result of egg collections, and to ensure future recruitment of sub-adult alligators to the breeding population, the LDWF initially required a quantity of juvenile alligators equal to 17% of the eggs hatched by the rancher be returned to the wild within two years of hatching. In the first 3 years of the release program (1988-1990) returns were limited to fewer than 15,000 alligators. Sizes at release were generally small, and averaged 91-97 cm.

In 1991, a variable return rate was established based on the estimated 17% survival from hatching to 122 cm predicted for wild juvenile alligators. Using the relationship of survival between size classes as specified in Taylor and Neal (1984), we extrapolated return rates based on expected survival rates for alligators from 91.4 cm to 152.4 cm (3 to 5'). More alligators must be returned if the average total length is smaller, and fewer animals are required if the average length is larger. Alligators must be at least 91.4 cm and are usually less than 152.4 cm total length at release and must be free of disease or deformities to be acceptable for release (Elsey *et al*. 1998, 2001). Each alligator released is measured, sexed, tail-notched, tagged and this data is recorded by LDWF staff members prior to release to the same area where the farmers had originally harvested the eggs. The farmers must release the juveniles within 2 years of collecting and hatching the eggs.

Due to concern that the largest alligators on farms may be of poorer quality, the Department (at the request of a few landowners) briefly limited the maximum size at release to 54" (137 cm) rather than 60" (152 cm). Landowners were concerned these alligators (if caught in subsequent wild harvests) would reduce the grade of wild harvested alligator hides. These new size restrictions on released alligators were enacted for the 2007 and 2008 egg permits, but proved very burdensome for alligator farmers to have alligators of such a narrow range in length during the months of the year that releases to the wild are conducted. The Department allowed farmers to release 5% of their head-start alligators between the lengths of 55” to 60” to allow some flexibility, but this was felt to be an obstacle to the farmers and the “sharing” of one farmer’s unused over 54” allocation with other farmers was problematic for Department personnel to track, and this size limitation was discontinued after the second year.

Releases were initially made from 15 March to 30 September, if the weather was suitably warm. Due to conflicts with administration of the September harvest and field staff scheduling limitations, in 2003 the ending date for releases was changed to 25 August of each year (2001 egg collection permits; releases due in 2003). The tagging, marking, data collection and release procedure have been documented in detail (Elsey *et al*. 2001). In an average year some 35,000-40,000 juvenile alligators are marked and released to the wild; in the peak year of 2007, nearly 62,000 alligators were reintroduced as part of the “head start” program. Many of these survive well, grow into the adult size class, and are recovered and harvested as adults in the annual September harvest.

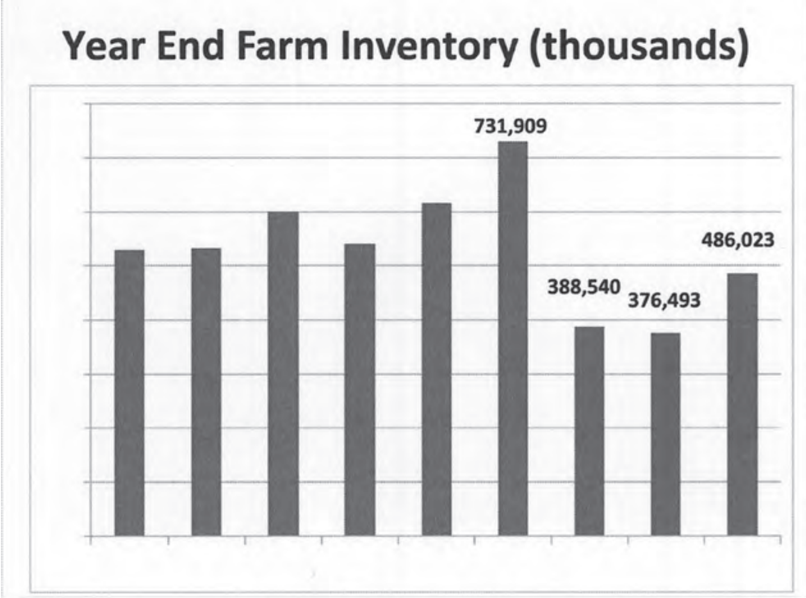
Enormous effort has been made by the LDWF to monitor the fate of the alligators released to the wild. We were very concerned that we document any failings or successes of the program, as it is costly to the ranchers to fulfill the “returns to the wild” obligation. However, it is an integral necessity of the program, considering the large number of eggs collected. In recent years, it has not been uncommon for up to 350,000-375,000 eggs to have been collected when weather conditions/ water levels led to good nesting efforts. In 2005, 2007, and 2008 over 500,000 eggs were collected in the ranching program; in recent years the Department has authorized collection of eggs on selected state-operated Wildlife Management Areas.



Our research and review of the ranching program documented that the released alligators are able to forage for food in the wild, grow well, have high survival rates, and successfully nest in the wild (Elsey *et al*. 2001). Thus, we decreased the return percentage to 14% of the eggs hatched, starting with the 2000 egg permit collection year (returns “due” in 2002; some done one year after collection in 2001). Similarly, the return percentage due was decreased again to 12% of eggs hatched starting with the 2007 year permits (returns due in 2009). Thus, our management program was adapted when available data warranted less demanding return requirements; although very close monitoring of the effects of this change will continue.

The number of alligator farms in Louisiana peaked during 1990-1992, when some 123-134 farms were licensed at any time (although not all were actively raising alligators). Some of this growth was undoubtedly a result of exceptionally high prices for wild alligator hides in the September harvests of 1988-1990, which ranged from approximately $48 per foot to $57 per foot (thus a single “average” sized alligator of 7 feet was worth some $400 for the hide alone).

Over time, many of the new, less experienced, and smaller farms were unable to compete with the more established farms, whose larger inventories and other factors led to their ability to maintain successful operations in years of more modest prices. The number of farmers/ranchers in Louisiana gradually dropped until around 1999, when it leveled off at around 60-65 farms; as of January 2012 there were 55 licensed farms. Again, many of these are small “hobbyists”, or others who simply maintain a farming license in order to ranch eggs, and transfer the eggs or new hatchlings to other farmers. However, the inventory on farms is far higher now (486,000 in December 2011) than when there were over 120 farms (318,000 in December 1991). The peak year-end farm inventory was 731,909 alligators in December 2008, just prior to the worldwide economic recession, which led to diminished egg collection efforts in 2009 and 2010.



With time, farmers experimented and have developed many techniques to improve efficiency and minimize costs of alligator production. Development of pelletized dry feeds with vitamin supplementation can avoid storage/freezer costs needed with frozen meat diets. Floating feed trays help minimize wastage. Sheds sometimes are constructed with multiple stacked levels to allow for housing of more alligators and more efficient use of heat. The use of heated refill water also encourages better feeding by maintaining constant warm temperature.

Beginning in 2007, we initiated a health surveillance program in conjunction with the Louisiana State University School of Veterinary Medicine (LSUSVM). Alligators are randomly sampled at alligator farms for a series of health profile tests (blood plasma and serum analyses, screening for West Nile Virus, Mycoplasma, etc.); in some cases full necropsies are performed to ensure alligators from cohorts to be released to the wild are healthy. Additionally, we have retained the services of veterinary staff at the LSUSVM for consultation, should an alligator farmer be concerned an alligator on his/her farm may be ill or developing any disease process.

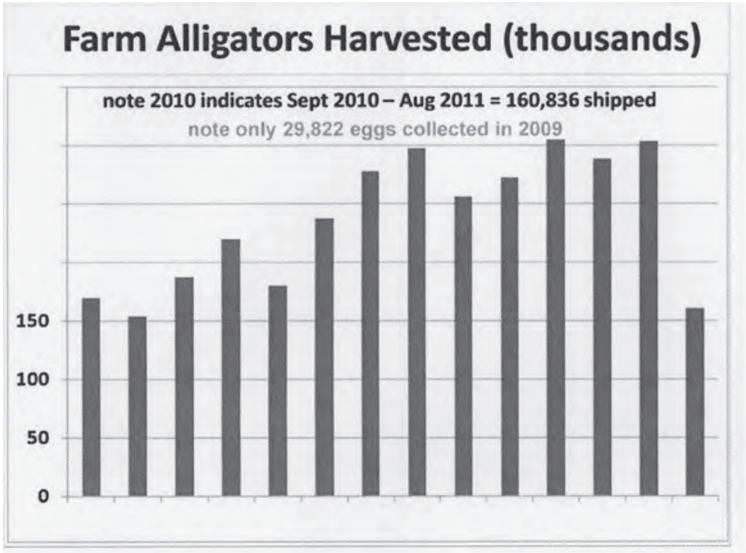
Hide Quality

As farm inventories increased, buyers and dealers were able to be more selective in choosing the highest grade/quality hides with which to prepare lots of hides to enter commercial trade. Increasingly stringent demands for near-perfect hides has been problematic for some farmers, as some portion of the hides produced will have damages due to scarring, bites, etc. Efforts are in place to find ways to continue to maintain excellent quality of skins produced on farms, such as use of deeper water (to avoid piling/scratching), hide boards (to limit stress and interaction with other alligators), vinyl liners (to avoid rough/abrasive surfaces), and filtered water (avoid possible infectious agents in standing water). Some farmers are experimenting with use of single pens in which to raise a single alligator by itself, to avoid any scars form fighting. Some farmers are also raising a portion of their alligators to larger sizes, although the majority are still sold as smaller alligators for the watchstrap industry.

Similar efforts are underway to maintain high quality wild harvested hides. Some problems (such as scars from fighting due to drought-imposed crowding) are unavoidable, but efforts have been directed to improving processing procedures (transport of carcasses in refrigerated trucks to avoid "slip" of scales, careful use of pressure washers to remove tissue remnants from hides, use of compressed air to assist in separation of the hide from the carcass and avoid knife/cuts to the hide, etc.).

Farm Production and Economic Crisis Factors

During the 2009 tag year (September 2009 through August 2010) a total of 301,017 farm alligators were harvested, averaging 28.62 cm belly width (4.58' in length). The total estimated value of these alligators was $US47.1 million. Although the data are still being compiled as skins are exported out of Louisiana, only an estimated 161,000 farm-raised alligators were harvested during the 2010 tag year (September 2010 through August 2011) reflecting the lowered egg collections in 2009 due to the economic crisis.



Beginning late winter and continuing into spring and summer of 2009, worldwide economic recession significantly impacted world trade in raw and tanned alligator skins and manufactured products. Price and demand for farm-raised alligator skins dropped precipitously during this period. The drop in price and demand coincided with the economic recession and with tanners implementing stricter quality standards. Throughout this period many farmers were unable to sell any skins; several farmers exported skins for crust tanning and later sale. Two of the largest alligator skin tanneries in the world made recommendations to the Department and alligator industry participants, urging actions which would act to reduce existing inventories of both live on-farm alligators and alligator skins. In June 2009 many farmers decided to forego egg collections in the summer of 2009 (only 29,822 eggs were collected) thereby reducing on-farm inventories of live alligators during 2009-2010. Coastal flooding associated with a tropical weather event during July 2010 limited egg collections to 205,261 eggs in 2010. Since early 2010, price and demand for both wild and farm-raised alligators has continued to rebound. Both the 2011 alligator egg harvest and the wild alligator harvest increased in 2011, with 352,381 eggs being collected.

Nuisance Alligator Program

The LDWF manages a statewide nuisance alligator control program. The nuisance program is designed to remove problem alligators in order to avoid potential human/alligator conflicts. Through the process of nuisance alligator hunter appointments and annual renewals the Department maintains a statewide network of qualified nuisance alligator hunters. Nuisance alligator complaints are phoned into various Department offices, where complaints are recorded and then forwarded to a nuisance alligator hunter in the vicinity of the complaint. Nuisance hunters respond promptly and catch and remove the alligator as deemed necessary. Hunters are allowed to harvest the nuisance alligator and to process the meat and skin of the alligator for commercial sale as reimbursement for their time required to investigate the nuisance complaint and handle the situation. This process provides for immediate response to problem alligators and for payment to the nuisance alligator hunter, thereby minimizing the program operating costs to the Department. Larger alligators are usually harvested, and smaller alligators may be relocated. Additionally, Department personnel are sometimes called to remove nuisance alligators as well.

During the winter and spring of 2009, the worldwide economic recession had a devastating impact on price and demand for alligator skins. Nuisance hunters were unable to sell large skins at profitable levels and had no sales for small (under 6' total length) alligator skins. In June 2009, the Department instituted a policy change which allows for nuisance alligator hunters to charge the complainant a fee of $US30 when they catch and remove a nuisance alligators under 6' (183 cm) in length. Preliminary records indicate this fee is rarely charged. Depending on market conditions in future years, further nuisance alligator policy changes may be necessary to ensure that appointed nuisance alligator hunters remain in the nuisance alligator program.

During 2010-11, a total of 63 nuisance alligator hunters were enrolled in the program; annually the nuisance hunters respond to an estimated 5,000 complaints and harvest some 1200-3000 alligators.

Lessons Learned

During the 40 years over which Louisiana's alligator programs have evolved, some segments have proven to be ineffective or problematic to administer, and were discontinued. For the wild harvest, in the early years "special skinning instructions" were used each year, to ensure no poaching would occur. In addition to the use of CITES tags, alligator carcasses had to be skinned in a certain fashion each year, and these instructions were not made known to trappers until the day before the season opened. This prevented prior harvest and storage of large alligators before the season opened. As centralized processing sheds for alligator carcasses were developed, the special skinning instructions proved burdensome. A legally taken, CITES tagged carcass might be improperly skinned by an inexperienced employee at a processing shed, and thus technically creates an "illegal" hide. Thus, the rule requiring special skinning instructions was discontinued. Starting in 1991 every wild or farm hide produced in Louisiana was inspected by a LDWF employee, to ensure the CITES tag is properly attached and all hides in the lot are listed on the shipping manifest.

As farm inventories became larger, and realizing that most farm hides are processed "on site" and in a controlled setting, beginning in late 2008 a policy was developed to allow for "partial" hide inspections of farm hides. Often farmers request thousands of CITES tags at a time, and these tags can be used in sequential order, which aids record keeping. In contrast, wild harvested hides can be brought to a processing shed and lots of hides are obtained from numerous trappers with CITES tags that are not in sequential order, thus record keeping is more challenging. If a farmer requests a "partial" hide inspection, some 10% of the hides are inspected (selected at random by LDWF personnel) and the farmer must sign off documenting that they requested a partial hide inspection, although a full inspection of every hide would be conducted if requested. Every wild hide must be inspected in full before a shipping label for export is issued. The use of bar coded CITES tags has helped eliminate record keeping problems due to human error.

An experimental spring/summer harvest at Marsh Island clearly showed that high numbers of adult females are harvested at this time; providing further data to reinforce the decision to have the adult alligator harvest in autumn, to select for adult males or immature alligators of either sex. It also clearly showed that conservative quotas must be set to avoid overharvest; this was discussed in detail by Elsey and Kinler (2004).

The development of the egg ranching program led to most farmers discontinuing captive breeding efforts, which have been less successful (Elsey *et al*. 1994) and less cost efficient. Captive breeding is still underway at some farms, one advantage being that the mandatory "12% returns to the wild" are not required for egg/hatchlings produced by captive breeders.

The wild ranching program also initially allowed for the collection of hatchlings, if ranchers preferred this option (to avoid construction and maintenance of egg incubators). A much higher percentage "return rate" was due (30% at 123 cm). Problems developed with the temptation for farmers to catch "hatchlings" that were older/larger than specified, and this program was discontinued.

Another problematic area which developed gradually as farmers tried to minimize costs was that less effort may be given to maintaining strict hygiene and husbandry. Obviously costs increase (heating water, labor, feed losses) the more often the alligator sheds are cleaned. We strongly encourage our farmers/ ranchers to maintain aggressive husbandry efforts. Most have learned that costs saved with lack of attention to husbandry might be offset by lower quality hides being produced, which are less valuable. Occasional "disease" outbreaks are often rectified by resuming stricter hygiene/husbandry practices. Similar problems occur in other species of intensively cultured livestock such as pigs, poultry, etc.

Best Management Practices

In 2011, the Department of Wildlife and Fisheries and the LSU School of Veterinary Medicine in conjunction with the Louisiana Alligator Farmers and Ranchers Association developed a document entitled "Best Management Practices for Louisiana Alligator Farming". The document details recommended practices to ensure animal welfare of captive reared alligators in Louisiana, including egg collection, hatching, rearing, release to the wild and euthanasia. This document will be updated as new information regarding any pertinent topic to alligator faming becomes available. The intent of this document is to ensure that licensed alligator farms and ranches are employing humane methods of working with alligators. Additionally the LDWF worked closely with Dr. Nevarez at LSU's School of Veterinary Medicine to investigate methods of euthanasia on commercial farms, and determine the most humane practice to recommend to the alligator farming industry. Results are currently being analyzed.

Future

The current level of harvest in Louisiana is clearly sustainable, as nesting counts are stable in southwest Louisiana and still gradually increasing in southeast Louisiana. Despite the harvest of wild adults and eggs in the ranching program, populations remain sufficiently healthy as to require a "nuisance" alligator program. Louisiana's alligator management programs employ many citizens and are a multi-million dollar industry (up to $US60 million in strong years) of tremendous benefit to the state.

Habitat Concerns

One threat or potential limiting factor to Louisiana's alligator population is habitat loss. Because the vast majority of Louisiana's alligators are in the coastal parishes, saltwater intrusion and wetlands/marsh deterioration from numerous causes are very real threats. The additional impacts of recent hurricanes will likely result in long term reduction of alligator habitat quality in coastal Louisiana. Some 20,000 acres (31 square miles) of coastal marshes are lost annually.

Vast resources by numerous state and federal agencies have been expended to attempt to limit these losses. Projects to restore/enhance marshes include construction of earthen terraces (to reduce wave action and turbidity), "breakwaters" and protection levees along coastlines, and freshwater diversions. Alligators benefit directly from these efforts to maintain/enhance wetlands. The freshwater diversion projects (Davis Pond and Caernarvon) shift water from the Mississippi River in hopes of re-establishing more favorable salinity conditions for numerous fish and wildlife species. Some preliminary data suggests alligator nesting has improved in the areas enhanced by lower marsh salinity levels. It is critical that habitat changes are monitored, mapped and incorporated periodically into the alligator program. This will ensure that our harvest programs are adjusted accordingly for corresponding alligator population and habitat changes.

Hurricane Impacts

Coastal Louisiana was impacted by devastating hurricanes in 2005 (Hurricanes Katrina and Rita) and 2008 (Hurricanes Gustav and Ike). In both of these years, storm surges inundated coastal marshes with high salinity waters across virtually the entire coast of Louisiana; which is prime alligator habitat. Some direct alligator mortality was observed; but overall long-term impact of these storms on alligator habitat remains to be seen. Direct physical damage to wetlands through scour, scrapes, erosion, and rolling has been noted, and high salinities were accentuated by lower than usual winter rainfall after the storms, which might have tempered the deleterious salinities. Effects of these storms on the subsequent wild alligator harvest were significant in 2006; but harvest numbers in 2007 and 2008 returned to pre-storm levels.

Results of the 2006 coastal nest survey indicated significant habitat damages in southwest Louisiana and extreme southeast Louisiana resulting from Hurricanes Rita and Katrina respectively. Nest production in 2006 was the lowest on record since 1986. During the fall and winter of 2006-2007 marsh water levels returned to near normal and the habitat recovered significantly. In 2007, coastal alligator nest production increased dramatically as wetland habitats and alligator populations recovered. Alligator farmers collected near record numbers of wild alligator eggs in 2007. In 2008, nest production was excellent and farmers collected a record of 530,579 wild alligator eggs. Hurricanes in the fall of 2008 and lower than normal spring water levels in 2009 resulted in reduced nest production in 2009 as compared to 2008. Nest production recovered gradually in 2010, however drought conditions continued to plague southwest Louisiana during 2011; southeast Louisiana had good alligator nesting in 2011.

Education/Outreach

In order to better meet the needs of the alligator industry, the Department sponsors meetings for all segments of the industry (farmers, hunters, processors, tannery personnel, and landowners) which gives the industry participants an opportunity to prioritize and discuss the current issues facing the state's alligator industry. The Department also created specific e-mail (LAalligatorprogram@wlf.la.gov) and website (http://www.wlf.louisiana.gov/wildlife/alligator-program) addresses for the alligator program to provide additional and easier methods for alligator industry participants and the general public to ask questions and acquire information. Alligator program staff continues to compile and update contact information, including e-mail addresses, which are used to promptly notify participants of available and arising program information. In addition to the on-site visits, the staff communicates with farmers on a regular basis to schedule releases, hide inspections, live animal inspections, coordinate farm transfers, alligator egg collection permits, and to issue and follow up on CITES harvest tags.

The Department contracts with the LSU School of Veterinary Medicine to provide various services to the alligator industry. On numerous occasions the staff arranged for transportation of sick or problem alligators and sample skins from farms to the LSU Vet School for necropsy or skin evaluation. One of these contracts provides for the availability of a veterinarian to respond to farm related problems. Farmers know they can contact the program staff or Dr. Nevarez and get a rapid response to their problem. We also arranged collection and delivery of alligator research specimens to numerous graduate students and university faculty.

Despite setbacks from Hurricanes Rita and Ike, numerous wildlife groups, including university and graduate students, are hosted annually at LDWF's Rockefeller Wildlife Refuge in Grand Chenier, Louisiana, for educational purposes; as are professional representatives from domestic and international organizations. Presentations are made at various civic organizations and captive alligators are often loaned out for educational purposes.

Research Activities

The Louisiana Department of Wildlife and Fisheries conducts numerous research studies annually, covering a wide range of broad categories including field studies on nesting ecology, reproductive endocrinology, captive rearing and husbandry studies, evaluation of our management programs, and we often provide research specimens or samples to university personnel. The university staff members often have expertise (molecular biology, etc.) beyond what we could accomplish in a rural remote field setting, and their detailed lab studies often support research endeavors and lead to advanced degrees by post-graduate students. Research studies would be a topic for an entire separate report than the scope of this document.

Revenue and Expenditure Information

In recognizing that the Louisiana alligator industry is a vital aspect of Louisiana's economy and recognizing the many, varied national and international impediments to industry development, and the need to develop and maintain a total alligator conservation program, the Louisiana legislature established the Louisiana Alligator Resource Fund in 1991 (R.S. 56:279). This Act established a dedicated source of revenue intended to help defray the costs of the alligator program within the Coastal and Nongame Resources Division of the Department. The specific goals of the legislation are:

1. To provide salaries and financial support including associated indirect costs for the following positions, to provide a minimum of two full-time technical positions (biologists) and 8 nontechnical positions such as computer operators, secretaries, and wildlife specialists existing within the Coastal and Nongame Resources Division of the Louisiana Department of Wildlife and Fisheries.
2. To assist with funding for law enforcement activities associated with the alligator farm industry when surplus funds are available and recommended by the Louisiana Alligator Advisory Council.
3. To assist with funding marketing programs recommended by the Louisiana Alligator Advisory Council when surplus funds are available.
4. To actively fund research on all aspects involved with alligator conservation and to develop the techniques needed to enhance the commercial alligator industry.
5. To assist in funding management of the alligator population through proper management, harvest and farm facility management.

This legislation provides all the enabling language required to establish the Louisiana Alligator Resource Fund including sources of income, investing of the fund, and expenditures from the fund. Further R.S. 56: 253 establishes the alligator hide tag fee and the alligator shipping label fee, specifies the details of collection of these fees, and establishes that these fees shall be no more than $4.00 per hide or live alligator. R.S.56:256, provides for the collection of a $0.25 severance tax on each alligator hide taken within the state. R.S. 56:279 C (1) provides that all revenues received by the state from tag fees, alligator shipping label fees, and from the severance tax on alligator skins shall be credited to the Louisiana Alligator Resource Fund. The alligator industry should be applauded for supporting these legislative endeavors to create a self-generated source of revenue to develop and maintain the state's alligator management program.

Currently the alligator program staff in Louisiana consists of five full time biologists (and one biologist who is assigned to do alligator work as half of his duties), three wildlife technicians, one full time and one half-time administrative coordinators, and one data manager.

Summary

Louisiana's alligator management programs have clearly illustrated that controlled sustained use of the species is feasible. The wild harvest has been in place for nearly 40 years (since 1972), and the egg ranching program for 25 years (since 1986) and may appear to operate unchanged every year. However, constant adaptations are made to try to improve both programs. The annual surveys lead to review of harvest quotas and possible changes for each parish as marsh types change and nesting efforts are affected. Constant requests by user groups (farmers, egg ranchers, trappers, landowners, buyers, dealers and other industry personnel) are received and considered as the LDWF tries to safely manage the resource to the benefit of many user groups with varied interests.

Louisiana's alligator industry is unique. It has recognized the necessity of establishing a self-generated revenue source to provide the necessary regulatory and management efforts to effectively manage the alligator resource. The Department will continue to protect the alligator resource while striving to ensure long term, sustainable harvest programs.

Literature Cited

Chabreck, R.H., Joanen, T. and Palmisano, A.W. (1968). Vegetative Type Map of the Louisiana Coastal Marshes. Louisiana Wildlife and Fisheries Commission: New Orleans.

Elsey, R.M., Moser, E.B., McNease, L. and Frederick, R.G. (1998). Preliminary analysis of survival of farm-released alligators in southwest Louisiana. Proc. Ann. Conf. Southeast. Assoc. Fish and Wildl. Agencies 52: 249-259.

Elsey, R.M., McNease, L. and Joanen, T. (2001). Louisiana's alligator ranching program: a review and analysis of releases of captive-raised juveniles. Pp. 426-441 *in* Crocodilian Biology and Evolution, ed. by G. Grigg, F. Seebacher, and C.E. Franklin. Surrey Beatty & Sons: Chipping Norton.

Elsey, R.M., and Kinler, N. (2004). Louisiana's alligator program: adapting management as populations recover and risk of unsustainable use decreases. Pp. 92-101 *in* Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Joanen, T. (1969). Nesting ecology of alligators in Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners Conference 23: 141-151.

Joanen, T. and McNease, L. (1970). A telemetric study of nesting female alligators on Rockefeller Refuge, Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners Conference 24: 175-193.

Joanen, T. and McNease, L. (1972). A telemetric study of adult male alligators on Rockefeller Refuge, Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners Conference 26: 252-275.

McNease, L. and Joanen, T. (1974). A telemetric study of immature alligators on Rockefeller Refuge, Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners Conference 28: 482-500.

McNease, L. and Joanen, T. (1978). Distribution and relative abundance of the alligator in Louisiana coastal marshes. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 32: 182-186.

Joanen, T. and McNease, L. (1981). Management of the alligator as a renewable resource in Louisiana. Georgia Department of Natural Resources Technical Bulletin 5: 62-72.

Joanen, T. and McNease, L. (1987a). The management of alligators in Louisiana, USA. Pp. 33-42 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Joanen, T. and McNease, L. (1987b). Alligator farming research in Louisiana, USA. Pp. 329-340 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Joanen, T. and McNease, L. (1991). The development of the American alligator industry. Pp. 9-28 *in* Proceedings Intensive Tropical Animal Production Seminar DPI: Townsville.

Joanen, T., McNease, L., Elsey, R. and Staton, M. (1997). The commercial consumptive use of the American alligator (*Alligator mississippiensis*) in Louisiana: its effect on conservation. Pp. 465-506 *in* Harvesting Wild Species - Implications for Biodiversity, ed. by C.H. Freese. The Johns Hopkins University Press: Baltimore.

McNease, L., Kinler, N., Joanen, T., Richard, D.M. and Richard, D.S. (1994). Distribution and relative abundance of alligator nests in Louisiana coastal marshes. Pp. 108-120 *in* Crocodiles. Proceedings of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Palmisano, A.W., Joanen, T. and McNease, L. (1973). An analysis of Louisiana's 1972 experimental alligator harvest program. Proceedings of the Southeastern Association of Game and Fish Commissioners Conference 27: 184-206.

Stevenson, O.H. (1904). Utilisation of the skins of aquatic animals. U.S. Comm. Fish and Fisheries Report 1902: 281-352.

Taylor, D. and Neal, W. (1984). Management implications of size-class frequency distributions in Louisiana alligator populations. Wildl. Soc. Bull. 12: 312-319.

Crocodile Management and Research in the Northern Territory of Australia, 2008-2011

Yusuke Fukuda[1], Keith Saalfeld[1], Brett Easton[1], Grahame Webb[2,3], Charlie Manolis[2] and Matthew Brien[2,3]

[1] Department of Natural Resources, Environment, the Arts and Sport, Northern Territory Government, PO Box 496, Palmerston, N.T. 0831, Australia
[2] Wildlife Management International Pty. Limited, PO Box 530, Karama, N.T. 0813, Australia
[3] School of Environmental Research, Charles Darwin University, N.T. 0909, Australia

Abstract

The wild populations of Saltwater Crocodiles (*Crocodylus porosus*) and the endemic Australian Freshwater Crocodiles (*C. johnstoni*) in the Northern Territory of Australia (NT) are managed by the Northern Territory Government, through the Department of National Resources, Environment, the Arts and Sport (NRETAS). The only exception is Kakadu National Park (KNP), where crocodiles are managed by the Commonwealth Government through Parks Australia. The primary aims of management are: (1) conservation of crocodiles through sustainable use where applicable (outside KNP); (2) monitoring of the population status and/or the impact of harvest; and, (3) control of problem crocodiles to promote public safety. The effective management of wild and captive crocodiles relies on evidence-based decisions, ideally derived from scientific research. The NT has a long history of pursuing crocodile research, and there remain many different people and organisations in the NT involved in research today. Some of the research programs currently being undertaken in the NT are summarized.

Management

The wild populations of Saltwater Crocodile (*Crocodylus porosus*) and the endemic Australian Freshwater Crocodile (*C. johnstoni*) in the Northern Territory of Australia (NT) are managed by the Northern Territory Government, through the Department of National Resources, Environment, the Arts and Sport (NRETAS). The only exception is Kakadu National Park (KNP), in which crocodiles are managed by the Australian Government through Parks Australia. The primary aims of management are: conservation of crocodiles through sustainable use where applicable (outside KNP); monitoring of population status and/or the impact of harvest; and, control of problem crocodiles to promote public safety. The management consists of the following components that collectively work as a mechanism to achieve the management goals.

Management Programs

Since 1987, the management of crocodiles in the Northern Territory has been governed by formal management programs, now with a 5-year life span, approved at the Territory level by the Administrator of the Northern Territory, and at the Commonwealth level by the Minister responsible for wildlife and the environment. The two programs currently in force are the: Management Program for the Saltwater Crocodile in the Northern Territory of Australia, 2009-2014 (Leach *et al*. 2009) and Management Program for the Freshwater Crocodile (*Crocodylus johnstoni*) in the Northern Territory of Australia, 2010-2015 (Delaney *et al*. 2010). Both programs are administered by NRETAS.

Both Saltwater and Freshwater Crocodiles are protected species under the *Territory Parks and Wildlife Conservation Act*, and at the Commonwealth level, under the Australian *Environment Protection and Biodiversity Conservation Act* which is Australia's enacting legislation for the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). *Crocodylus johnstoni* and the Australian population of *C. porosus* are both on Appendix II of CITES, which allows commercial use of wild populations subject to the demonstration of non-detriment and other conditions of Article IV of CITES (Regulation of Trade in Specimens of Species included in Appendix II).

Saltwater Crocodiles are and always have been serious predators (Caldicott *et al*. 2005) and for people to co-exist with abundant crocodile populations presents a number of challenges to the Territory community. On the other hand, crocodiles also provide significant opportunities through consumptive (skins and meat) and non-consumptive (tourism) uses. They are a valuable resource to both Indigenous and non-Indigenous people in northern Australia (Webb and Manolis 1993; Leach *et al*. 2009).

Historically, uncontrolled trade in Saltwater Crocodile skins between 1945 and 1971 stimulated intensive hunting that depleted the wild populations to the point of near extinction (Webb *et al*. 1984). It was unclear whether the remaining crocodile population had the capacity to recover when full protection of the species was introduced in 1971. In contrast, *C. johnstoni* were only hunted intensively for some 5 years, from 1959 to 1964 before protection (Webb *et al*. 1987). The skin of *C. johnstoni* had limited commercial value relative to *C. porosus*, and entered the market when the availability of the latter declined. Because *C. johnstoni* were considered innocuous relative to *C. porosus*, were endemic to Australia, and their hunting in large numbers within freshwater rivers and billabongs was unpopular with cattle station owners and the public, they were protected earlier, in 1964.

The recovery of the *C. johnstoni* population in the NT since 1964 went largely unnoticed by the general public. The species does not have a high profile as a predator on humans (Webb and Manolis 1989), although they occasionally bite swimmers (Hines and Skroblin 2010; Somaweera 2011; Lindner 2004). Furthermore, they tend to occupy upstream freshwater habitats away from populated areas (Webb *et al*. 1987). Since the late 1990s, their population status has changed greatly due to the arrival of cane toads (*Rhinella marina*, formerly *Bufo marinus*), which is discussed below.

In contrast, the recovery of the *C. porosus* population in the NT since protection (1971) quickly became the focus of public attention. The recovery of depleted populations was originally fostered on the basis of re-establishing them as an integral part of the NT wetland ecosystems. By 1979/80, the population had increased from an estimated 3000-5000 mostly small juveniles, to around 30,000 mostly larger animals (Webb *et al*. 1984). When a series of fatal and non-fatal attacks occurred within 12 months, and some crocodiles started attacking fishing boats, public concern about the population recovery increased. The negative view associated with increasing human-crocodile conflict threatened the conservation program, which was broadly aimed at rebuilding the wild population back to carrying capacity. Some people opposed any further expansion of crocodile numbers and calls for widespread culling became commonplace.

In the early 1980s the NT Government implemented an "incentive-driven conservation" strategy (Hutton and Leader-Williams 2003), through which the potential economic benefits of having large populations of crocodiles was actively promoted. Positive incentives were created through commercial activity (tourism, crocodile farming and ranching) and negative incentives countered by an active 'Problem Crocodile' control program. Ranching of eggs (the commercial collection of eggs from the wild for incubation and raising in captivity) was introduced as the safest strategy for sustainable use to reward landowners for tolerating crocodiles. The egg stage is an abundant and naturally vulnerable part of the life cycle and more importantly, it had the potential to make *C. porosus* nesting habitats on private lands a commercial asset, worth protecting, as had occurred with American Alligators (Alligator mississippiensis) in Louisiana, USA (Joanen and McNease 1987).

At that time, *C. porosus* was on Appendix I of CITES and no wild-caught animals (even if taken as eggs) could be traded internationally. In 1985 Australia was successful in having its *C. porosus* population transferred from Appendix I to Appendix II of CITES, specifically for ranching, so that farms could export the skins produced from the harvested eggs they purchased from landowners. In 1987, the first NT crocodile management program was approved by the Australian Government and skins derived from the ranching program began to be exported. In 1994, Australia obtained an unrestricted Appendix-II listing so that landowners with crocodiles, but no crocodile nesting habitat, could also receive commercial benefits from crocodiles through a wild harvest (Leach *et al*. 2009).

The NT Government initially fostered and assisted the establishment of the crocodile farming industry. This role is now largely free of Government, and over the last decade the industry has invested significantly in infrastructure to increase its capacity commensurate with the increasing availability of eggs. Competition for eggs has increased prices for landowners, including Aboriginal people in remote areas where conventional opportunities for economic development are limited. Skin exports have been rising continually over the last decade.

Saltwater Crocodile populations have recovered in the NT (Webb *et al*. 2000; Fukuda *et al*. 2011). They are abundant in most coastal wetlands, and they are no longer a threatened species. They continue to be viewed as a valuable commercial resource, generating wealth and employment in the community, which provides on-going incentives for their conservation. The continuation of a viable crocodile farming industry is recognized as the key economic driver for the Saltwater Crocodile Management Program. The incentive driven conservation approach explicitly encourages management practices that favour the Saltwater Crocodile and protects wetland habitats outside the boundaries of parks and reserves.

The Saltwater Crocodile Management Program addresses the balance that is required between conservation goals, sustainable harvest, a growing industry, and the maintenance of public safety. It focuses on mechanisms to improve public awareness and safety, on population dynamics, harvest limits and monitoring the impact of the harvest on population trends.

Population Monitoring

The wild populations of both *C. porosus* and *C. johnstoni* have been monitored at varying levels of intensity since protection (Messel *et al*. 1981; Webb *et al*. 1984, 2000; Fukuda *et al*. 2011). The first surveys of Saltwater Crocodiles in tidal rivers were conducted in 1971 by Professor Harry Messel from the University of Sydney. His team introduced standardized spotlight surveys in tidal rivers in 1975 (Messel *et al*. 1981), and the standardization of the method has been maintained despite surveys being conducted by various institutions, giving consistent time-series data on population recovery. Furthermore, the same survey methods have been employed in some upstream, non-tidal rivers, containing mainly *C. johnstoni*.

With *C. porosus*, survey results allow changes in population density (abundance and biomass per km) and the population size structure, in different rivers, to be quantified over time (Fukuda *et al.* 2007, 2011). The results also provide insights into changes in the spatial distribution of both species over time. Such information from the analysis of the survey data is essential for the effective management of crocodile populations.

The original aim of surveying *C. porosus* populations was to quantify the status of the depleted wild populations in different rivers around the NT coastline; trying to discover where any larger populations may have been remaining. However, over time, the continued surveys focused on quantifying the rate of recovery over time and ensuring that the uses of crocodiles (ranching, problem crocodiles, wild harvest) were sustainable. To rationalize the costs of monitoring, the number of rivers surveyed regularly was reduced to 12, all with medium to high densities of Saltwater Crocodiles. Four of these rivers are within KNP and 8 are outside KNP [see Fukuda *et al.* (2011) for river specifications]. The frequency of surveys in these 12 rivers was annual for 5 rivers and biennial for 7 rivers. The results confirm the large and obvious recovery of *C. porosus* populations that has occurred in the NT (Webb *et al.* 1984, 2000; Fukuda *et al.* 2011). Abundance (number of non-hatchlings sighted per kilometre of river surveyed) and biomass (kilogram of non-hatchlings sighted per kilometre of river surveyed) have both increased (Fig. 1). It is expected that crocodile abundance will be saturated before the biomass density reaches the carrying capacity (Fukuda *et al.* 2011), because the mean size of animals continues to increase. The survey results provide unequivocal evidence that the harvest programs since 1979 have not been detrimental to the population.

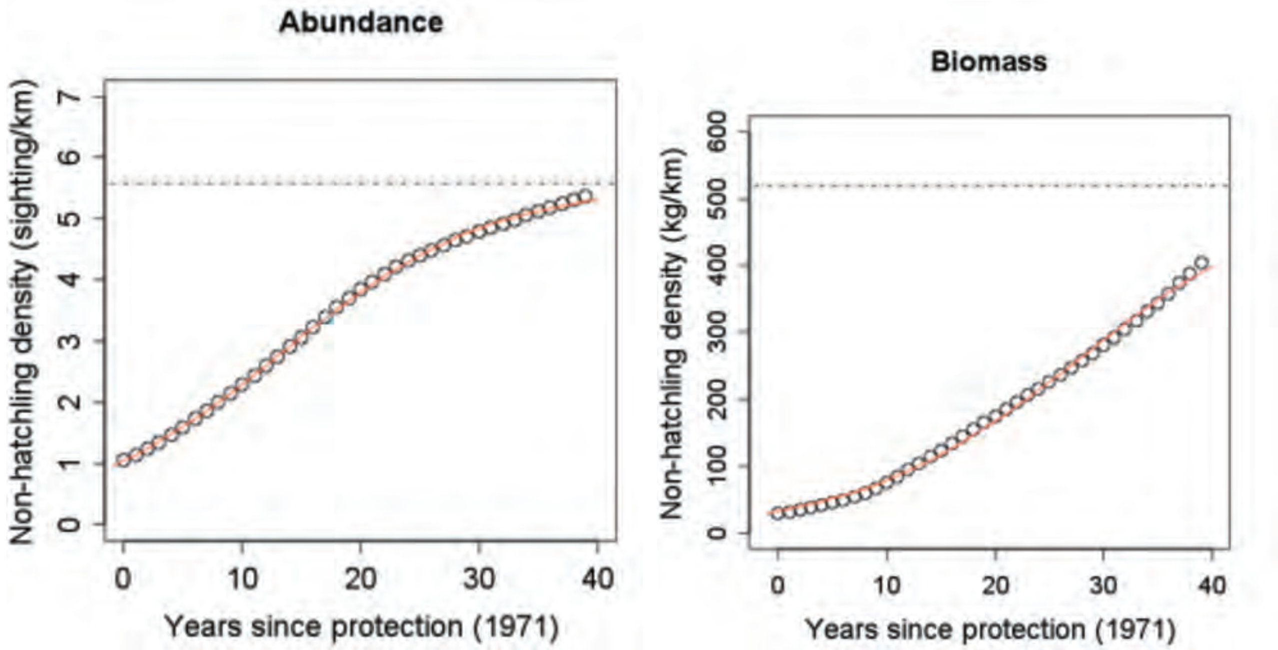


Figure 1. Abundance and biomass densities of non-hatchling (>0.6 m) *C. porosus* across all monitored sections of all monitored rivers (682 km) in the Northern Territory, Australia, predicted for 1971-2010 (derived from Fukuda *et al.* 2011).

For *C. johnstoni*, the Adelaide, Daly and Mary Rivers are surveyed for the population monitoring purpose under the current management program (Delaney *et al.* 2010). In the upstream tidal part of the Adelaide River, the numbers of Freshwater Crocodiles sighted are low by comparison to the increasing numbers and sizes of Saltwater Crocodiles (Fig. 2). Between 1977 and 2001 there was no significant relationship between density of *C. johnstoni* and time ($p = 0.44$; mean density= 0.20 ± 0.02), but between 2002 and 2011, density decreased by 67.3% (0.06 ± 0.01). Similarly, in the tidal parts of the Daly River, the populations of both *C. porosus* and *C. johnstoni* were increasing linearly up to 2001, when the Freshwater Crocodile population went into dramatic population decline (but not the Saltwater Crocodile population). In both cases these results are correlated with the arrival of invasive cane toads (*Rhinella marina*), which some evidence (Letnic and Ward 2005; Letnic *et al.* 2008) indicates are far more toxic to Freshwater Crocodiles than to Saltwater Crocodiles. Competitive exclusion of Freshwater Crocodiles by Saltwater Crocodiles has perhaps been ongoing in these areas of sympatry since the recovery of Saltwater Crocodiles started (1971) (Webb *et al.* 1983), but cannot explain the dramatic and sudden decrease in Freshwater Crocodile abundance.

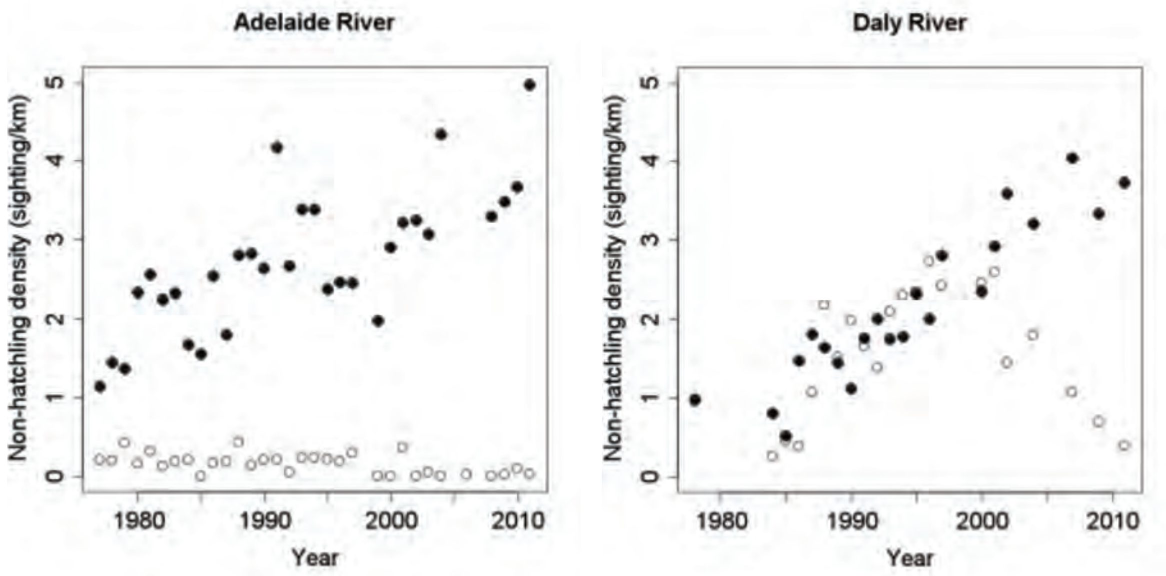


Figure 2. Abundance density of non-hatchling (>0.6 m) Saltwater Crocodiles (closed symbols) and Freshwater Crocodiles (open symbols) sighted during spotlight surveys.

These results of the monitoring programs detecting and quantifying the decline in Freshwater Crocodile populations confirm the ability of the monitoring programs sufficiently robust to detect any serious population decline resulting from unsustainable use or any other potential threat, and add weight to the case for standardized monitoring remaining an implicit part of all future management programs for crocodiles in the NT.

The long-term consequences of the decline in freshwater crocodile populations, due to cane toads, are unclear. In Queensland of Australia, cane toads occur in most areas where Freshwater Crocodiles occur, but there are no data indicating what happened to Freshwater Crocodile abundance when the cane toads first arrived (in the 1930s). Furthermore, the population processes may be further complicated by cane toads appearing to have an even greater impact on the monitor lizards, which are the major predator on freshwater crocodile eggs (discussed below in McKinlay River).

Sustainable Harvest

Prior to European settlement in the 19th century, Aboriginal people hunted crocodiles and harvested eggs for food and ceremonies for tens of thousands of years (Webb *et al.* 1984; Lanhupuy 1987). Their customary use is considered to have always been within sustainable levels (Webb *et al.* 1984; Leach *et al.* 2009).

Intense commercial hunting started in the 1940s and continued until Freshwater Crocodiles and Saltwater Crocodiles became protected in 1964 and 1971, respectively (Webb *et al.* 1984). The uncontrolled hunting resulted in a serious decrease in the number of crocodiles throughout northern Australia (Messel *et al.* 1981; Webb *et al.* 1984). As the populations recovered under protection, the experimental harvest of Saltwater Crocodile eggs started in the NT in 1983. Because the trial harvest of eggs in the first few years (1983-1985) showed no negative effect on the number of hatchlings in the harvested population (Webb *et al.* 1989), raised juveniles were not returned to the wild as compensation for the egg harvest. The egg collection program for commercial farming, without any compensation, has continued for almost 30 years (Leach *et al.* 2009). The annual quota of eggs has increased over time (Fig. 3) and is currently up to 60,000 live eggs per season (Leach *et al.* 2009). The extensive population monitoring has shown no detrimental impact of the harvest in any rivers (Fukuda *et al.* 2011). Direct harvest of crocodiles (hatchlings, juveniles and adults) from the wild also started in 1998. Currently, up to 500 hatchlings, 400 juveniles and 500 adults are allowed to be harvested annually under the management program (Leach *et al.* 2009). Safari hunting of up to 50 crocodiles (>3.5 m) per year as part of the annual quota for adults has been proposed by the NT Government, and the Australian Government is assessing the proposal for approval. Safari hunting will allow landowners to gain more income from the same crocodiles through charging higher fees for hunters to shoot a crocodile for a trophy under the supervision of licensed operators.

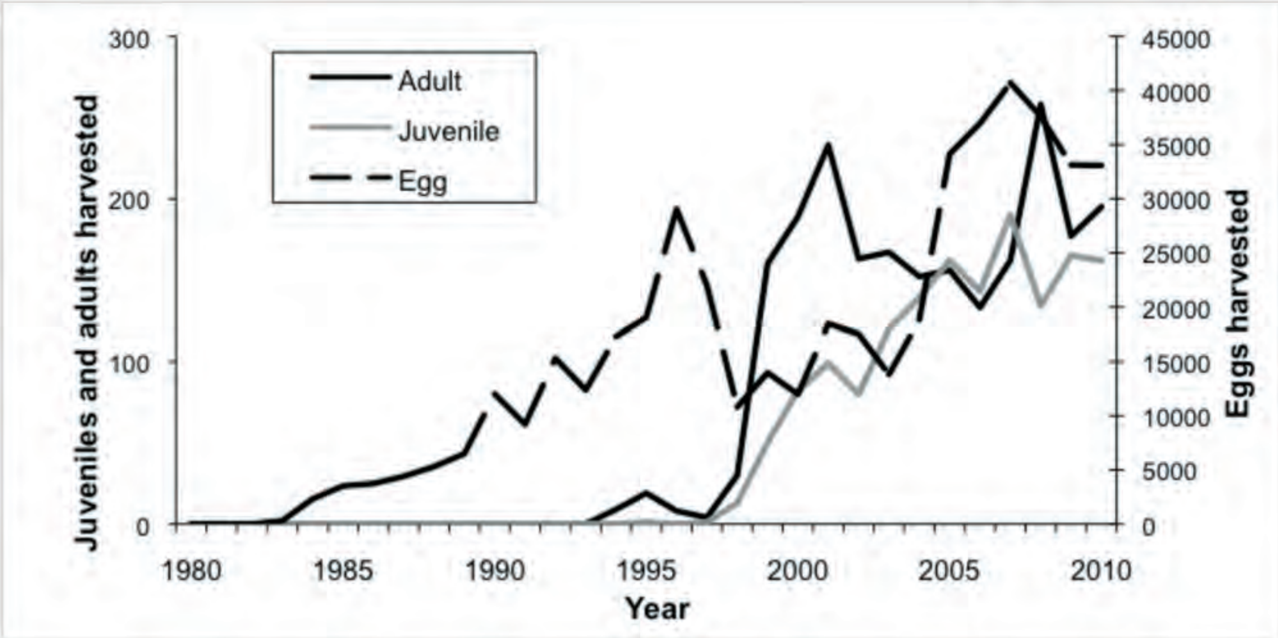


Figure 3. Historical harvest of eggs, juveniles and adults of Saltwater Crocodiles after protection (1971) in the Northern Territory.

Like Saltwater Crocodiles, the sustainable harvest of freshwater crocodiles has also been allowed under the management programs since 1983, mainly for eggs and hatchlings (Delaney *et al*. 2010). Because of the lower value of their skin due to larger osteoderms and scale pattern, the demands for leather from Freshwater Crocodiles, and thus pressure to harvest, havealways been small (Delaney *et al*. 2010). Neither eggs nor hatchlings of Freshwater Crocodiles are commercially harvested for farming although some are taken for the pet industry (Delaney *et al*. 2010).

All the harvest activities for both Freshwater and Saltwater Crocodiles are carried out under the Northern Territory permits (Leach *et al*. 2009; Delaney *et al*. 2010). The NT Government reports to the Australian Government to fulfill the requirements for the international trading of crocodile products under CITES. Harvesters are required as a permit condition to submit to the NT Government a return with harvest details (eg the number of eggs or animals harvested, GPS location, date, etc.).

Farming

Crocodiles and eggs harvested from the wild, and those produced through captive breeding, are reared and/or processed at licensed crocodile farms in the Northern Territory or interstate. There are currently 6 crocodile farms operating in the NT. For Saltwater Crocodiles, harvested eggs are transferred into an incubator immediately after collection and hatched crocodiles are reared in raising pens until they grow to a preferred size for production (approximately 1.8-2.1 m). Crocodiles are processed at an abattoir into skins, meat,backstraps, heads and other byproducts. Most skins are exported and most byproducts sold domestically. Crocodiles caught as problem crocodiles (see below) are also transferred tocontracted farms and they are either immediately processed for commercial production or kept as breeding stock.

The Management Programsfor both freshwater crocodiles and saltwater crocodiles approved by the Australian Government requires the NT Government to conduct annual audits of eggs and hatchlings to ensure that the harvest does not exceed the annual harvest ceiling (Leach *et al*. 2009). Should there be any permit compliance issue, such as a failure to submit the permit return or discrepancies between the number of animals reported and the number kept on farms, the case is further investigated by the responsible government agency (Leach *et al*. 2009). Animal welfare in capturing, keeping and processing crocodiles is also monitored by the NT Government. Harvesters and farmers are required to meet the animal welfare standards specified by the Australian Code of Practice and the *Animal Welfare Act*, as a condition of permits. All crocodile famers are visited regularly by the NT Government staff and welfare standards are monitored during these visits. The NT also issues a permit for exporting live crocodiles or their product to the other states and territories of Australia. Overseas export of live crocodiles and their products requires an additional CITES permit issued by the Australian Government.

Public Safety

Australian Freshwater Crocodiles are generally considered harmless to people unless provoked (Caldicott *et al*. 2005; Delaney *et al*. 2010), although some attacks occur and they can cause injuries (Hines and Skroblin 2010). In contrast, the frequency of human-crocodile conflict with Saltwater Crocodiles is increasingly becoming a major concern, particularly in urban and residential areas (Nichols and Letnic 2008; Leach *et al*. 2009). As the Saltwater Crocodile population recovered, crocodiles started appearing in areas where they had rarely been seen in the past (eg far upstream of freshwater rivers, recreational water areas for swimming and fishing), and where people had assumed swimming was "safe".

The NT Government runs a public safety management program which actively reduces crocodile numbers in populated areas(NRETAS 2012), and in other situations where they poseanundue risk to people or livestock. Such crocodiles are termed "problem crocodiles". The public safety program called "Be CROCWISE" is a strategy that combines a series of campaigns to increase the public awareness of the risk of crocodiles around NT waterways through public education, advertisement in the various forms of media and warning signs at sites. Problem crocodile management zones are defined around Darwin and Katherine as well as in various parks and reserves where recreational swimming is permitted (Leach *et al*. 2009). Problem crocodiles are removed from these management zones and are relocated to a crocodile farm by the crocodile management unit (Nichols and Letnic 2008; Leach *et al*. 2009; Letnic *et al*. 2011). Permits to remove problem crocodiles from private land such as pastoral and indigenous areas are also issued by request. With the increasing effort in catching problem crocodiles (eg increasing the number of traps and patrolling staff), the number of problem crocodiles caught by the NT Government has been consistently increasing (Fig. 4). As the population of both humans and crocodiles keeps expanding, the continuation of the crocodile management program is critical to reduce the conflict. Commercial harvest in its various forms (egg, hatchlings, juveniles and adults) under regulated quotas has not been considered an effective tool for controlling problem crocodile numbers in the NT as yet. Similarly, proposed safari hunting is primarily supported for commercial gain to the operators and landowners, and not as a strategy for improving public safety or reducing crocodile numbers.

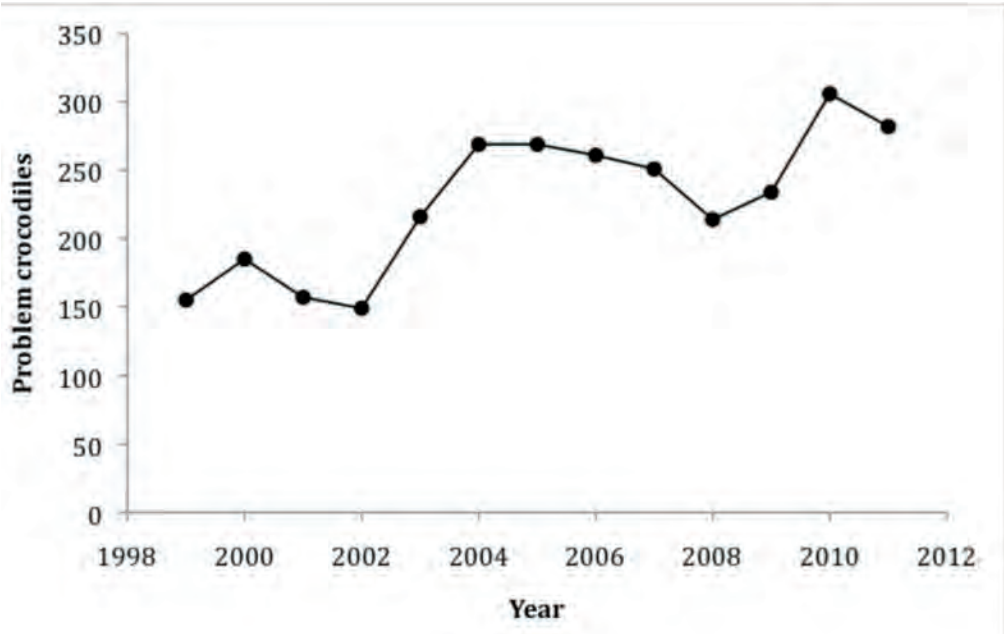


Figure 4. Numbers of Problem Saltwater Crocodiles captured in the Northern Territory, 1999-2011.

Research

The effective management of wild and captive crocodiles relies on evidence-based decisions, ideally derived from scientific research. The NT has a long history of pursuing crocodile research, and there remain many different people and organisations involved in general research involving crocodiles. Some of the research programs currently being undertaken in the NT are summarised below.

<u>Satellite Tracking (G. Webb, C. Manolis, G. Lindner and M. Brien)</u>

The upstream movement of large Saltwater Crocodiles into freshwater areas used for recreational activities by people (Letnic and Connors 2006) poses a particularly challenging management problem, yet our knowledge base on the movement of large saltwater crocodiles remains remarkably limited. Under the direction of Wildlife Management International (WMI), a consortium of interested stakeholders [Parks Australia North (PAN), WMI, Parks and Wildlife Service of the Northern Territory (PWSNT), Charles Darwin University (CDU); NT Tourist Commission] initiated a satellite racking study, mainly of large Saltwater Crocodiles. A novel method for attaching the transmitters was developed (Brien *et al*. 2010), and tracking devices were deployed on 22 mainly adult males, 4 of which were relocated 350 km from their site of capture. The relocated individuals were highly mobile after release (relative to those released at their capture site), but did not return to their capture site. The results are still in the process of being analysed.

Mckinlay River (G. Webb, C. Manolis)

The Australian Freshwater Crocodile population in the McKinlay River was the main population at which basic research on the ecology and population dynamics of this species was conducted. Part of that study was a large mark-recapture study, initiated in 1978, which led to one of the first descriptions of the age-structure of a crocodile population, which in turn allowed calculation of age-specific mortality rates (Smith and Webb 1986; Webb *et al*. 1983). During the 1980s and 1990s various additional studies resulted in a high proportion of the crocodiles in the river system being marked, with a known history. Prior to the arrival of cane toads, a major recapture effort (with more marking) was conducted so that survival rates could be quantified before the cane toads arrived (2004-05) and resources permitting a further capture effort will be made in 2013, to quantify survival rates since the toads arrived. It has already been established that cane toads are particularly toxic to the varanid lizards that are the main predator on crocodile eggs, and that hatchling recruitment increased by 600% after the toads arrived (even if less nests are made).

Hatchling *C. porosus* growth and survival (M. Brien, G. Webb)

Survival rates of hatchling *C. porosus* to one-year-of-age are a fundamental population dynamic contributing to the health and ongoing survival of the wild population (Webb and Smith 1987), but also to the captive or farmed population which ultimately generates the economic incentives needed for the public to tolerate large, wild populations of a serious predator within the NT (Webb *et al*. 2000).

Survival of hatchling *C. porosus* to one-year-of-age in captivity (85-90%) is high compared to in the wild (20-60%) in northern Australia. However, not when compared with survival rates (95-99%) of farmed American Alligators (*Alligator mississippiensis*) (Joanen and McNease 1976). Mortality of hatchling *C. porosus* is ultimately due to a 'failure to thrive syndrome' (FTT) in which growth is compromised for unknown reasons in a segment of the population ultimately leading to increased mortality.

The main focus of this study is to examine poorly understood aspects of thermal and social behaviour of hatchling *C. porosus* both in the wild and in captivity. The results of this research will improve our understanding of the requirements of hatchling *C. porosus*, and will provide valuable information to help achieve conservation, management and industry goals for this species.

Harvest simulation Models (Y. Fukuda)

To understand better the impacts of the harvest and removal of problem crocodiles on the population size and structure, stage-based matrix models were developed for the density-dependent Saltwater Crocodiles (*C. porosus*) population in the NT, incorporating environmental stochasticity and harvest at historical (1983-2010) and projected (2011-2030) levels.

The models simulate the population growth based on vital rates, some of which are density dependent, derived from the literature and survey data. It provides the estimates of the population size and structure at any year in 1971-2030, as well as the different influences of each life stage (egg, hatchling, juvenile and adult) on the viability of the whole population. By running the models with harvest intensities at different levels for each of the life stages, it can also simulate the likely impact of the harvest under different scenarios.

This will be used as a tool for assessing the sustainability of the future harvest quota and the effectiveness of the strategic removal of problem crocodiles. The scale of this study is the Northern Territory (one large population for the whole Northern Territory) but the models are expected to be divided into regions or catchments, especially where intensive harvest consistently occurs, as more localised, deficient data become available in the future. The project is conducted as a part of the crocodile population monitoring program by the NT Government (Leach *et al*. 2009).

Acknowledgements

The Department of Natural Resources, Environment, the Arts and Sport of the Northern Territory, and Wildlife Management International, provided resources needed for preparing this paper. We thank to all involved in the management and research of crocodiles in the Northern Territory of Australia. Without the commitment of hundreds of people over many years, we surely would not have been this far today with the conservation of crocodiles.

Literature Cited

Brien, M., Webb, G., Manolis, C., Lindner, G. and Ottway, D. (2010). A method for attaching tracking device to crocodilians. Herpetological Review 41: 305-308.

Caldicott, D.G.E., Croser,D., Manolis, C., Webb, G. and Britton, A. (2005). Crocodile attack in Australia, an analysis of its incidence, and review of the pathology and management of crocodilian attacks in general. Wilderness and Environmental Medicine 16: 143-159.

Delaney, R., Neave, H., Fukuda, Y. and Saalfeld, K. (2010). Management Program for the Freshwater Crocodile (*Crocodylus johnstoni*) in the Northern Territory of Australia, 2010-2015. NRETAS: Darwin. Available online at http://www.nretas.nt.gov.au/plants-and-animals/programs/approved.

Fukuda, Y., Webb, G., Manolis, C., Delaney, R., Letnic, M., Lindner, G. and Whitehead, P. (2011). Recovery of saltwater crocodiles following unregulated hunting in tidal rivers of the Northern Territory, Australia. Journal of Wildlife Management 75: 1253-1266.

Fukuda, Y., Whitehead, P. and Boggs, G. (2007). Broad scale environmental influences on the abundance of saltwater crocodiles, *Crocodylus porosus*, in Australia. Wildlife Research 34: 167-176.

Hines, K.N. and Skroblin, A. (2010). Australian freshwater crocodile (*Crocodylus johnstoni*) attacks on humans. Herpetological Review 41: 430-433.

Hutton, J.M. and Leader-Williams, N. (2003). Sustainable use and incentive-driven conservation: realigning human and conservation interests. Oryx 37: 215-226.

Joanen, T. and McNease, L. (1976). Culture of immature American alligators in controlled environment chambers. Proceedings of the World Mariculture Society 7: 201-211.

Lanhupuy, W. (1987). Australian aboriginal attitude to crocodile management. Pp. 145-147 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton, Australia.

Leach, G.J., Delaney, R. and Fukuda, Y. (2009). Management Program for saltwater crocodile (*Crocodylus porosus*) in the Northern Territory of Australia, 2009-2014. NRETAS: Darwin. Available online athttp://www.nretas.nt.gov.au/plants-and-animals/programs/approved.

Letnic, M. and Ward, S. (2005). Observations of freshwater crocodiles (*Crocodylus johnstoni*) preying upon cane toads (*Bufo marinus*) in the Northern Territory. Herpetofauna 35: 98-100.

Letnic, M., Webb, J.K., and Shine, R. (2008). Invasive cane toads (*Chaunus marinus*) cause mass mortality of freshwater crocodiles (*Crocodylus johnstoni*) in tropical Australia. Biological Conservation 141: 1773-1782.

Messel, H., Vorlicek, G.C.,Wells, G.A. and Green,W.J. (1981). Monograph 1. Surveys of the Tidal Systems in the Northern Territory of Australia and their Crocodile Populations. The Blyth-Cadell River Systems Study and the Status of *Crocodylus porosus* Populations in the Tidal Waterways of Northern Australia. Pergamon Press: Sydney.

Nicholds, T. and Letnic, M. (2008). Problem crocodiles: reducing the risk of attacks by *Crocodylus porosus* in Darwin Harbour, Northern Territory, Australia. Pp. 509-517 *in* Urban Herpetology: Herpetological Conservation Vol. 3, ed. by R.E. Jung and J.C. Mitchell. Society for the Study of Amphibians and Reptiles: Salt Lake City, USA.

NRETAS. (2012). Be CrocWise. NRETAS: Darwin. Available online athttp://www.nretas.nt.gov.au/plants-and-animals/becrocwise.

Smith, A.M.A. and Webb, G.J.W. (1985). *Crocodylus johnstoni* in the McKinlay River area, N.T. VII. A population simulation model. Australian Wildlife Research 12: 541-554.

Webb, G.J.W., Bayliss, P.G.and Manolis,S.C. (1989). Population research on crocodiles in the Northern Territory, 1984-86. Pp. 22-59 *in* Crocodiles. Proceedings of the 8th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Webb, G.J.W., Britton, A.R.C., Manolis, S.C., Ottley, B. and Stirrat, S. (2000). The recovery of *Crocodylus porosus* in the Northern Territory of Australia: 1971-1998. Pp. 195-234 *in* Crocodiles. Proceedings of the 15th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Webb, G.J.W., Buckworth, R. and Manolis, S.C. (1983). *Crocodylus johnstoni* in the McKinlay River area, N.T. III. Growth, movement and the population age structure. Australian Wildlife Research 10: 383-401.

Webb, G.J.W., and Manolis, S.C.(1989). Crocodiles of Australia. Reed Books: Sydney.

Webb, G.J.W. and Manolis, S.C.(1993). Viewpoint: conserving Australia's crocodiles through commercial incentives. Pp. 250-256 *in* Herpetology in Australia, ed. by D. Lunney and D. Ayers. Surrey Beatty & Sons: Chipping Norton.

Webb, G.J.W., Manolis, S.C. and Sack, G.C. (1983). *Crocodylus johnstoni* and *C. porosus* co-existing in a tidal river. Australian Wildlife Research 10: 639-50.

Webb G.J.W., Manolis S.C., Whitehead P.J. and Letts G. (1984).A Proposal for the Transfer of the Australian Population of *Crocodylus porosus* Schneider (1801), from Appendix I to Appendix II of C.I.T.E.S. Conservation Commission of the Northern Territory: Darwin.

Webb, G.J.W and Smith, A.M.A. (1987). Life history parameters, population dynamics and the management of crocodilians. Pp. 199-210 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty & Sons: Chipping Norton.

Webb G.J.W., Whitehead, P.J. and Manolis, S.C. (1987). Crocodile management in the Northern Territory of Australia. Pp. 107-124 *in* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty and Sons: Chipping Norton.

Assessing Crocodile Conservation Potential in Non-Protected, Rural South Africa

Ashley Pearcy

Organization for Tropical Studies/University of Witwatersrand, P.O. Box 33, Skukuza, South Africa 1350

Abstract

Following the die-off in 2008 of several hundred Nile Crocodiles within a protected area of the Olifants River, crocodiles were moved to the forefront of conservation attention in South Africa. One major concern that arose from this event was the need to reassess the balance between conservation in non-protected versus protected areas. Smaller populations of crocodiles that reside outside the borders of protected areas may offer a valuable buffer to the metapopulation of the species. However, crocodiles living in unprotected habitat are often overlooked by conservation measures. Under this premise, a small population of Nile Crocodiles outside of the Kruger National Park, South Africa, was chosen as a focal sample for a pilot study to assess the likelihood of a successful conservation program in the area. A rapid habitat assessment, in conjunction with an assessment of resource availability, was performed to determine suitability for further population expansion.

Introduction

In a country where developing and developed overlap so assiduously, the Nile Crocodile (*Crocodylus niloticus*), an iconic species of the African continent, is becoming lost in the South African mix. As rivers turn from main resources of human survival to recreational areas, crocodile habitat, while it should be experiencing benefits from reduced human conflict, is being contaminated by signs of development. Of other concern, the IUCN ranks *C. niloticus* as "of least concern" throughout its range. Outside of South Africa, these areas have high human-crocodile conflict, no fenced protected areas, and little to no enforced policies to protect either crocodiles or the habitats in which they abide. South Africa boasts reduced conflict due to development and the ability to move away from dependence on rivers, fenced protected areas such as Kruger National Park, a reptile protection legislation instated for over 40 years (Ashton 2010), and a forward thinking water policy (*The National Water Act of 1998*). However, the crocodile in this country is considered vulnerable. Current estimates suggest that only 12,000 Nile Crocodiles remain in the wild throughout southern Africa and populations are on the decline in much of their home range (Alexander and Marais 2007). In South Africa, the current range is restricted to the eastern and northern areas of the country between the Limpopo and Tugela Rivers and is largely limited to protected areas like nature and game reserves (Calverley 2010; Alexander and Marais 2007). Crocodile numbers are declining in both protected and non-protected areas due to threat by direct and indirect human influence (Combrink 2011; Fergusson 2010). In South Africa, the main threats to crocodile populations are habitat loss due to water extraction by humans and water pollution (Alexander and Marais 2007).

The restriction to protected areas suggests that success of Nile Crocodiles in South Africa will be highly dependent on the size and scale of these reserves (Calverley 2010). However, river systems are difficult to conserve and 82% of rivers in South Africa are threatened, with 44% of those being critically endangered (Driver *et al*. 2004). The 2008 die-off in the Olifants River Gorge highlights the vulnerability of these freshwater systems (Ashton 2010; Ferreira and Pienaar 2011). While many actions are in place to alleviate the pressures on these systems, the dependence on protected areas for assurance of healthy freshwater systems must be supplemented with successes in non-protected areas.

In the remote hills of Venda country near the Zimbabwe border, a small, remnant population of crocodiles exist in the Mutale River. The dynamic of the river, and in turn, the crocodile population, was immensely altered by the floods of 2000, creating a shallow, narrow river with very few tributaries having enough water to sustain individual crocodiles. This habitat is limited in its capacity to carry crocodiles as the breeding habitats are minimal. However, despite this, nests have been located and the population has been sustained, in small numbers.

The interest in the area is in several arenas (1) the comparison between protected areas and non-protected areas with concern to river health and crocodile conservation, (2) the basic ecology of a population limited to a linear system and the distribution along that system with regard to age and size class, (3) and the effects of a coal mine on the health of the river prior to entering a reserve and the greater complex of the park systems, (4) which also includes the comparison between the Olifants River Gorge due to the possibility of acid mine drainage in the system and similarities in landscape.

A short-study was conducted to determine the plausibility of conducting research on the crocodiles upstream (of the coal mine) and the likely success of a conservation program. Pre-emptive action often reduces misallocation of time and funds. The information gathered in this study will be repeated both at the mine and further downstream as the study progresses.

Methods

Study Site

The Mutale River flows through the north of South Africa in the Limpopo Province. Its source is Lake Fundudzi, a sacred site to the Venda culture. The lake itself is believed to have numerous crocodiles, but can only be accessed with special permission. The river then flows through villages and agricultural fields through a gorge. Further downstream, Tshikondeni Coal Mine uses tributaries of the river in the mining process. Finally, the Mutale enters the Makuya Reserve, where it joins the Luvuvhu River to flow into Kruger National Park.

The study site was located in HaMakuya, a collection of 19 villages in the rural Mutale Municipality of the Vhembe district in Limpopo Province. The Mutale Local Municipality consists of 58 villages, contains approximately 100,000 inhabitants, and is one of the poorest districts in South Africa (Rietveld *et al*. 2008; Vhembe district stats overview 2011).

Study Design

A rapid habitat assessment was conducted in October and December of 2011 and March 2012 on a 10-km stretch of the Mutale River between the Tshikondeni Mine and Lake Funduduzi at the Thusulu Trust Research Camp (S22 34.779' E30 48.518'). The river was described, including a 7 m buffer zone from the edge of the water, to identify tributaries, ponds, rapids, pools, and sand banks, in order to asses usable, suitable habitat need for basic ecological needs of crocodiles. In both October and December, invertebrates were sampled for indication of diversity and water health under the SASS5 guidelines (Chutter 1994). In December, the fish populations were surveyed over three days to identify potential prey items.

Night surveys were conducted over three 6-day periods in October, December and March to assess the current population in the 10-km stretch.

Five fishermen were interviewed in March 2012 to better understand the human perspective on the conflicts with and fear of crocodiles and the current attempts to alleviate those conflicts and fears.

Results

The rapid habitat assessment gave a general overview of the suitability of the river for crocodile presence and population expansion and of the health of the river. The invertebrate studies, fish count, and habitat description defined the resource availability while the surveys gave some insight to the carrying capacity of the area. Finally, the interviews gave some context to the interest in and vulnerability to of the villagers of HaMakuya to local crocodile populations. When combining these above factors, the success of the area as a conservation area could be assessed.

Habitat Description

Within the description of habitat, 61% of the river described consisted of pools and runs. The presence of rapids will limit the movement of crocodiles until a certain size is reached, therefore altering distribution by age and size class. Habitat studies found the presence of suitable nesting grounds, defined as sandy banks, in ≈19% of the river (of 10-km stretch studied). Only one nest was found during the study periods, suggesting space for other breeding females.

Resource Availability and Quality

Invertebrates collected represented 11 different families, of which three have extremely high water quality requirements (Table 1). The invertebrates also offer plentiful prey for fish, the main diet of crocodiles in the river.

Nine different species of fish were trapped and identified (*Barbus annectens. Marcusenius macrolepidotus, Labeo cylindricus, Petrocephalus wesselsi, Schilbe intermedius, Tilapia sparrmanii, Mesobola brevianalis* and *Clarias gariepinus*). Of these six species (*B. annectens, M. macrolenidotus, L. cylindricus, P. wesselsi* and *S intermedius*) are known to occur in shoals (Skelton 2001), suggesting ample food supply. Bottom-feeders such as catfish (*C. gariepinus*), a link in the bioaccumulation and die-offs of crocodiles in the Olifants, are the main fish present in the area. These are the dominant prey item for Nile Crocodiles (Alexander and Marais 2007).

Table 1. Invertebrates captured in a 10-km stretch of the Mutale River near Tshulu Camp, HaMakuya in March 2012. Sensitivity scales were derived from pollutant tolerance levels as used in the SASS-5 scoring system. 1-5 Highly tolerant to pollution; 6-10 Moderately tolerant to pollution; 11-15 Very low tolerance to pollution (Gerber and Gabriel 2002).

Invertebrate	Category	Number	Sensitivity
Batidae	Mayfly larvae	3	4
Dytischidae	Beetles	3	5
Ecnomidae	Caddisfly larvae	4	8
Hydraenidae	Beetles	1	8
Leptophlebiidae	Mayfly larvae	2	9
Libellulidae	Dragonfly larvae	18	5
Notonectidae	Brushlegged mayfly	35	15
Notonemouridae	Stonefly larvae	4	14
Oligochaetae	Aquatic earthworm	5	1
Oligoneuridae	Mayfly larvae	1	15
Perlidae	Stonefly larvae	4	12

Population Surveys

Crocodile presence was confirmed (N= 23), with larger crocodiles (>2.5 m) preferring the gorge area, which offers deeper pools, often with larger fish. Larger crocodiles are also found downstream in areas where livestock graze close to the river. Smaller crocodiles form more communal groups or as individuals are found in shallow waters, not conducive to larger crocodiles. Crèches seem to be in these shallow waters or in short runs between rapids. Hatchlings (N= 18) were found in December and by March, 12 of those were sighted again despite the flood in January.

Human Influence

Human-crocodile conflict is passive, taking shape in the consumption of livestock by large crocodiles. For the most part, people avoid crocodiles through acknowledged methods- setting up fishing locations away from bank, no fishing at night, avoidance in general of crocodiles, and telling newcomers where to fish to avoid crocodile territories. In the past, there are stories of people being attacked, but it is assumed that two factors influenced this: (1) more crocodiles were in the area given the deeper waters prior to the 2000 floods and (2) people relied more heavily on the river before the placement of bore holes in the villages. Currently, there are initiatives in place for incurring consequences for killing a crocodile by the municipal government. Local people may contact the municipality or the local Makuya Reserve for the removal of problem crocodiles. Recently, two crocodiles moved into a dam, primarily used for watering livestock. The crocodiles took several cattle. The nature reserve rangers shot one of these; the other was relocated to the reserve.

Discussion

With the increase in development outside of reserves in South Africa, potential threats to the health of freshwater systems increases and the efficacy of protected areas with regard to river systems reduces. The rapid habitat assessment along with information gleaned from the local peoples highlights the potential success of this non-protected area as a conservation site for dilapidated crocodile populations in the north of South Africa.

We expect a larger population to be currently in the area then what was assessed given the difficulty of surveying large sections of the river. Given the availability of suitable habitat within the 10-km stretch, the river is capable of maintaining a higher load of crocodiles than is currently present. Some sections of the river are not ideal for stagnant populations as they have shallow waters, but could cater to younger crocodiles before they are physically too large for the depth of the water column.

The local peoples of HaMakuya do not use the river as means of a main economic resource and therefore would not be at odds with a full conservation program within the area. With the installment of water taps in the villages, the dependence on the river has itself been reduced. Even the chief of Tshikundamalema across the Mutale River from HaMakuya has expressed interest in crocodile conservation, suggesting that there is local support for a future conservation program.

From these assessments, we have concluded that a conservation movement would in fact be successful, to further stabilize the population in the upper reaches of the Mutale River. The limitations exist in suitable habitat to maintain nesting locations. With further studies, researching the effects of the mine downstream (around 12 km from the current site), we will be able to identify further needs of the Mutale River population based on present pollutants and the health of the river as it enters Makuya Reserve to join the Luvuvhu. We will also be able to identify any threats to the river as it flows into Kruger National Park, thereby reducing the chance of another incidence like in the Olifants River gorge and perhaps lending further insights into the reasons behind the die-offs.

While the preliminary study is informative, the overlap between ecology of this population of crocodiles and the habitat available needs to be more closely analysed. The full range of river used by these individuals needs to be monitored and more areas along the river need to be surveyed to assess the current population. These small populations become valuable as larger populations in protected areas are threatened by side-effects of development, such as habitat encroachment and water pollution. Rivers are one of the most difficult natural resources to protect as between the source and the delta the river may flow through multiple countries, landscapes and protected and non-protected areas alike. The knowledge gained in the exploration of this site will be helpful in other locations of Africa and other progressing countries to identify a balance between development and conservation and the value of non-protected areas in buffering metapopulations.

Acknowledgements

Thanks to the Organization for Tropical Studies for use of vehicles and equipment, SANParks for use of equipment, Thsulu Trust for accommodation and relations with local peoples and guides, the OTS Spring 2012 class for their efforts in data collection in particular Qimeng Gao, Maria Correra, and Mary McClay.

Literature Cited

Alexander, G. and Marais, J. (2007). A Guide to the Reptiles of Southern Africa. Struik: Cape Town, South Africa.

Ashton, P.J. (2010). The demise of the Nile crocodile (*Crocodylus niloticus*) as a keystone species for aquatic ecosystem conservation in South Africa: the case of the Olifants River. Aquatic: Marine and Freshwater Ecosystems 20: 489-493.

Calverley, P. (2010). The conservation ecology of the Nile crocodiles (*Crocodylus niloticus*) at Ndumo Game Reserve in northeastern KwaZulu-Natal, South Africa. MSc thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.

Chutter, F.M. (1994). The rapid biological assessment of streams and river water quality by means of macroinvertebrate communities in South Africa. Pp. 217-234 *in* Classification of Rivers and Environmental Health Indicators, ed. by M.C. Uys. Water Research Commission Report No. TT 63/94, South Africa.

Combrink, X., Korrûbel, J.L., Kyle, R., Taylor, R. and Ross, P. (2011). Evidence of a declining Nile crocodile (*Crocodylus niloticus*) population at Lake Sibaya, South Africa. South African Journal of Wildlife Research 41(2): 145-157.

Driver A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. and Strauss, T. (2004). National spatial biodiversity assessment 2004: priorities for biodiversity conservation in South Africa. Strelitzia 17. South African National Biodiversity Institute: Pretoria.

Ferreira, S.M. and Pienaar, D. (2011). Degradation of the crocodile population in the Olifants River Gorge of Kruger National Park, South Africa. Aquatic Conservation: Marine and Freshwater Ecosystems 21: 155-164.

Fergusson, R.A. (2010). Nile Crocodile *Crocodylus niloticus*. Pp. 84-89 *in* Crocodiles. Status Survey and Conservation Action Plan, ed. by S.C. Manolis and C. Stevenson. Crocodile Specialist Group: Darwin.

Gerber, A. and Gabriel, M.J.M. (2002). Aquatic Invertebrates of South African Rivers Field Guide. First Edition. Private Bag: Pretoria, South Africa.

Rietveld, L.C., Haarhoff, J. and Jagals, P. (2009). A tool for technical assessment of rural water supply systems in South Africa. Physics and Chemistry of the Earth 34: 43-49.

Skelton, P. (2001). A Complete Guide to the Freshwater Fishes of Southern Africa. Stuik Publishers: Cape Town, South Arica.

Vhembe District Stats Overview (2011). Vhembe District, Limpopo Province, South Africa.

Extinction of the Orinoco Crocodile, *Crocodylus intermedius*, in the Guárico River, Venezuela

Ernesto O. Boede

FUDECI, Palacio de Las Academias, Edif. Anexo, piso 2, Av. Universidad, Esq. Bolsa a San Francisco, Caracas 1010 A, Venezuela (ernestoboede@gmail.com)

Abstract

The Orinoco Crocodile (*Crocodylus intermedius*) historically inhabited all the Orinoco River basin of Venezuela and Colombia. As a result of indiscriminate commercial hunting in the first half of the 20th Century the species was greatly depleted and in danger of extinction. Over the last 60 years, the Guárico River, previously one of the most important rivers in the central Venezuelan Llanos for crocodiles, has lost its entire *C. intermedius* population. With the development of the Camatagua and Guárico Reservoirs about 50 years ago, most of the Guárico River has been reduced to a polluted trickling watercourse, severely limiting possibilities for recovery programs for the species.

Introduction

Commercial hunting of the Orinoco Crocodile begun in the Venezuelan and Colombian Llanos at the end of 1920, with a peak in the mid-1930s (Godshalk 1982; Thorbjarnarson and Hernández 1992; Seijas 2007). Around 900,000 hides were exported from Venezuela to Europe between 1933 and 1935. At that time 3000 to 4000 hides where sold daily. Although trade persisted until the end of 1960, in most Venezuelan and Colombian rivers commercial hunting had finished by the end of 1940 and the beginning of 1950 (Fig. 1).

Figure 1. Commercial hunting of *C. intermedius* lasted some 40 years, until the species in the Llanos was almost extinct. Photograph: Faoro (Photograph Archive of Ernesto O. Boede).

On his journey in 1800, Alexander von Humboldt wrote that there were so many crocodiles and he could see up to 10 animals sunbathing on the river banks of each meander of the Apure River (Humboldt 1959; Seijas 2001; Boede 2009). Even Calzadilla Valdez (1988), in his reports from 1932, wrote that these crocodilians in the dry season swarmed in the marshy lagoons of the almost dry rivers.

It is thought that there were more than three million *C. intermedius* in the Llanos at the beginning of the 20th Century (Antelo Alberts 2008). The total population in Venezuela is now around 1500 individuals, with even less in Colombia (Seijas and Chávez 2000; Llobet and Seijas 2003; Rodriguez and Rojas-Suárez 2008). There are few reports of *C. intermedius* in the Guárico River, which begins at the northern Venezuelan State of Carabobo near the village of Belén, and flows 580 km from north to southeast through the Llanos of Aragua and Guárico States, and into the Orinoco River, near the village of Cabruta.

The Chilean priest José Cortés de Madariaga, sailing in 1811 from the Orinoco River into the Guárico River to the villages of Guayabal and Calabozo, wrote that it was a wide river, navigable, with much current, and many "caimanes" or Orinoco Crocodiles (Portal Oficial. Guárico 2011). Also, Humboldt, travelling from Calabozo to San Fernando de Apure, crossed the Orituco River, which is a tributary of the Guárico River, and described the danger of the crocodiles there, which could be very aggressive for his companion dogs, where they could be predated even on land by these huge reptiles (Humboldt 1959; Seijas 2001).

In 1932 the author's father, Ernesto G.A. Boede travelled by boat south on the Guárico River, from the nearby village of Calabozo to Guayabal (Fig. 2). He observed and photographed the huge Guárico River before two dams were built upstream, and also photographed some of the last Orinoco Crocodiles in this river (see Figs. 3-7).

Figure 2. Map showing Guarico and Apure Rivers.

Figure 3. Crocodiles hunted in the Guárico River in 1932, ready to be skinned and the hide sold. Photograph: Ernesto G.A. Boede (Photograph Archive of Ernesto O. Boede).

Figures 4 and 5. The skins of Orinoco Crocodiles slaughtered in the Guárico River were commercially exported. In the era of the commercial hunting in 1932, there were still challenging and intimidating crocodiles to be found in the Guárico River. Later on, the few survivors left in some rivers in the country were wary, and learned to elude and avoid humans to survive (Godshalk 1978). Photograph: Ernesto G.A. Boede.


Figures 6 and 7. Large Orinoco Crocodiles on the banks of the Guárico River in 1932. Photographs: Ernesto G.A. Boede.

Methods

Twenty-five (25) photographs, taken in the 1930s, of the Guárico River and its Orinoco Crocodiles were collected and analyzed. Recent photographs were taken in the Guárico Reservoir and the downstream river channel. For the literature review, data were collected from scientific papers and from unpublished data of the Venezuelan Crocodile Specialist Group (GECV).

Results and Discussion

The Guárico River was an important navigable river until the beginning of the 20th Century (Fig. 8; Portal Oficial. Guárico 2011). Big bongos and houseboats came along the river in the rainy season from the villages of San Fernando de Apure and Guayabal to Calabozo for commercial trade. They transported back to San Fernando de Apure, with the main storage facilities, the Orinoco Crocodile hides that were taken along the Guárico River (Figs. 1, 3-5; Boede, pers. comm.; Godshalk 1978; Calzadilla Valdez 1988; Boede 2009). As in the rest of the country, in the Guárico River the Orinoco Crocodiles were overhunted and driven to local extinction between 1920 and 1960 (Godshalk 1978, 1982; Thorbjarnarson and Hernández 1992; Seijas 2007).

Before the Camatagua and the Guárico Dams and Reservoirs where built, in the dry season the Guárico River had many sandy riverbanks, and in the rainy season it was very wide and flooded the nearby savannas and its gallery forests - suitable habitats for crocodiles (Figs. 4-7). Over the last 40 years the river downstream of the Calabozo Dam has been transformed into a polluted narrow waterway (Fig. 8; Portal Oficial. Guárico 2011).


Figure 8. (Left) Until the beginning of the 20th Century, the Guárico River was an important waterway for trade and crocodile habitat. (Photograph: Ernesto G.A. Boede). (Right) Today, most of the Guárico River is a trickling watercourse, probably without any Orinoco Crocodiles left. Photograph: Ernesto G.A. Boede.

Godshalk (1978) wrote that a lot of crocodile hides were harvested from the Guárico River some years before his visit. Confidential sources told him that some crocodiles were still seen in the artificial Guárico River reservoir, built in 1957, upstream of its dam near the village of Calabozo. Due to intense agriculture near the village, the presence of crocodiles in that part of the river was very doubtful. But downstream the river has many meanders and there could be some Orinoco Crocodiles left, according to his informants. Between 1987 and 1988 Thorbjarnarson and Hernández (1992) were informed that downstream in "Caño el Caballo", a river arm of the Guárico, some crocodiles had been seen. These authors commented that a few adult crocodiles also lived more upstream to the north, in the Camatagua Reservoir. These crocodiles were derived from resident animals from the Guárico River, before the construction of the Camatagua Dam in 1969. Few crocodiles survived in the Camatagua Reservoir, and Blohm (1982) wrote that in July 1980 3 nests were recorded on an island in the artificial lake of the reservoir. One month earlier (June 1980) 6 hatchlings were observed 3 km south of the nest site. In 1971 Blohm (1982) reported seeing 3 crocodiles 16 km to the east, and in 1972 a poacher killed one about 9 km eastwards.

In 1985, 5 hatchlings collected in Camatagua Reservoir, were brought to the El Pinar Zoo in Caracas. Around the beginning of 1990 an adult Orinoco Crocodile was killed in "Caño Rabanal", which is also a southern river arm of the Guárico River (A. Seijas, pers. comm.). In October 2006, 152 one-year-old *C. intermedius* from the Venezuelan Captive Breeding Program were released in the Orituco River, 9 km upstream from its mouth into the Guárico River (Venezuelan Crocodile Specialist Group, unpublished data).

Conclusions

Now, at the beginning of the 21st Century, about 50 years since the construction of two important dams and reservoirs on the Guárico River, it is now a bad-smelling trickling watercourse, polluted from Calabozo village and surrounding agricultural plantations. Its main channel and river banks are now dense bushes and forests, which is not a suitable habitat for Orinoco Crocodiles (Fig. 8). But downstream to the south the Guárico River receives some fresh water from its tributaries, the Orituco River and the Apurito River arm, where perhaps some Orinoco Crocodiles could exist. Upstream to the north, in the Guárico and Camatagua Reservoirs, *C. intermedius* is probably extinct.

Since mid-1990, no data have been collected nor any census undertaken, but there have been no reported sightings or any *C. intermedius* being hunted in the Guárico River. Intensive hunting between 1920 and 1960 is considered the main factor contributing to the probable extinction of *C. intermedius* in the Guárico River, with recovery constrained by alteration of the river through the construction of dams.

Acknowledgements

Omar Hernández provided unpublished data from the GECV archives, and Hermann Boede helped find and select my father's photographs. Andrés Eloy Seijas reviewed this manuscript and made important suggestions and contributions. Álvaro Velasco also reviewed the manuscript and presented it on my behalf at the 21st CSG Working Meeting.

Literature Cited

Antelo Alberts, R. (2008). Biología del cocodrilo o caimán del Orinoco *Crocodylus intermedius*, en la Estación Biológica El Frío, Estado Apure, Venezuela. PhD Thesis, Universidad Autónoma de Madrid, Spain.

Blohm, T. (1982). Husbandry of Orinoco crocodiles *Crocodylus intermedius* in Venezuela. *In* Crocodiles. Proceedings of the 5th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Boede, E.O. (2009). Para el recio Llano sería una pérdida invalorable, la extinción del caimán del Orinoco, *Crocodylus intermedius*. Revista Venezuela Bovina, Valencia, Venezuela 80: 3-11.

Calzadilla Valdes, F. (1988). Por los Llanos de Apure. Productora Hernández, S.A. (PROHESA): Caracas. (217-236).

Godshalk, R.E. (1978). El caimán del Orinoco *Crocodylus intermedius*, en los Llanos occidentales venezolanos con observaciones sobre su distribución en Venezuela y recomendaciones para su conservación. FUDENA: Caracas. (58).

Godshalk, R.E. (1982). Status and conservation of *Crocodylus intermedius* in Venezuela. Pp. 39-53 *in* Crocodiles. Proceedings of the 5th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Humboldt von, A. (1959). Vom Orinoko zum Amazonas, Reise in die Äquinoktial Gegenden des neuen Kontinents (Dritte Auflage). Wiesbaden: Brockhaus, F.A. (Ed.): 213.

Llobet, A. and Seijas, A.E. (2003). Estado poblacional y lineamientos de manejo del caimán del Orinoco (*Crocodylus intermedius*) en el río Capanaparo, Venezuela. *In* Manejo de Fauna Silvestre en Amazonía y Latinoamérica. Selección de Trabajos V Congreso Internacional, ed. by R. Polanco-Ochoa. CITES, Fundación Natura: Bogotá.

Portal Oficial. Guárico (2011). Río Guárico: Reseña Histórica. http://guarico.com.ve/?p=1480. Available 31 July 2011.

Rodríguez, J.P. and Rojas Suárez, F. (2008). Libro Rojo de la fauna venezolana. Provita. (Tercera Edición): 175

Seijas, A.E. (2001). Caimanes y babas en la narrativa de Humboldt. *In* Alexander von Humboldt: Homenaje al Bicentenario de su Llegada a Tierras Venezolanas (16 de julio-1799 al 26 de noviembre-1800). Biollania Edición especial 7: 224-233.

Seijas, A.E. (2007). Tendencias de las poblaciones del caimán del Orinoco *Crocodylus intermedius* en Venezuela: Balance de las investigaciones de los últimos 30 años. Biollania Edición Especial 8: 11-21.

Seijas, A.E. and Chavez, C. (2000). Population status of the Orinoco crocodile (*Crocodylus intermedius*) in the Cojedes River system, Venezuela. Biological Conservation 94: 353-361.

Thorbjarnarson, J.B. and Hernández, G. (1992). Recent investigations of the status and distribution of the Orinoco crocodile *Crocodylus intermedius* in Venezuela. Biological Conservation 62: 179-188.

Population Status of the American Crocodile (*Crocodylus acutus*) in the Tempisque Great Wetland, Guanacaste, Costa Rica, 2009-2010

Juan Rafael Bolaños Montero

(cocodrilo1@gmail.com)

Abstract

To determine the status of the crocodile (*C. acutus*) population in the Tempisque River, Guanacaste, Costa Rica, I studied the whole influence area of the river, rather than just its navigable segment. Every contributor river, small lagoon and related wetland were taken into account, in what I named here as the Tempisque Great Wetland (TGW). I partially examined the effect of some climatic factors, as well as the historical use of land. I estimated the population size as 2315 individuals, and a total of 1951±25.26 (84.3%) non-hatchling crocodiles; split in 292 (15.0%) in the Upper Basin, 1262 (64.7%) for the Lower Basin, and 397 (20.4%) for the Marshes Area. Relative density is 4.56, 8.79 and 23.08 ind/km respectively. Estimated general relative abundance was 8.68 ind/km. General size structure estimated was 386 (16.7%) recruits, 454 (19.6%) juveniles, 648 (28.0%) sub-adults, and 463 (20.0%) adults. Sex ratio was 3.3:1 (male:female).

Introduction

Studies about the state of the populations of crocodiles (*Crocodylus acutus* Cuvier 1807) are nowadays more frequent in Costa Rica, with pronounced interest in the populations of the Pacific coast (Sasa and Chaves 1992; Bolaños *et al*. 1997; Piedra 2000; Porras-M 2004); as much as to determine the population of the Tempisque River as the most important among all others in the country. Information exists regarding the size and sex distribution of this population (Bolaños *et al*. 1997; Sánchez 1992, 2001). Nevertheless, these studies have been carried out only in the navigable river channel, with an approximate total length of 50 km from its mouth in the Gulf of Nicoya, to the place known as La Cutacha, upstream at a height of the Hacienda El Viejo.

During the last 15 years, repeated accident occurrence with crocodiles, reports of crocodiles in places where they had not been sighted before, as well as reports of high numbers of individuals in several Tempisque's contributors, like the Bebedero, Charco and Cañas Rivers; besides the worrying crocodile visit in aquaculture ponds in the counties of Cañas and Bagaces (Bolaños, in prep.), have attracted attention towards the possibility that the actual evaluations of the population of crocodiles in the Tempisque river have been showing underestimated results, if considered that the studied population was always the same relatively small fraction of the real population of crocodiles of what I call here as the Tempisque Great Wetland (TGW), from the High Basin of the river in the birth of the Tempisquito River, down to the Gulf of Nicoya in the Toro Island; including its most important contributors and adjacent wetlands along its trip towards the sea.

The present study establishes an integral conception of the habitat of the crocodile in the Tempisque River, as well as an improved conceptualization and better estimation of the status of its crocodile population.

Materials and Methods

Study Area

It is possible to split the TGW into Upper Basin, Lower Basin and Area of Marshes, since each of them is clearly differentiated by conditions of soil genesis, geomorphologic gradient, water regime and green coverage.

The Upper Basin is characterized by soils of volcanic origin (Cabrera 2007) where the clear water runs on a stone bed where the river has washed cannons of up to 6 m deep in the stone, with a range in altitude from up to 90 m asl at the bridge of the Inter-American Highway on the Tempisquito River, down to 30 m asl along the community of Guardia (Cabrera 2007). This condition determines the existence of a system of gradients, by means of which the connection is established between long ponds of up to 600 m long and with a 30 m average width. There exists an average threshold of 30 m of area of damping forest coverage in both margins of the watercourses, with secondary forest mostly, with a canopy of approximately 10 m high in species as espavel (*Anacardium excelsum*), jobo (*Spondias mombin*), gallinazo (*Schizolobium paraibum*), ceibo (*Ceiba pentandra*), tempisque (*Sideroxylon capiri*) among others. During the achievement of the study, I observed local proper fauna, like coyote (*Canis latrans*), nutria (*Lutra longicaudis*), iguana (*Iguana iguana*), garrobo (*Ctenosaura similis*), guatuza (*Dasyprocta punctata*), pizote (*Nasua narica*), mapache (*Procyon lotor*), urraca (*Calocitta formosa*), martín peña (*Tigrisoma mexicanus*), garza real (*Ardea alba*), tamandúa (*Tamandua tetradactyla*), mono congo (*Alouata paliata*), mono cariblanco (*Cebus capuchinus*), boa (*Boa constrictor*) among others. There is an extensive use of land to raise cattle for meat, with wide extensions of area covered by pastures (Peters 2001). The urban pressure on the water river beds is here of low impact, with the unique reference to the small town of Irigaray.

The Lower Basin is considered from the community of Guardia, 30 m asl down to 0 m asl, at the mouth of the river in the sea. The river's water runs here in a sedimentation substratum of alluvial origin, which goes by a lot slower than it uses to go in the High Basin, without the presence of rapids along the river bed. The waters here are cloudy, as a result of the sedimentary effect of waters running on soil. The river has here a 50 m average width and the average depth is of between 6 and 8 m during the rainy season. Meanwhile, during the dry season, the width of the river and its average depth is 20 m and from 2 to 4 m respectively, with the frequent existence of deep large ponds. From La Cutacha to its end in the sea, the river reduces the speed of its current, acquires more width and depth and allows, thanks to the fact that the tides affect up to this sector, the navigation by crafts of low openwork like boats and tourist longboats. In this area the shores of the river are of light slopes, with green coverage basically of bushes, except in the area protected by the Palo Verde National Park, where the forest coverage is from primary and secondary forest composed by proper forest species of the area (Sánchez, 2001) and from swamp and mangrove forest. The agricultural activities as the raising of rice, sugar cane and watermelon or cantaloupes are taken up to the very margin of the river, without respect of the damping area required by Law 276 for protection of the watercourses. Along the river, every year the companies dedicated to the production of these goods accustom to "clean" the shore of the river with heavy machinery up to a 50 m margin from shore, they keep and maintain the dike that must protect them from the winter floods, jeopardizing the crocodile nesting banks already established. There also exist water authorizations granted by Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento (SENARA) for the irrigation of cultures in the Low Basin of the Tempisque. During the dry season (ENE-ABR) this water extraction goes as far as to reduce the water volume in a very significant way (Alvarado *et al*. 2008), to the point in which the inhabiting fauna migrates in search of water and life in the internal area of the territory, in the areas of cultivation. The Low Basin of the Tempisque presents a strong impact for urban pressure, owed to the growth of cities like Guardia, Liberia, Filadelfia, Santa Cruz, Bagaces, Cañas, Bebedero, Comunidad, Belén, Bajo Tempisque. Some of the faunistic species sighted during the achievement of the work were raccoons (*P. lotor*), pizotes (*N. narica*), coyote (*C. latrans*), garza real (*A. alba*), martin peña (*T. mexicanum*), iguana (*I. iguana*), garrobo (*C. similis*), mono cariblanco (*C. capuchinus*), mono congo (*A. paliata*), chocuaco (*Cochlearius cochlearius*), garza azul (*Egretta caerulea*), cigüeñón (*Mycteria americana*), garza bueyera (*Bubulcus ibis*).

As Area of Marshes I classified to what would represent a species of attached wetland inside the TGW adjacent to the Tempisque river in the field of its Lower Basin and in the side of the Peninsula de Nicoya. This area gets completely connected every year with the main river bed of the Tempisque during the rainy season, product of the floods; but it remains in a relative separation during the months of the dry season, only connected across minimal courses of water of the El Charco and Bolsón Rivers, as well as other small meanders that drain the area, thus connecting the lagoons Mata Redonda, Corral de Piedra and Sonzapote with the rest of the marsh and with the main river channel.

Since the beginning of the colonization of the Guanacaste Province in 1821, it has been experienced a sensitive decrease of the green coverage, and a large area has been transferred from wilderness to the development of pastures for cattle raising, both in the Upper Basin and in the Lower Basin (Peters 2001). Further on, the advent of the mechanization in the cultivation, supported by the creation of the Irrigation District of Moracia, made possible the incorporation of more grounds of the Lower Basin plains, as well as the replacement of some areas of extensive cattle for cultivation like rice, sugarcane, sorghum, cotton and corn (Peters 2001). At present the basic cultivation is rice and sugarcane, watermelon and cantaloupe, which occupy large extensions of land, up to the very margin of the water courses, and which minimize the water volume of the Tempisque River, determining that with a normal environmental water volume, only 31% of the whole of profiles of depth fulfill with the requests of *C. acutus* (Alvarado *et al*. 2008).

The development of the livestock business, and then the expansion of the agricultural border, promoted in the area the improvement of the road network and general routes of communication, to ease the supply of inputs and products extraction to the available markets (Peters 2001); as a result, the additional labor force brought with it a strong urban development, which expanded the limits of the existing establishments and propitiated the establishment of more urban centers for the development of the area. Under these circumstances, the habitat provided by the rivers, estuaries, swamps and attached wetlands, turned out to be submitted to the joint effect of these factors, and led to a reduction of the space available for the species that inhabit this habitat, to the overcrowding of their populations, and to an inconspicuous condition of life, in which there was more and more frequent and normal to meet a crocodile, and crocodiles were pressed to be mobilized up to places that earlier they had not dared to visit, in search for water and their natural preys.

During the 1990s it initiated the development of aquaculture in the area, with the consolidation of companies favored by the Irrigation District of Moracia, dedicated to the production of tilapia in the counties of Cañas and Bagaces, which establishments induced positively the food offer for the native fauna and relieved the scarcity that should have happened as a result of the negative effects aimed in the previous paragraph.

Table 1. Sampling segments in the area within the established cartographic land marks.

Segment	Location	m asl
Upper Basin		
Corobicí River	10° 27’ 11.1” N 85° 07’ 44,6” W	29
Interamericana - Tenorio	10° 26’ 00.2” N 85° 09’ 24.2” W	21
Tempisquito River		
Interamericana - Ahogados	10° 48’ 56.1” N 85° 32’ 37.3” W	90
	10° 44’ 00.5” N 85° 31’ 32.9” W	75
Los Ahogados River	10° 48’ 10.0” N 85° 30’ 02.1” W	66
Ahogados - Tempisquito	10° 44’ 00.5” N 85° 31’ 32.9” W	75
Colorado River	10° 39’ 43.3” N 85° 31’ 37.2” W	60
Colorado - Tempisque	10° 38’ 08.5” N 85° 33’ 46.8” W	42
Tempisque River		
Irigaray - Guardia	10° 43’ 14.6” N 85° 31’ 09,8” W	66
	10° 34’ 13.6” N 85° 35’ 20.8” W	39
Lower Basin		
Tempisque River		
Segment A	10° 12’ 44.6” N 85° 14’ 05.0” W	0
Níspero - Puerto Humo	10° 18’ 59.2” N 85° 21’ 09.7” W	0
Segment B	10° 18’ 59.2” N 85° 21’ 09.7” W	0
Pto. Humo - Pto. Chamorro	10° 20’ 31.1” N 85° 21’ 59.3” W	8
Segment C	10° 20’ 31.1” N 85° 21’ 59.3” W	8
Pto. Chamorro - Bolsón	10° 21’ 53.8” N 85° 24’ 36.6” W	7
Segment D	10° 21’ 53.8” N 85° 24’ 36.6” W	7
Bolsón - Puente Pelón	10° 25’ 20.1” N 85° 24’ 08.0” W	9
Bebedero River	10° 22’ 11.4” N 85° 11’ 50.9” W	11
Bebedero - Tempisque	10° 15’ 08.4” N 85° 14’ 20.6” W	1
Tenorio River	10° 22’ 11.4” N 85° 11’ 50.9” W	11
Bebedero - Interamericana	10° 27’ 59.6” N 85° 09’ 44.1” W	34
Blanco River	10° 22’ 11.4” N 85° 11’ 50.9” W	11
Bebedero - Puente bajo	10° 23’ 24.4” N 85° 12’ 38.1” W	12
Cañas River	10° 21’ 11.3” N 85° 08’ 05.0” W	17
Hotel - Bebedero	10° 20’ 04.7” N 85° 12’ 04.4” W	
Tempisque River		
Palmira - Filadelfia	10° 30’ 47.8” N 85° 34’ 08.8” W	21
	10° 25’ 19.5” N 85° 31’ 42.7” O	17
Tempisque River		
Las Bombas - El Pelón	10° 26’ 37.2” N 85° 26’ 14.9” W	17
	10° 25’ 48.1” N 85° 24’ 37.1” O	9
Marshes Area		
Mata Redonda Lagoon	10° 19’ 58.7” N 85° 24’ 50.3” W	4
	10° 18’ 47.8” N 85° 24’ 42.5” O	3
El Charco River	10° 20’ 26.7” N 85° 25’ 29.2” W	9
	10° 20’ 48.2” N 85° 24’ 29.8” O	7
Bolsón River	10° 22’ 08.2” N 85° 25’ 41.3” W	8
	10° 21’ 53.7” N 85° 24’ 37.8” W	7

The Working Segments

I determined the study area based in available information in the cartographic sheets 1:50000 of the National Geographical Institute; numbers 003 Murciélago, 004 Ahogados, 006 Carrillo Norte, 065 Belen, 066 Tempisque, 067 Cañas, 021 Talolinga, and 022 Abangares; with support in reviews realized in Google Earth. I proceeded to evaluate thru actual surveys in the field, the best possibilities of both day and night action, as well as the importance and relevancy of inclusion of the segments; according to the knowledge acquired thru years of work in the rivers and marshes of the studied area, and of the dynamics of the populations of crocodiles in every place. This way, according to my best criterion, I chose to make direct observations in the following study segments.

Related to climate, the National Meteorological Institute (2010) has two small meteorological stations in the study area, Llano Grande in Liberia and Taboga in Cañas. According to information gotten from this source in series of time of 20 years between 1989 and 2008, Table 2 delivers information about the behavior of some climatic factors at both stations.

Table 2. Average daily climatic parameters (standard deviation in brackets) by meteorological station and season, for 2008.

Parameter	Season	Llano Grande	Taboga
Humidity (%)	Dry	62.39 (4.37)	65.21 (5.34)
	Rainy	83.27 (4.94)	82.72 (5.34)
Rainfall (mm)	Dry	7.5 (17.86)	17 (34.01)
	Rainy	283.3 (212.52)	253.97 (159.81)
Maximum Temperature (°C)	Dry	34.65 (1.16)	33.18 (1.25)
	Rainy	31.43 (0.97)	31.76 (0.79)
Minimum Temperature (°C)	Dry	21.5 (1.11)	23.31 (1.43)
	Rainy	22.21 (0.65)	22.64 (0.93)

Data Collection

I made as much as 22 field trips of an average of 3 nights each, between December 2008 and October 2010. Sometimes I could make observations both day and night. In every case, I did the field work during nights with no moon light, in order to prevent from affecting crocodile sighting in the river. I used a 3.5 m inflatable boat AVON and a 15HP Yamaha engine, in the usually navigable rivers like Tempisque from the ocean to the Bridge at Hacienda El Viejo, and the Bebedero River, from its confluence with the Tempisque River, up to the town of the same name. I worked the Blanco River using the same boat, but with a 2.5 HP motor in the first section from Bebedero, and continued then by rowing when it was necessary to remove the engine in order to go on. In the rest of segments of the Upper Basin, where there are frequent rapids and areas of very low depth and cobbled floor, I required to use a 3.2 m inflatable boat AIR brand, and worked sliding stream down, rowing from the beginning point. This was also the way I did the Cañas River and the Lagoon of Mata Redonda. Every time it was needed, I walked at the water body to come closer the animal and to observe it straight or to capture it, so that the depth was not a factor preventing me from doing an observation or capture. Five of the field trips were dedicated exclusively to the apprehension of the crocodiles that would provide with information about the sex rate in the TGW. I used a 6V and 10A RAYOVAC head lamp, as well as a Garmin ETREX GPS to trace the routes and monitoring of the trips.

Size structure was done by means of visual estimation, whenever it was possible to observe the complete animal, or for extrapolation when I could only observe its head on the surface of the water, according to which the length of the head fits 6.6 times in the entire size of the crocodile, in accordance with performed measurements I made in up to 275 crocodiles of all the different sizes. According to this, individuals were placed in a size classification every 0.5 m between SIZE I and SIZE IX, this is, from "X≤ 0.5 m" to "4≤X≤ 4.5 m". Whenever it was not possible to determine any measurement of the animal, and as it gets used in this type of studies, I checked the observation as "eyes only" (King *et al.* 1990). Then these classes were added up into groups representing actual stages in the natural growing up of the crocodile, as hatchlings, recruits, juvenile, sub-adult and adult. The class "hatchling" (≤0.5 m) appears in the remarks table because it exists as such, and its report turns out to be important to demonstrate a working and dynamic population, nevertheless, its number will not be considered for further analysis in this study, since the survivorship percentage in this class is about 5%, and its incorporation to the active population is as improbable as that.

Trying to maintain parallelism with earlier studies performed in the main river bed of the Tempisque during the past 19 years, I kept the division of the observations in four segments, in order to be able to make segment counts when the climate conditions demand so. Statistical tests were done using SPSS, version 15 for Windows.

Results

I designed this work to estimate the real size of the population of the TGW, determining the structure of its population for sizes and for sex. I established for the first time the distribution of the crocodiles along the diverse water courses, and made an estimation of the relative abundance of crocodiles in the whole wetland. In the hope to construct a sufficient factual foundation to sustain some management lines to wisely handling the actual problem being faced by civil population and environmental authorities related to crocodiles in the TGW, in such a way that they allow to preserve this crocodiles population, at the same time relieve the pressure that they allege to suffer. I analyzed my field observations considering historical information of meteorological nature, as well as information relative to the green coverage of the area of study, the agricultural and cattle practices in the place, and the town-planning pressure in the area.

Thinking that the work segments are a representative partial vision of the existing reality in the whole study area, I estimated the whole population using sampled values gathered, with the information obtained in every class of habitat as it is the case.

Table 3. Crocodile counts in the Tempisque Great Wetlands by area and segment. Counts were corrected for area not surveyed (Correc. km), and then for visibility bias (Correc. visib.). H= hatchlings, R= recruits, J= juveniles, SA= sub-adults, A= adults, EO= eyes only.

Area/Segment Size category (m)	H <0.5	R 0.5-1.0	J 1.0-1.5	SA 1.5-2.0	SA 2.0-2.5	A 2.5-3.0	A 3.0-3.5	A 3.5-4.0	A 4.0-4.5	Eyes Only	Counts	Correc. km	Correc. visib.
Upper Basin													
Corobicí R.			4	3			4			2	13	13	14
Tempisquito R.		5	6	3	5	8	1			1	29	52	56
Los Ahogados R.	10	6	2	6	7	1					32	56	60
Colorado R.	4	4	5	2	4	3	1				23	23	25
Irigaray - Guardia	65	31	27	15	5	5				13	161	178	192
Sub-Total	**79**	**46**	**44**	**29**	**21**	**17**	**6**	**0**	**0**	**16**	**258**	**323**	**347**
Lower Basin													
Tempisque - main channel													
Níspero - Humo	15	33	8	8	18	10	18	2	2	9	123	123	140
Humo - Chamorro	6	21	8	10	5	1	11	1		2	65	65	74
Chamorro - Bolsón	22	18	14	16	38	24	33	4	4	5	178	178	202
Bolsón - Puente Pelón	25	13	3	3	12	13	18	8	3	11	109	109	124
Bebedero R.	4	27	26	16	11	6	3		1	5	99	99	113
Tenorio R.	5	6	7	6	4	5	10			4	47	47	53
Blanco R.		8			2	1	1			2	14	30	34
Cañas R. - Cañas	11	2	5	1	2	9	3	1		4	38	67	76
Palmira - Filadelfia		3	26	3	10	5	1			4	52	62	70
Las Bombas - Pelón		16	68	47	44	3	4			8	190	538	612
Sub-total	**88**	**147**	**165**	**110**	**146**	**77**	**102**	**16**	**10**	**54**	**915**	**1317**	**1497**
Marshes Zone													
Mata Redonda Lagoon	20	6	24	3	25	6	4			25	113	283	314
Charco R.	3	3	4	2	3	2	2	0	0	2	21	21	23
Bolsón R.	7	7	9	5	7	4	4	1	0	4	48	120	133
Sub-Total	**30**	**16**	**37**	**10**	**35**	**12**	**10**	**1**	**0**	**31**	**182**	**424**	**471**
Totals	**197**	**209**	**246**	**149**	**202**	**106**	**118**	**17**	**10**	**101**	**1355**	**2064**	**2315**
Totals (size categories)	**197**	**209**	**246**	**351**			**---------------- 251 ----------------**			**101**			

These observations were done along the different segments of work, the length of those segments is presented in Table 4.

Table 4. Total river distances and survey lengths.

Area/Segment	Surveyed (km)	Total (km)	Area/Segment	Surveyed (km)	Total (km)
Upper Basin					
1. Corobicí River	6	6	10. Bebedero River	20.5	20.5
2. Tempisquito River	9	16.22	11. Tenorio River	18.2	18.2
3. Los Ahogados River	6	10.5	12. Blanco River	3.3	7
4. Colorado River	7	7	13. Cañas River	10	17.5
5. Tempisque River Irigaray - Guardia	22	24.37	14. Tempisque River Palmira - Filadelfia	14.5	17.27
Sub-total	**50**	**64.09**	15. Tempisque River Las Bombas - El Pelón	6	17
Lower Basin			**Sub-total**	**118.6**	**143.57**
6. SEGMENT A - Tempisque Níspero - Puerto Humo	22	22	**Marshes Zone**		
7. SEGMENT B - Tempisque Pto. Humo - Pto. Chamorro	7.7	7.7	16. Mata Redonda	4	10
			17. Charco River	2.2	2.2
8. SEGMENT C - Tempisque Pto. Chamorro - Bolsón	7.7	7.7	18. Bolsón River	2	5
			Sub-total	**6**	**17.2**
9. SEGMENT D - Tempisque Bolsón - El Pelón	8.7	8.7	**Total**	**174.6**	**224.86**

The field work considered a fraction of 78% of the whole potentially workable kilometres. Segments from 1-5 (Upper Basin) represent 29% of the surveyed area with visibility of 93%; segments 6-15 (Lower Basin) represent 68% of the surveyed area with visibility of 88%, and segments 16-18 (Marsh Zone) represent 3% of the surveyed area with visibility of 90%.

I could only work 35% of the available Marshes Zone habitat, due to the difficulties imposed by the environment to actually make effective observations, with too many vegetation in the edge of the water, and a profuse aquatic flora or tifa (*Typha domingensis*), lotus (*Nymphaea* sp)., choreja (*Eichhornia crassipes*), elodea (*Elodea canadensis*) and gamalote (*Paspalum fasciculatum*), which seriously difficult the transit of any type of craft, and even the researcher himself whenever I decided to get to the water trying to improve my possibilities. On the other hand I covered more than 75% of the sampleable potential habitat of the Upper Basin and Lower Basin, and in general more than 75% of the available habitat in the TGW.

A proportional distribution of the "eyes only" among the size classes results in a distribution of: hatchlings 364 (15.7%), recruits 386 (16.7%), juveniles 454 (19.6%), sub-adults 648 (28.0%) and adults 463 (20.0%).

Given that hatchlings are not considered to be a part of an effective and stable population, then substrating them from the gotten numbers, the entire number of crocodiles estimated in the TGW added up to n = 1951 crocodiles, ± s=25.96.

Distributed by area with 292 (15.0%), 1262 (64.7%), and 397 (20.4%) individuals, according to Upper Basin, Lower Basin and Area of Marshes respectively; for a general relative abundance of 8.68 ind/km; and partial for area of 4.56 in the Upper Basin, 8.79 in the Lower Basin and 23.08 in the Area of Marshes.

I captured 25 small crocodiles during the general observation field trips, every time it meant no extra difficulties to grab and manipulate them while accomplishing the general objectives of the survey. Furthermore, I carried out five field trips with the only aim of capturing as many crocodiles as possible in every one of the three environments studied. Among some other complementary targets, the purpose of these captures was to get information to estimate the population sex rate. I captured a total of 72 crocodiles, 55 males and 17 females, for a general sex rate of 3.3:1 male:female. In the High Basin I captured 12 crocodiles, 3 females, for a sex rate of 3:1 male:female. In the Low Basin I captured 52 crocodiles, 12 turned out to be females, for a sex rate of 3.33:1 male:female. I captured 8 crocodiles in the Area of Marshes, 2 of which were females, for a sex rate of 3:1 male:female. The size of capture was between 75 and 352 cm. I avoided sexing individuals of a smaller size due to the difficulties in determining sex in hatchlings and small recruits, as well as the risk injury they would run trying to sex them (Allsteadt and Lang 1995).

Table 5. Comparison of 1989-1994 (early) and 2003-2008 (late) periods with respect to meteorological station. Values are Student-t and probability. Mean (and estimated deviation) values are also provided for rainfall and minimum temperature.

	Years	Llano Grande	Taboga
Humidity		t= 0.005	t= -1,635
		p= 0.996	p= 0.105
Rainfall	1989-94	110.14 (125.47)	113.07 (106.33)
	2003-08	160.25 (181.92)	160.82 (171.98)
		t= -1,924	t= -2
		p= 0,057	p= 0.048
Max. Temp.		t= 1.015	t= 0.439
		p= 0.312	p= 0.662

On a 20-year time series between 1989 and 2008, for the climatic factors precipitation, temperature and moisture, I run a statistical analysis to contrast between the first six and last six years of the series, considering only 4 summer months in each of two existing meteorological stations in the studied area. I did this, trying to determine the effect of the climate on the skewed sex rates in the TGW, and the chosen months are these in what eggs incubate. I found significant values just for precipitation at both meteorological stations; and for the minimal values of temperature at the Taboga station, in Cañas (Table 5).

It can be seen that there has been a significant increase of up to 50.11 mm in the precipitation levels between the first and last years of the series; nevertheless, although it is true that the increase in the precipitation favors the general conditions of the crocodile's habitat, it is not proven that precipitation influences somehow the sex definition during the incubation time.

On the other hand, a highly significant change has been acquainted, of 0.66°C during this 20 years time span in the minimum temperature, in the Taboga meteorological station. In spite of this, the compared averages as can be seen in Table 6, do not even reach 24°C, therefore they do not qualify as temperatures to incubate crocodile eggs, and could not be associated this variable to the sex rate encountered.

Discussion

The crocodile population along the navigable main river channel, represents 23% of the whole estimated population for the Tempisque Great Wetlands; I verified that in effect, the real size of the local population of crocodiles has been underestimated, as a product of a limited conception of what should be the objective habitat.

The Area of Marshes constitutes a nursery for the individuals of lesser sizes, and a refuge area for crocodiles of medium total length (Sánchez 2001). Some adult crocodiles rejected from the main river channel during the season of courtship and mating, use to visit this place, and sometimes they remain there indefinitely. Lara (1990) reports as better relative abundance 5.9 ind/km for the marsh crocodile (*C. moreletii*) in a marsh segment in secondary forest, in the Petén area, Guatemala, and he argues reasons similar to those of Sánchez (2001). Casas-A and Méndez-DC (1992) report 12.3 ind/km, for a study on *C. acutus* done in 1989, in the Cuitzmala River, Jalisco, Mexico. Barahona-B and Bonilla-C (1999) report 2.16 ind/km for Orinoco Crocodile (*C. intermedius*) in the Arauca area in Colombia. Sánchez (2001) accounts for a relative abundance of 18.3 ind/km in the Tempisque river, on the navigable main river bed; right after his Sánchez *et al.* (1993) report of a relative abundance of 2.3 ind/km , scarcely in an 8 years time span. This present study, of a more integral character from the spatial point of view, seems to agree more with the last observation of Sánchez, if it is considered that there have been visited areas of diverse environmental characteristics, and the hatchlings have been excluded definitely from the analysis. It might be speculated that important events have happened during this time, to justify, along with normal changes that usually happen in any natural environment, for a jump of up to almost four times in the growth of this population, unwillingly of what it would be expectable given the loss of habitat due to the advance of the agricultural border and of the urban pressure. Porras-M (2004) reports 5.58 ind/km of *C. acutus* in the Tusubres River, in the Central Pacific coast of Costa Rica, in the area of coverage of the Playa Hermosa Wildlife Refuge, with important agricultural activity in the area, and the constant alertness of the wildlife rangers; without mentioning that according to personal information under analysis, apparently the most pristine and rainy areas affect negatively the relative abundance of *C. acutus*. As a corollary, given the existence of a report of a relative abundance of 2.28 for the Sierpe and Térraba Rivers (Bolaños *et al.* 1997), and under this former assumption, this datum is not a good reference to compare for the occasion, since the environmental conditions in the South Pacific coast of the country (Very Humid Tropical Forest) are a lot different from those found in the North Pacific coast (Tropical Dry Forest); and the impact of man is also different in both regions. Cedeño *et al.* (2006) report relative abundances from 0.13 to 2.69 ind/km for C. acutus; and of between 0.87 and 7.57 ind/km for C. moreletii, in the state of Quintana Roo, Mexico. Rainwater and Platt (2009) report 0.49 ind/km for *C. acutus* in the keys of Blackbird and Calabash, in Turneffe Atoll, in Belize. Sasa and Chaves (1992) and Piedra (2000) found in the Tárcoles River, in the Central Pacific Ocean, relative abundances of 19.2 and 32.02 respectively; comparison that must be carefully done, considering that the Tárcoles River in the segment where these studies were done, passes by the edge of the Carara National Park and also considered the Guacalillo protected mangrove. Besides, and this is more important, the tourist activity with crocodiles was born and it has developed in this place, and the tourist guides provide the animal of a special protection and feeding; without mentioning that the hatchlings class was part in these studies, and depending on the season, a large number of eyes can be seen in the river during the nights when the bloom has just taken place.

The size structure presents a peak in the class of sub-adults with 28%, and then fall down up to 20% in the adults class. The classes of lesser size, although with a high absolute frequency, are relatively speaking, of low profile, since the samplings were done almost always during the second semester of the years of field observation, and present hatchlings show a very low survivorship during the first two months of age. As for the recruits (17%) and juvenile (20%), although they were also observed in fair amount, it turns out to be very probable that they prefer to inhabit the small adjacent wetlands to the river, areas of cultivation and proper and abundant channels of irrigation in the TGW, to avoid the contact with their major size congeners and to hide better than their natural predators, until the time of having a more competitive size to introduce themselves openly before their community.

On having compared the results obtained in previous studies with the present one, it turns out to be clear that the percentage contribution of "recruits" to the population grew scarcely moderately in 6%, followed by an average growth of 8% "juvenile" in the class. In both cases the increase happened during the first 8 years of the interval, and stayed approximately stable during the space of 7 remaining years up to the present study. This might be reflecting that the nests quantity in the field increased the same way as the reproductive females stock increased in the wild during the first period. Apparently this condition remained constant during the second period.

Table 6. Comparative distribution (%) by size according of the TGW crocodile population in different years. * Sánchez *et al*. (1996); ** Sánchez (2001).

Class	1993*	2001**	2008
Recruits	12	18	18
Juveniles	14	24	7
Sub-adults	5	8	23
Adults	7	17	32

Of the same way, the quantity of "sub-adults" increased lightly from 5% to 8% during the first lapse, to advance in a change of 20% for the second period, in which the surviving recruits of the first period reached sizes of up to 2.5 and 3 m. The same relation is observable in the class of "adults", which reached an increase of 10% in the first period, and 3 more points during the second, consistent with the fact that during this stage of its lives, the crocodiles approach more its asymptotic size, and its yearly growth is perceptibly slower than the one shown by individuals of lesser sizes.

In general, the evidence points towards a population in plain growth, as demonstrated by the absolute numbers, and although it should not have been an object of this study, it would be necessary to expect that the dispersion of this population should happen of a homogeneous form in the whole area of the TGW, and according to the proper characteristics of different habitat recounted, with a better expectation in the Lower Basin of the river, because of the aquaculture companies cited.

Cedeño *et al*. (2006) reported percentages of 6.25, 34.3 and 53.1 for juvenile, sub-adult and adult respectively in the *C. acutus* population in Quintana Roo in Mexico, which demonstrates an increasing tendency towards the individuals of larger sizes, which joined to the low relative abundance might indicate a population being harvested in its individuals of lesser sizes, what marks the disappearance of these classes of size.

The fragmentation of the habitat product of the economic activities, along with the human increase in the river as a product of the boom of the tourist activities, and of the fact that human settlements seek always to be established next to the water courses; the loss or migration of the considered species "natural preys" for the crocodile, and the disappearance of some of the species that normally would prey on crocodiles during their first weeks, like coyote (*C. latrans*), puma (*Panthera concolor*), garrobo (*C. similis*), pizote (*N. narica*), martín peña (*T. mexicanus*) and real heron (*A.alba*) among others, have brought as a result that the loss of nests and of hatchlings owed to natural depredation has diminished, and that for his part, due to its proximity with man, crocodiles have changed their everyday menu towards other species that previously were not occupying its interest, like dogs, ducks, pigs, calves, and even humans when the occasion has allowed it. Additional to this, the successful establishment of the aquaculture industry has meant a constant food provision in the form of tilapia (*O. niloticus*) in all the watercourses in the area; and with this, it is reasonable to hope that the implicit reduction in the competition for food, have brought a consistent increase in the numbers of the populations of the species that feed on this fish, crocodiles one of them.

Although places exist with similar relative abundance inside the limits of our borders, and although the existing habitat presents conditions the same way adapted for the development of a numerous population of crocodiles, according to the stereotype of which places more retired and less invaded by the man present better characteristics for the development of a better population of crocodiles, nevertheless, they do not exhibit higher values and do not even be equal to what I found.

The Tárcoles River, in the Central Pacific coast presents the higher relative abundance in Costa Rica, motivated possibly by its proximity with the National Park CARARA, and for the incidence of a wide and awkward tourist activity that deals with staying awake and feeding to the crocodiles in the river. A relatively pristine area as the Sirena and Corcovado Rivers, in the Corcovado National Park, as well as the Matina, Pacuare and Sucio Rivers, in the Caribbean and North areas respectively, present values of low relative abundance (Bolaños, unpubl.), although the habitat conditions are ideal for occurring of a crocodiles population in accordance with the brought for the bibliographical references (Thorbjärnarson 1989).

Table 7. Relative crocodile abundance in several rivers of Costa Rica. *Porras-M (2004).

	2004	2005	2007	2009
Tarcoles	9.22 *	-	-	9.5
Terraba	-	-	-	2.07
Sirena	1.42	-	-	-
Corcovado	0.83	-	-	-
Matina	-	-	2.3	-
Pacuare	-	-	1.3	-
Sucio-Sarapiqui	-	2.9	-	-

Interestingly, the relative abundance in Tempisque practically has been quadrupled in a period of 18 years, with a valuation average of growth of 3.59 for the period between 1993 and 2009; the same area in which the urban and agricultural pressure increased during this time span, accompanied by the development of the road network and its consequent habitat fragmentation in the upper and low basins of the river (Cabrera 2007).

In conditions like the existing one, to attend such an important development of the resident population, where the migratory effects are practically despicable due to the relative isolation of the area as regards to the populations of the Central Pacific coast and of the external area of the Nicoya Peninsula (Porras-M 2004), and where it has not been possible to determine for the route of the analysis of the variables of climate any significantly detrimental change, must be thought about the existence of some important exogenous factor that should have affected positively in the growth of this population of crocodiles, promoting the environment load capacity to provide sustain for this induced growing population. This still not investigated evidence, but observed in the different courses of water of the Lower Basin and Area of Marshes of the TGW, points according to field observations, towards an artificial increase in the natural offer of food, with the constant organisms escape from the ponds of culture of the aquaculture companies established in Cañas and Bagaces, with direct access to the main rivers of the basin, as the propitiator of an artificially supported growth of the crocodiles population. This observation has not been scientifically evaluated, and constitutes a truth which dimension has yet to be established.

The sex rate found is distant by much from the brought one for Joanen and McNease (1980) as the ideal for a healthy population of crocodilians of 1:2 male:female. A sex ratio like the one found in this study, bears witness to the existence of a males' overpopulation that becomes problematic at the moment of initiating the courtship and mating season; the advent of more fights for the possession of the suitable places for mating and for the females in the river, result in more disabled and rejected reproductive crocodiles of the places of courtship; more crocodiles in search of refuge, strolling around for the wetland in search for a provisional place of refuge and feeding. With an increasing population like that of the TGW, it would mean also the sudden appearance of individuals of big sizes in places in what earlier they had not been sighted; more crocodiles with their high hormonal load, and in places that are not its territory; there would be more crocodiles annoying and scared with major readiness to defend themselves or to attack at all times. This has happened every time and more frequently during the last years. It is important to highlight that frequent crocodiles denunciations exist in invasion to places next to the people's houses, and also they are protagonists in the denounces about domestic animals attacked by crocodiles. Individuals with 3 or more meters of entire size, which is the size that has turned out to be consistently involved in accidents with human beings as it is possible to see in Table 8, they constitute 24% of the entire population.

Table 8. Some documented crocodile attacks on humans in Costa Rica.

Date	Size (m)	Sex
	Fatal	
3 Sep 1995	4.5	M
8 Apr 1997	5	M
1 May 1998	3	F
6 May 1999	Various crocodiles	
16 Jun 2002	3	-
11 Apr 2005	4	M
8 Apr 2007	6	M
5 May 2007	6	M
3 Mar 2008	3	F
3 Apr 2008	4	-
11 May 2010	3.5	F
17 May 2010	4	M
	Non-Fatal	
Apr 1996	3	-
Sep 2002	3.5	M
Sep 2002	3	-
7 Mar 2006	3	M
19 Sep 2006	2.5	M
19 Sep 2006	3	-
22 Feb 2007	4	M
6 Mar 2007	3	M
30 Mar 2007	4	M
22 Jan 2008	2.5	M
19 Sep 2008	3	M
17 Jan 2009	3.5	M
5 Feb 2010	4.5	M
11 May 2010	3.5	-
19 Apr 2011	4.5	M

Casas and Méndez (1992) surmise a sex rate of 1:1 M:F for their study in the Cuitzmala River, in Jalisco, Mexico; waiting for a behavior similar to the exhibited one by the species in the state of Florida, and reported like that by Kushlan and Mazzotti (1989). Cedeño-V. *et al*. (2006) found a similar relation of sexes of 1:1, so much for *C. moreletii* as for *C. acutus* in its study in the state of Quintana Roo, in Mexico. Porras-M (2004), informs a sex rate of 1:1 in three rivers of the Costa Rican Central Pacific coast. Sánchez (2001) speculates about the existence of 114 females and 38 males in the area corresponding to the navigable river bed of the Tempisque River, for what according to its criterion it would be a relation of sexes of 1:3 M:F, such as which Joanen and McNease (1980) suggest it for a healthy crocodilids population. In the estuary La Ventanilla, in Oaxaca, Mexico, García-Grajales *et al*. (2007) reported a sex rate of 3:1 M:F, similar to the one found in this study, and also deserving a deeper analysis.

Additionally, the sex rate found in this study, reflects what is already apparent in the distribution of sizes reported for this population over the course of time, where the number of smaller sizes crocodiles exhibited an important increase during the first half of the period of studies, but then it established and maintained for the second half; while on the other hand, the reproductive class showed an important increase along the whole period (Table 9), this might be demonstrating the fact that the increasing numbers of the two upper classes of the structure of sizes of the population, is sustained mostly in the increase of the males quantity over that of females, with the consequence then, that the nests of every year are being laid by a relatively constant stock of reproductive females, and then, the increase in the lower classes of the scale has stagnated, which is observed relatively constantly during the second part of the period.

Thorbjärnarson (1997) analyzes an important slant phenomenon in favor of the females in the different reports of sex rates for studies realized in crocodilids. It indicates that in general terms there should to be a tendency to which slant is brought in favor of females in case of crocodiles, as in the species *C. niloticus*, *C. novaguineae* and *C. porosus*. Thorbjärnarson (1997) points out that the skew sampling affects straight in the determination of precise reasons of sex, and establishes three potential error sources in the achievement of the samplings, distinguishing mortality in both sexes, separated habitat selection for each sex, and lacking in skill to determine the sex of the juvenile individuals. I would aim even at one more source of slant, which would be related straight on one hand to the capacity or the determination of the investigator to gain access to the most difficult spaces where it is known that there are crocodiles, and on the other hand with the decision to really capture the animals who are in conditions of difficult apprehension or who infuse sufficient fear as to discourage its potential captor.

In case that distinguishing mortality exists, which has not been studied in *C. acutus,* the current condition of the population of crocodiles of the TGW would be even the same one found during this study, and needs in this moment to establish correctional policies to return to the normality, in whose case should carry out as soon as possible a study that specially determines the occurrence of this phenomenon to establish correctional policies by size class, if it is possible to do such a thing, of course in its sizes of hatchling and recruit. As regards the second one and third slant sources, bearing in mind these remarks, I chose the apprehension environment of individuals carefully to prepare the possible environment preference on the part of both sexes; it was also decided not to sex crocodiles from the two lower size classes. I tried to be especially careful of not falling down in any of the possible causes of slant discussed.

Conclusions

The observed growth of the population of crocodiles in the TGW to have almost quadrupled in the space of 18 years; in conditions that normally would aim towards the decrease of its numbers as a result of the urban pressure on the wild areas, the expansion of the agricultural border, and of the more important human use of the water courses; induces to think that in this moment there should exist in the wild, a population that goes too far the normal possibilities of support of the wetland, not to be for the existence of a hypothetical exogenous factor, which artifitially propitiates this particular fact.

Considering the impact of the populations of crocodiles on the human populations and human activities, joined the existing growth in the population of crocodiles of the TGW, it turns out to be pertinent to design and to deal with politics of control that trend to diminish the number of crocodiles in the TGW, in the best interest of conservation of the species, and of the safety of the settlers of the region. Considering the skewed sex rate, it turns out to be logical to think that it would proceed the selective removal of males from their respective niches and in a proportional way to the individuals quantity for sub area, up to finding a more balanced sexes rate.

As an element intimately tied to the problem of quantities of crocodiles in the area, and of conflict between crocodiles and human beings, the atypical sex rate must be analyzed in a closer context, to determine the associated factors to this malady, and to propose solutions that return the indicator up to more normal values in wild populations.

It is necessary to determine the magnitude of the effect of the aquaculture farms on the load capacity of the wetland in which they are operating, across the organisms escape from their cultivation ponds; as well as the importance of implementing the possibility of exercising effective control on this escape, with the interest to induce in an immediate way a better balance in the populations of crocodiles and of other species in the ecosystem of the TGW, independently that this factor influences or not the condition of the population of local crocodiles. The real load capacity of the TGW as for crocodiles refers, it will be possible of determining once successfully gotten this balance.

Acknowledgements

Alberto Alvarado Núñez and Blas González Cruz, who actively and disinterestedly collaborated during the phase of gathering information for the achievement of this study.

Literature Cited

Allsteadt. J. and Lang, J. (1995). Sexual dimorphism in the genital morphology of young American alligators, *Alligator mississippiensis*. Herpetológica 51: 314-325.

Alvarado, J., Jiménez, J., González, E., Pizarro, F. and Jiménez, A. (2008). Determinación preliminar del caudal ambiental en el río Tempisque, Costa Rica: el enfoque hidrológico con limitación de datos. Kurú: Rev. forestal, 5 (13). Recuperado en setiembre 11, 2010 disponible en http://www.tec.cr/sitios/Docencia/forestal/Revista_Kuru/anteriores/anterior13/pdf/articulo%201.pdf.

Barahona-B, S.L. and Bonilla-C, O. P. (1999). Evaluación del status poblacional del caimán llanero (*Crocodylus intermedius* Graves, 1819) en un subareal de distribución en el Departamento de Arauca (Colombia). Rev. Acad. Colomb. Cienc., 23: 445-451.

Bolaños, J.R., Sánchez, J. and Piedra, L. (1997). Inventario y estructura poblacional de crocodílidos en tres zonas de Costa Rica. Rev. Biol. Trop. 45(1): 283-287.

Cabrera, R. (2007). Tierra y ganadería en Guanacaste. Vida y trabajo de Virgilio Angulo Reyes/Roberto Cabrera Padilla. Cartago, Costa Rica: Editorial Tecnológica de Costa Rica.

Casas-A, G. and Méndez-DC F. R. (1992). Observaciones sobre la ecología de *Crocodylus acutus* en el río Cuitzmala, Jalisco. México. Rev. Soc. Mex. Hist. Nat. 43: 71-80.

Cedeño-V. J.R., Ross, J. P. and Calmé, S. (2006). Population status and distribution of *Crocodylus acutus* and *C. moreletii* in southeasthern Quintana Roo, México. Herpetological Nat. Hist. 10(1): 17-30.

García-Grajales J., Aguirre-León, G. and Contreras-Hernández, A. (2007). Tamaño y estructura poblacional de *Crocodylus acutus* (Cuvier 1897) (Reptilia:Crocodylidae) en el estero La Ventanilla, Oaxaca, México. Acta Zool. Mexican 23(1): 53-71.

Instituto Meteorológico Nacional. (2010). Atlas Climatológico de Costa Rica. Recuperado setiembre 11, 2010 disponible en http://www.imn.ac.cr/educacion/atlas/manual_atlas.pdf.

Joanen, T. and McNease, L. (1980). Reproductive biology of the American alligator in southwest Louisiana. Pp. 153-9 *in* Reproductive Biology and Disease of Captive Reptiles, ed. by J.B. Murphy and J.T. Collins. Society for the Study of Amphibians and Reptiles: Laurence, Kansas.

King, F.W., Espinal, M. and Cerrato, C.A. (1990). Distribution and status of the crocodilians of Honduras. Pp. 313-354 *in* Crocodiles. Proceedings of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Kushlan, J.A. and Mazzotti, F.J. (1989). Population biology of the American crocodile. Journal of Herpetology. (23): 7-21.

Lara, O.F. (1990). Estimación del tamaño y estructura de la población de *Crocodylus moreletii* Duméril & Duméril (Crocodilidae - Reptilia), en los lagos Peten-Itza, Sal-Peten, Petenchel y yaxha, El Petén, Guatemala. Tesis de Maestría no publicada, Programa Regional en Manejo de Vida Silvestre para Mesoamérica y el Caribe, Universidad Nacional, Costa Rica.

Peters, G. (2001). La cuenca del Tempisque: una perspectiva histórica. Pp. 1-21 *en* La cuenca del río Tempisque: perspectivas para un manejo integrado, ed. por Jiménez J. y E. González. OET. 150 p. Recuperado en enero 14, 2011 disponible en www.wetlands.org/reports/SiteReports/CostaRica/6CR001/6CR001_ManPlansp.pdf.

Piedra, L. (2000). Población de cocodrilos (*Crocodylus acutus*) en tres ríos del Pacífico Central de Costa Rica. Tesis para optar al grado de Licenciatura en Biología Marina con énfasis en acuacultura, no publicada, Universidad Nacional, Costa Rica.

Porras-M, L.P. (2004). Abundancia relativa y estructura poblacional del cocodrilo americano (*Crocodylus acutus*) en tres ríos del Pacífico Central de Costa Rica. Tesis de Maestría no publicada, Programa Regional en Manejo de Vida Silvestre para Mesoamérica y el Caribe, Universidad Nacional, Costa Rica.

Rainwater, T.R. and Platt, S.G. (2009). Possible decline of an American crocodile (*Crocodylus acutus*) population on Turneffe Atoll, Belize. Herpetological Bull. 107: 3-11.

Sánchez, J., Bolaños, J. and Piedra, L. (1996). Población de *Crocodylus acutus* (Crocodylia: Crocodylidae) en dos ríos de Costa Rica. Rev. Biol. Trop. 44(2): 835-840.

Sánchez, J. (2001). Estado de la población de cocodrilos (*Crocodylus acutus*) en el río Tempisque, Guanacaste, Costa Rica. Informe final presentado a Área de Conservación Tempisque (ACG) e Instituto Nacional de Biodiversidad (InBio). 49 p. Recuperado enero 26, 2011 disponible en http://www.inbio.ac.cr/es/estudios/PDF/informe_Cocodrilos.pdf

Sasa, M. and Chaves, G. (1992). Tamaño, estructura y distribución de una población de *Crocodylus acutus* (Crocodylia: Crocodilidae). Rev. Biol. Trop. 40: 131-134.

Thorbjärnarson J. (1989). Ecology of the American crocodile, *Crocodylus acutus*. Pp. 228-259 *in* Crocodiles. Their Ecology, Management and Conservation. IUCN: Gland, Switzerland.

Thorbjärnarson J. (1997). Are crocodilian sex ratios female biased? The data are equivocal. Copeia 1997(2): 451-455.

Conservation of *Crocodylus acutus* by Local Communities in the Mangroves of Cispata Bay, Cordoba, Colombia, South America

Giovanni Andrés Ulloa Delgado and Clara Lucía Sierra Díaz

Estación CIMACI-CVS, Vereda Amaya, San Antero, Córdoba, Colombia (croco_mangle@hotmail.com, clsierra@hotmail.com)

Abstract

Over the last 8 years, a group of 18 former crocodile hunters, known as "caimaneros" at Cispatá Bay, Colombia have turned conservationists, joining a project to save the critically endangered American crocodile (*Crocodylus acutus*). The project includes recovery programs, population monitoring, biological studies on sustainable use, education and communication and it was created a capacity-building program since 2004, in order to promote local livelihoods and give the reptiles a fighting chance. Crocodile eggs are hatched in incubators and reared until they are large enough to release into the wild. As the project is based on sustainable use of the population it will need ongoing monitoring and research that will help form a sound management plan. The project is supported by the Environmental Regional Authority CVS and is part of the integrated management plan for local mangroves on which many people depend for livelihoods.

Preliminary Management Plan for the Conservation of Populations of Caiman Aguja (*Crocodylus acutus*, Cuvier 1807) at Sardinata, San Miguel, New President and Tibu Rivers, Norte de Santander, Colombia

Giovanni Andrés Ulloa Delgado and Juan M. Peláez Montes

croco_mangle@hotmial.com; juanmanuelpelaez@gmail.com

It was discovered and scientifically documented the population of crocodiles or "caiman aguja or caiman of Magdalena" (*Crocodylus acutus*) most important of Colombia, for its abundance and because population structure corresponds to an acceptable condition of conservation. In the 132 studied kilometres of Sardinata, San Miguel, new President and Tibú Rivers, the census showed 196 established crocodiles with total density of 1.48 crocodiles per km at Sardinata River basin, and an estimate of several thousands of animals. Also the research concluded that deforestation in gallery forest formations was identified as the most significant alteration of the ecological context in the four rivers, with direct influence on the habitat of the crocodiles. In addition to the own research results, the study allowed to structure a line of continuity spanning all possible strategies, which are touted at the global level, to ensure the conservation of biodiversity and in the case of crocodiles in Sardinata River basin. Today we know where are and how are the populations of crocodiles for much of the Sardinata River basin. Also know wthat it should be done for immediate conservation: Research, Education, Community Participation and Declaration of Protected Areas; these are some of the main strategies proposed in the preliminary plan.

Monitoring Program for Morelet's Crocodile (*Crocodylus moreletii*) Mexico-Belize-Guatemala

Hesiquio Benítez Díaz

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Autoridad Científica CITES de México, Av. Liga Periférico-Insurgentes Sur 4903, Parques del Pedregal, Tlalpan, C.P. 14010, D.F., México (hbenitez@conabio.gob.mx; ac-cites@conabio.gob.mx)

Abstract

Since 2009, CONABIO coordinates Morelet's Crocodile Monitoring Program in Mexico, looking towards a trinational scope (Mexico-Guatamala-Belize) and aiming to provide periodic information on a long term basis on conditions and trends of the main wild populations and habitat of *Crocodylus moreletii*. It included two phases: 1. Design: a Trinational Workshop (Mexico City, January, 2010) was held with experts and authorities of the three countries and members of CSG-IUCN, reaching agreement on methods, periodicity, populations to be surveyed, coordination and equipment needs, and mechanisms to systematize and analyze information. Such agreements where compiled on a Procedures Manual for training and field work, published in June 2011 (http://www.conabio.gob.mx/institucion/cooperacion_internacional/doctos/manualf_monitoreo_cocodrilo.pdf). 2. Implementation: agreements were signed between CONABIO and four institutions for establishment and training of field teams, surveys and systematization of field data. CONABIO administrate the Database, which is accessible via internet to data providers. Field work initiated on 2011 and information is already available at the Database. On 8-9 March 2012 another Workshop was held in Mexico City on Evaluation of Results for Season 2011 to analyze results, share lessons learned, identify opportunities, and plan for 2012 season. Final monitoring sites and some changes to the database, field formats and methods were agreed.

Criteria and Basis for Implementing a Management System of Brazilian Amazonian Caimans

Robinson Botero-Arias[1] and Boris Marioni[2]

[1] Caiman Research in Conservation and Management Program, Mamirauá Institute for Sustainable Development, Estrada do Bexiga, no 2584, Bairro Fonte Boa, CEP 69470-000, Tefé/AM, Brazil (robin@mamiraua.org.br)
[2] Amazonian Crocodilians Conservation Program, Piagaçu Institute, Rua UZ n°8 Cj Morada do Sol, 6900-000, Manaus-AM, Brazil (bmarioni@mac.com)

Abstract

Records of large populations of black caiman in the Brazilian Amazon and a legal and political environment led to the development of a proposal for caiman management in Protected Areas. Since 2004, Amazonas State Government, Brazil, developed an experimental caiman extraction the in Mamirauá Reserve. The implementation of this management experienced technical failure, primarily due to the inappropriate use of models developed and applied in other regions and with other caiman species. Moreover, legislation and health regulations are not suitable to local reality. Since 2008, we intensified the studies to develop technical and scientific criteria to support a community-based sustainable management system of Amazonian caimans. These criteria are based mainly on the identification of nesting areas and potential areas for extraction, as well as exclusion criteria associated with the size and sex of caimans to be captured. Some of these criteria were included in the state law that, since 2011, regulates caiman management in Amazonas. In addition to these technical and scientific basis, the the Caiman Research Program of Mamirauá Institute and of Piagaçu Institute are developing the basis for strengthening the community-based system. This system stands on the participative zoning of potential management areas, community organization and monitoring of caiman populations.

Update on Population Monitoring of *C. porosus* and *C. novaeguineae* in Middle-Upper Sepik River Region of Papua New Guinea, 1981-2012

Veari Kula[1] and Godfrid Solmu[2]

[1] Department of Environment and Conservation, P.O. Box 6601, Boroko, National Capital District, Papua New Guinea (vkula@dec.gov.pg)
[2] Mainland Holdings Limited, P.O. Box 196, Lae, Morobe Province, Papua New Guinea (crocresearch@mainland.com.pg)

Abstract

The objective of this report is to present nest count survey results of both species since inception of surveys and highlight key issues including recommendations for the CITES Management Authority for consideration in managing the resource. The surveys are conducted by straight transecting through survey sites in a systematic fashion and nesting trends examined for dufferent survey periods. The results of nesting effort for both species indicate increasing trends for both species. For *C. porosus*, regardless of which nesting indices (12, 27 and 41 sites) are used, the results showed increasing trends, similar to the trends for *C. novaeguineae* for 3 nesting indices (21, 36 and 49 sites). An issue of particular interest is habitat degradation particularly due to two exotic fish species, *Puntius goniontus* and *Pacu piarcatus*, introduced in 2004 by FAO as part of its food security program. It is evident that nesting efforts will continue to be a challenge from the fish species for the future monitoring program with further habitat degradation which will require interventions with both capacity, technical and financial assistance.

Introduction

The Middle-Upper Sepik River is home to two species of crocodiles identified as having significant cultural heritage and importantly the economic value for its skin to local communities that live along this river system. Majority of local communities have no other means of income and the use of crocodiles for skins, meat and eggs harvested through the egg harvest program conducted by industry increases its value and make it a valuable natural resource in this region.

The surveys for *Crocodylus porosus* and *C. novaeguineae* commenced in the Middle-Upper Sepik River in 1982 and 1981 respectively. Papua New Guinea is a Party to CITES and is required to ensure that its obligations are fulfilled through the continuation of the annual surveys and reporting program. However, since the program commenced, surveys have been inconsistent over the years due to funding limitations including capacity constraints within the Department of Environment and Conservation (DEC). Despite these difficulties, DEC is working in coordination with Industry has continued to maintain this important program.

The efforts from Government, Industry, NGOs and CBOs have all played a significant role in sustaining this program particularly in environmental management, biodiversity conservation, introduced exotic species and wetlands awareness. WWF has assisted DEC in partially funding surveys in the past and has maintained a strong presence in this area for some of its programs. A more recent intervention by a local CBO, the Sepik Wetlands Management Initiative (SWMI), an initiative of late Jack Cox with efforts in creating awareness on preservation and management of crocodile nesting habitat in supporting Government efforts is greatly appreciated by the local communities.

Methodology

The survey methodology is described in detail in previous reports (Solmu 2011) with the 41 Primary, Secondary and Tertiary sites for the C. porosus and 49 sites for C.novaeguineae covering a distance of 80 km along the Middle-Upper Sepik River. Using a Bell Long Ranger helicopter, survey sites are traversed in a systematic fashion to ensure consistency with previous years. In survey areas where flooding or burning is apparent and accompanied by flimsy vegetation as well as areas degraded by exotic fish species, adjustments were made to traverse sites. The principle spotter is the main spotter of nests and confirmation with the navigator is made prior to recording nests. Additional information on survey variables such as habitat condition including flooding, burning and extent of damage caused by exotic fish are also noted. In instances, where a backup spotter is required, sites are traversed in a manner using both spotters.

Results

Crocodylus novaeguineae

The analysis of 21 nesting sites for *C. novaeguineae* surveyed since 1981 allowed some broad trends within three different periods to be identified (Fig. 1).

1. Between 1981 and 1988 nest numbers were stable over time (r^2= 0.005, p= 0.88; N= 7), with a mean of 91.4 nests per year (SD= 16.08, N= 7, range 73 to 107).
2. Nest numbers decreased significantly between 1988 and 1993 (r^2= 0.89, p= 0.005, N= 6), from 103 nests in 1988 to 72 nests in 1992 to 1993.
3. Between 1993 and 1999 nests numbers increased significantly over time (r^2= 0.54, p= 0.037, N= 8), but a more significant increase has occurred since 1999 (see Fig. 2).

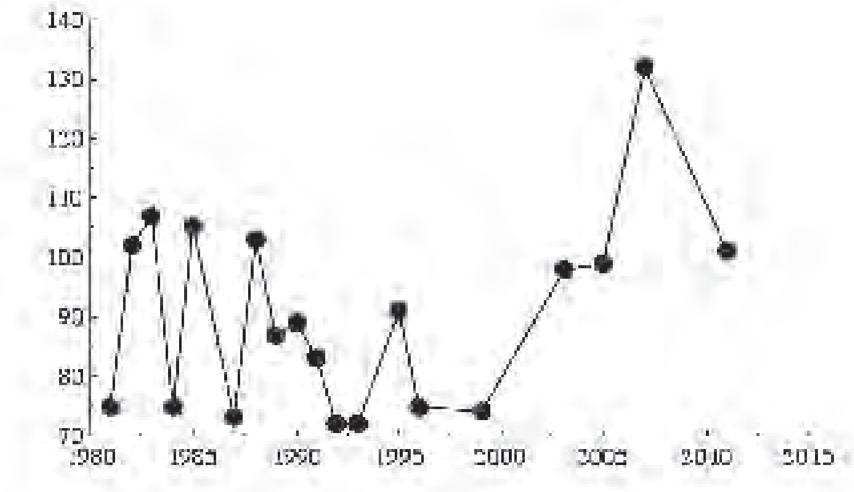


Figure 1. Numbers of *C. novaeguineae* nests recorded at 21 nesting sites, 1981-2011.

With the 21 primary sites, we further examined two other subsets of *C. novaeguineae* data (21, 36 and 49 sites respectively) over the 1992-2011 period. Data indicate that the increasing trends in nesting are significant (r^2= 0.59, p= 0.016; r^2= 0.61, p= 0.013; r^2= 0.56, p= 0.021; for 21, 36 and 49 sites respectively; Fig. 2). Mean annual rates of increase were similar for the three subsets of data, at 2.6, 3.1 and 3.3% p.a. respectively. The mean rate of increase of 3.3% p.a. for the 49 sites is considered to reflect the situation with the species at this time. The 49 sites also represent all sites for the species being surveyed.

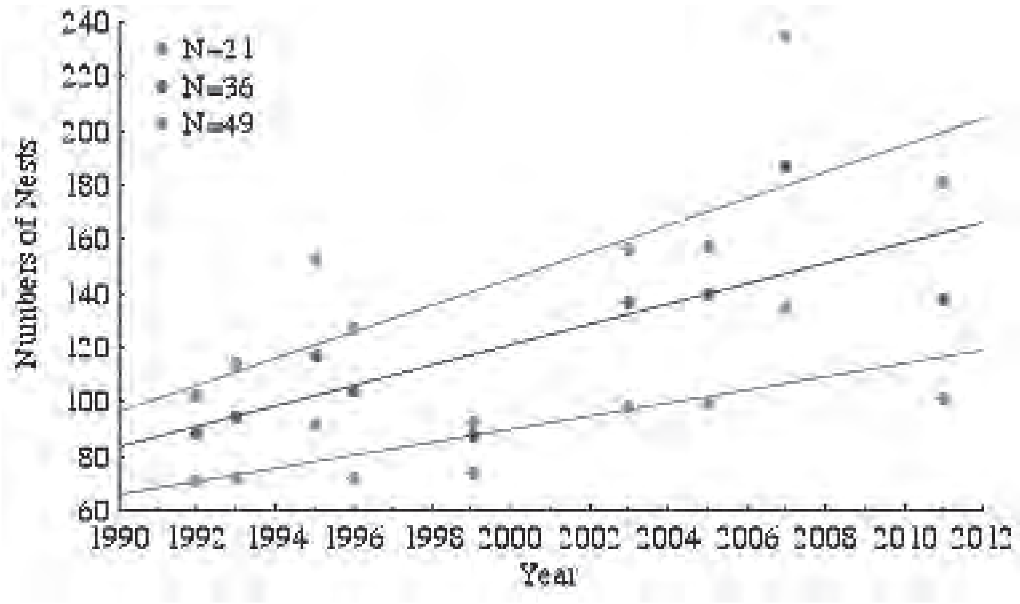


Figure 2. Linear regression relationships between numbers of *C. novaeguineae* nests and year for three subsets of data [21 (bottom), 36 (middle) and 49 (top) nesting sites], 1992-2011. All regressions were significant.

Crocodylus porosus

The analysis for *C. porosus* was also carried out for Primary Sites N=12 sites (1982-2012), excluding 1998, which had a particularly low count (Fig. 3). The trend reflected a significant relationship between nest counts and year (r^2= 0.77, p= 0.0001), and a mean rate of increase of 2.5% p.a. When the 2012 data set were excluded, a higher proportion of the variation was explained (r^2= 0.83, p= 0.0001), and the mean rate of increase was slightly higher at 2.8% p.a.

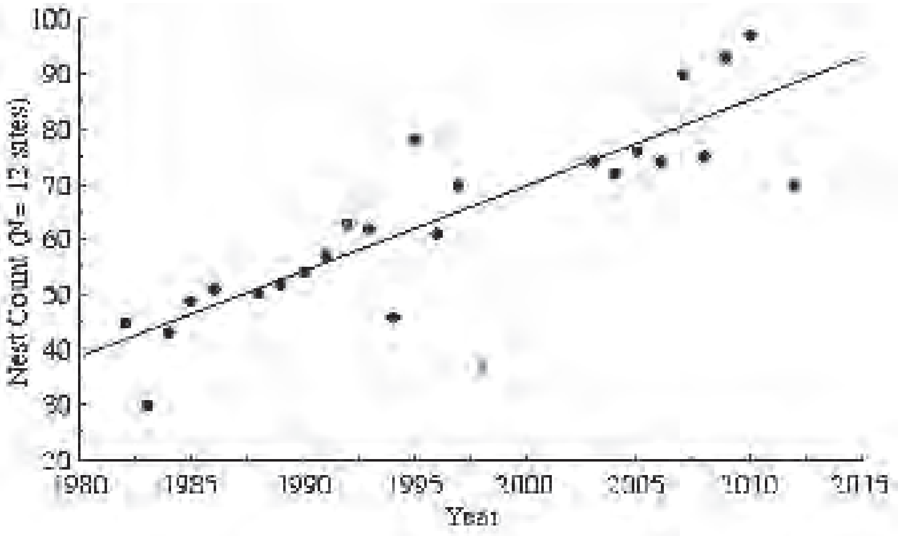


Figure 3. Relationship between *C. porosus* nest counts in 12 Primary Sites and year (1982-2012). Line indicates the significant linear regression relationship, with 1998 excluded.

At the same time the other subset surveyed (N= 27 sites, 1988-2012), Figure 4, was also looked at excluding 1998 which had a particularly low count, there was a significant relationship between nest counts and year (r2= 0.70, p= 0.0001), and a mean rate of increase of 2.4% per annum. When the 2012 was excluded, a higher proportion of the variation was explained (r2= 0.88, p= 0.0001), and the mean rate of increase was slightly higher at 2.9% p.a. In addition, a greater rate of increase is apparent since 2003, indicating a mean rate of increase of 4.9% p.a. between 2003 and 2010.

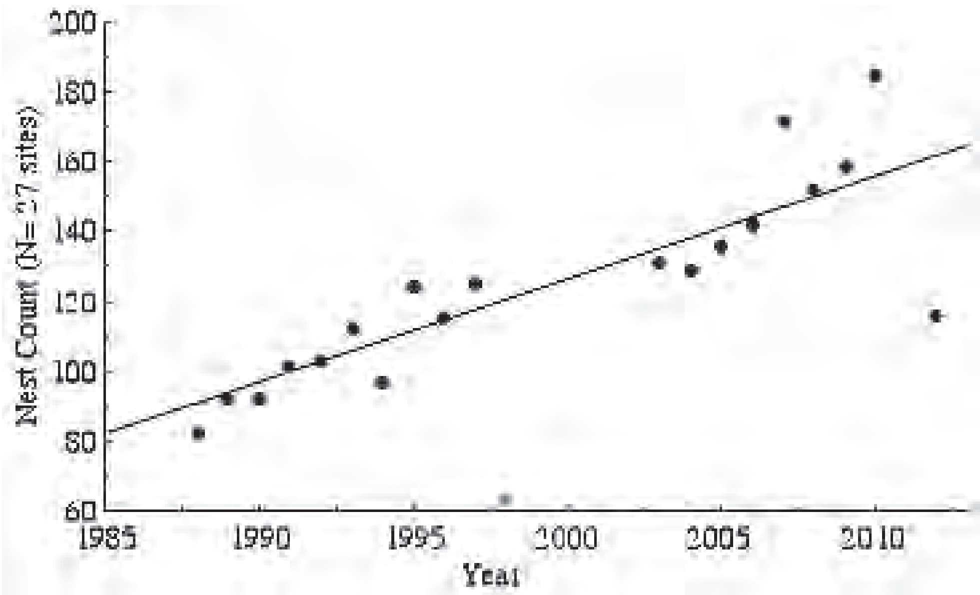


Figure 4. Relationship between *C. porosus* nest counts in 27 Primary Sites and year (1988-2012). Line indicates the significant linear regression relationship, with 1998 excluded.

When the whole *C. porosus* data sets were again examined (N= 41) for the years in which all sets were consistently surveyed (1991-2012; Fig. 5), with the exclusion of 1998 again due to the low counts observed in that year following the

1997 El Nino. It showed a significant relationship between nest counts and year (r^2= 0.66, p= 0.0001), and a mean rate of increase of 2.7% per annum. With 2012 excluded a much higher proportion of the variation was explained (r^2= 0.87, p= 0.0001), and the mean rate of increase was slightly higher at 3.3% p.a. Similarly, as with the 49 *C. novaeguineae* sites, the 41 *C. porosus* sites are also representative of the survey area as a whole and that the nesting effort continues to increase at a significant rate.

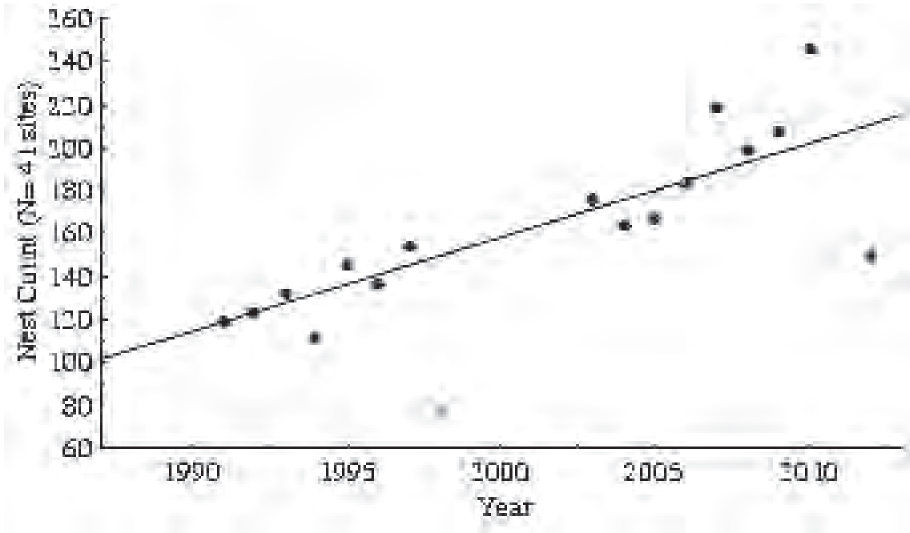


Figure 5. Relationship between *C. porosus* nest counts in 41 sites (Primary and secondary) and year (1991-2012). Line indicates the significant linear regression relationship, with 1998 excluded.

A comparative analysis was also carried out for the results of *C. porosus* and *C. novaeguineae* nest counts at 17 of the primary sites between 1982 and 2010, and this revealed quite a different nesting trend (see Fig. 6).

1. Between 1982 and 1994 nest counts increased significantly over time (r^2= 0.91, p= 0.0001, N= 11), at a mean rate of increase of 8.9% p.a.
2. Between 1994 and 2006 nest numbers continued to increase (r^2= 0.84, p= 0.001, N= 8), albeit at a greatly reduced rate (1.7% p.a.).
3. Between 2006 and 2010 nest numbers increased rapidly (r^2= 0.76, p= 0.05, N= 5), returning to a similar rate of increase (8.6% p.a.) as observed in the 1982-94 period (8.9%).

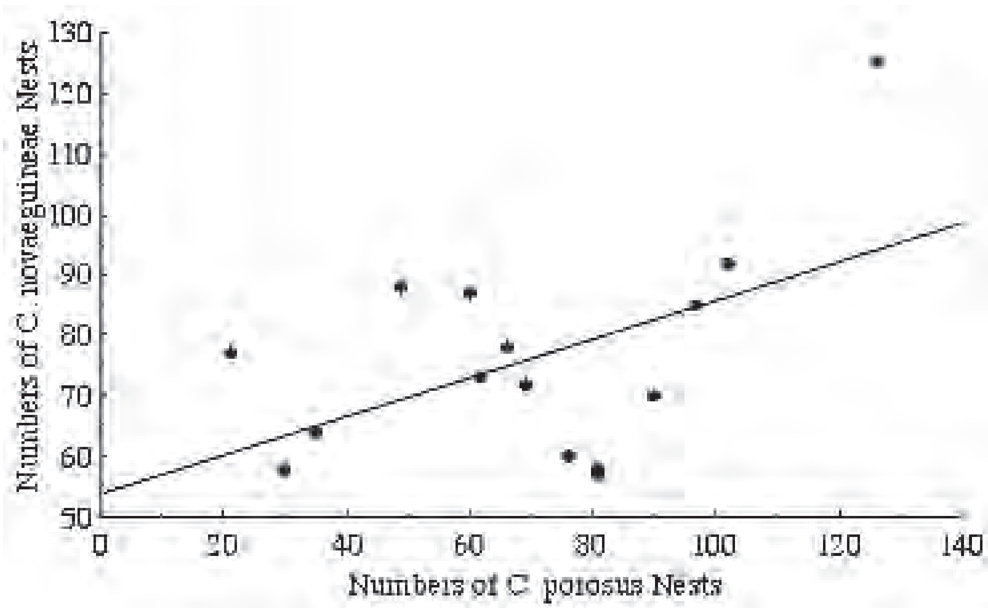


Figure 6. Linear regression relationship between numbers of *C. novaeguineae* and *C. porosus* nests within 17 representative sites in the survey area.

Discussion

The sites surveyed for each species are primary and secondary nesting areas, and the nesting trends derived are considered representative of trends for each species in the area as a whole. For *C. porosus*, the two nesting indices (12 and 41 sites) indicate significantly increasing trends over time, indicating a healthy breeding population, despite general disintegration of habitats across all sites. The 41 sites showed a significant relationship between nest counts and year (r^2= 0.66, p= 0.0001), and a mean rate of increase of 2.7% p.a. This is also reflected for *C. novaeguineae* (21, 36 and 49 sites). The data indicate that the increasing trends in nesting are significant (r^2= 0.59, p= 0.016; r^2= 0.61, p= 0.013; r^2= 0.56, p= 0.021 respectively) with a mean rate of increase for the 49 sites at 3.3% p.a.

With the observed results from the analysis for both species it can be assumed that there is little doubt that the increases in nesting especially for the *C. porosus* began when the egg harvest program in partnership between Department of Environment and Conservation, Mainland Holdings and importantly the landowners themselves agreeing to the initiative resulting from greater community awareness and subsequent "protection" of breeding females. At the same time it is also noted that the nest counts may be variable from year to year due to various factors for instance the nesting effort in 1998 which was affected by extended drought "El Nino" throughout Papua New Guinea resulting in very low nest counts.

Considering the significance of continued long term monitoring program, DEC also made an effort to improve and streamline surveys. This includes two survey sites for *C. porosus*, Japandai and Bimba, being dropped in 2012, due to no nests being recorded over the past 8-10 years. By excluding the two sites from the counts and the analysis, it reduces flight time by at least 2 hours. This approach will continue to be considered on other sites in the long-term as part of DEC's strategy in cost saving where helicopter hire rates are now becoming very competitive due to the mining and liquefied natural gas (LNG) explorations in PNG. With the increase in hourly rates DEC needs to justify the importance of financing this program for the benefit of the industry and communities that depend on the use of the resource. The current progressive arrangement at DEC in moving into an Authority will be a key component to ensure surveys are sustained. Thus, it has to seriously consider the outsourcing of the program with financing from the government so that sustainability of surveys, the conduct and reporting is not comprised.

For the longer-term, the conservation-oriented egg harvest program, initially established in conjunction with the nest survey, has changed its focus, with majority of egg harvests now confined outside of the survey areas. According to Cox *et al.* (2006), the volume of harvest has increased significantly in recent years. Despite the significant income gained by local communities through the purchase of eggs by Mainland Holdings, it may be necessary in the short-term for a detailed assessment of the egg harvest on wild juvenile populations, hence DEC`s obligation is to conduct monitoring surveys in harvested areas to better provide evidence relating to long-term impacts of this activity. It is apparent from survey data that few active nests were harvested within survey areas, which defeats to some degree the initial purpose of the conservation-oriented egg harvest program. This is an issue that DEC should discuss with Mainland Holdings to seek avenues for developing monitoring tools. Manolis (1995) recommended assessing harvest data for live animals and skins as an important tool in determining whether egg harvests have a significant impact on juvenile crocodiles and this is yet an outstanding issue for DEC to follow through.

In addition to the exotic fish, a wetlands management plan or strategy needs to be adopted and put in place as a working document for the local communities. This will enhance the issue and provide a wider local community understanding. The continued degradation of primary nesting areas by introduced fish species raises grave concerns. Habitat degradation is eminent and with the current rate, in the next 3-5 years there may be very little nesting habitat in some primary nesting sites (Solmu 2009). Explicit examples of degradation are at Ningyum Lagoon, an inundated oxbow lake with compact floating mats (eg *Acrostichum aureum* with a mixture of *Lersia* and *Phragmites*), has now vanished, with only the remnant mats of *Thoracostachyum sumatranum* and pandan patches along the western lake fringe (Solmu 2009).This scenario places the Department in a situation where conduct of surveys need to be tailored to accommodate degradation of nesting habitat within specific sites. Compounded with that, there is no specific program within concerned agencies in PNG to monitor introductions of exotic fish species and their impact on the ecology of the river systems. DEC needs to take a leading role with stakeholder and partner government agencies and industry to mitigate the continued degradation to nesting habitat and native species (Solmu 1999).

Conclusions

The results indicate that the nesting data for the past 18 survey years, from the breeding segments of the crocodile population at many of the sites is increasing even with the degradation of prime nesting habitats. Current market prices and lower demand on *C. novaeguineae* skins may have reduced hunting pressure on wild populations. This is evident from current population trends for the species which exhibit significant increasing trend (Solmu 2011). Current increasing nesting trends for both species support to a larger extent a basis for surveys to be conducted due to the wild harvesting regimes being employed by the local communities and the exotic fish introductions on the habitats. Again, these surveys are very technical and costly for DEC as compared to other surveys, and presents difficulties in securing funds to implement. Thus, recommendations have been made for the implementation of surveys for both species to be alternately carried out bi-annually.

In summary, the observation of the recorded results from surveyed data, indicate the number of nests per site, which when plotted suggests variable increases, given the similarity in survey methodology since 1981 and 1982 respectively for both species. Whilst, the survey maintained the same line of survey at many sites, sometimes the flight path is slightly modified due to the structure of floating habitats being disintegrated by introduced fish species. The modification is considered minimal as the survey could not maintain the "fly over open water" in many areas where there is no vegetation strips or corridors. This is to minimise both costs and time from site to site. Importantly the consistency is being maintained to operate these survey and that the overall number of nests would not account for a large variance in nests counted as the survey dates have been consistent over many years.

Acknowledgements

In our endeavour to consistently seek annual funding from government to support the conduct of this survey we are also indebted to various kind-hearted colleagues who have generously out of their busy schedule are able to assist analyse, review and comment on various parts of our data sets. Thus, we are very grateful and would like to especially acknowledge the contributions by Charlie Manolis of Wildlife Management International, Darwin, Australia. At the same time we are also grateful that for the support contributed by the industry in Papua New Guinea - the Mainland Holdings Limited for assisting with technical personal to conduct this very important annually surveys. It further consolidates the stakeholder partnerships and provides the capacity support that underpins this important program.

Literature Cited

Cox, J. et al (2006), The saltwater crocodile *Crocodylus porosus* egg harvest program in Papua New Guinea: linking conservation, commerce and community development. *In* Crocodiles. Proceedings of the 18th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Hollands, M. (1984), Preliminary examinations of the crocodile population trends in PNG from 1981-1984. Prepared for the 7th Crocodile Specialist Group meeting in Caracas, Venezuela, 1984. Crocodile Management Project, Livestock Division, Department of Primary Industry, PO Box 2141, Boroko, Port Moresby.

Manolis, C. (1995). Monitoring *Crocodylus porosus* nest numbers in Papua New Guinea. A Review with Recommendations. Wildlife Management International: Darwin.

Solmu, G.C. (2011). Aerial nest surveys of the New Guinea Freshwater crocodile (*Crocodylus novaeguineae*) nesting trends. A report produced for the Department of Environment and Conservation. Report No: 1/2011.

Solmu, G.C. (1999). Aerial Nest Counts Survey of the Estuarine crocodile (*Crocodylus porosus*) Nesting Effort in the Upper Sepik River of Papua New Guinea, 24-27th March 2009. A report produced for the Department of Environment and Conservation. Report No: 1/2009.

Harvesting of Wild Crocodile Eggs in Queensland by Aboriginal Landowners

Adam R.C. Britton

Big Gecko Crocodilian Research, McMinns Lagoon, N.T., Australia
(abritton@crocodilian.com)

Abstract

An investigation into the feasibility of a sustainable harvest of wild Saltwater Crocodile (*Crocodylus porosus*) eggs from Cape York Peninsula was initiated in 2008 following the publication of the *Cape York Peninsula Heritage Act 2007*. The Act provides the possibility of a wild harvest benefiting Traditional Owners as long as sustainability can be demonstrated. Surveys were conducted on nesting habitat, nesting activities, population density and structure in 11 notable tidal rivers around Pormpuraaw and Kowanyama in western Cape York Peninsula over a period of 4 years. This habitat is not considered optimal nesting habitat for *C. porosus* but the proximity of the Edward River Crocodile Farm provided the motivation for its selection as a potential trial area by the Queensland State Government. Despite finding relatively low densities of crocodiles, the breeding population appeared to be healthy on the basis of regular nesting and a population structure in most rivers that closely reflected one near to carrying capacity. This remained true despite high levels of egg mortality recorded, due primarily to largely predictable annual flooding, and high levels of post-hatching mortality within the first 6 months which was independent of egg mortality within the natural extremes measured. This not only reflects a strategy adapted to unpredictable environments, it also suggests that harvest pressure on crocodile eggs in the area, as part of a proposed management strategy to benefit Traditional Owners, would very likely have no measurable impact on recruitment. In early 2012 the Queensland Government approved the first experimental harvest of wild *C. porosus* eggs in Queensland since protection (1974). This initial harvest will be appropriately conservative in scope, will be combined with continued monitoring, and will test the conclusions drawn from the previous survey results.

Vectorized Photos of Crocodile Heads and Skins

Alvaro Velasco B.

Fauna Silvestre: Productos & Servicios, Apartado Postal 66597, Caracas, Venezuela (velascocaiman@gmail.com)

Abstract

The Crocodile family is divided in three sub families. Crocodylinae or "True" Crocodiles, conformed by 13 species distributed in all continents. Alligatorinae "Alligators and Caimans" represented by 11 species, principal in Latin America (9), one in USA and other one in China. Gavialinae "Gharials and False Gharials" involve only 2 species distributed in South Asia. Differences between the crocodile sub families are associated with the head. These include the bones and jaws structures generating the variation that allow identify the three Crocodile sub-families. One the other hand, skins are split in classic and non-classic by the international market. This classification is based on the type and distribution of scales, and bones or osteoderms present into flanks and skins. Through a Graphic Design computer program, Adobe Illustrator CS5, I have selected juvenile's crocodile head photographs in dorsal and ventral view, and tanned or fresh skins, and tanned flanks to be transformed into vectorized or digitalized images. This results in an image with all head and leather details, which permit a better identification of the differences of crocodiles species and skins.

Resumen

La familia de los Cocodrilos está dividida en tres sub familias. Crocodylinae o verdaderos cocodrilos, conformada por 13 especies distribuidas en todos los continentes. Los Alligatorinae "Aligatoridos y Caimanes" representados por 11 especies, principalmente se encuentran en Latino América (9 especies), una es USA y otra en China. Los Gaviales o falsos Gaviales con dos especies, distribuidos en el Sureste Asiático. Las diferencias entre las familias de los cocodrilos están asociadas a la forma y tipo de cabezas, donde las variaciones de los huesos y las estructuras de las mandíbulas permiten identificar y/o separar las tres sub familias. Con las pieles, en el mercado internacional se identifican las denominadas pieles clásicas y las no clásicas. Esta clasificación se basa en el tipo, distribución y patrón de las escamas, y en la presencia de huesos "osteodermos" en los flancos o pieles. Utilizando un programa de diseño Gráfico, Adobe Illustrator CS5; se seleccionaron fotos de la cabeza, tanto dorsales y ventrales de cocodrilos juveniles, y fotos de pieles y flancos curtidas o no, para ser vectorizadas o digitalizadas. El resultado es una imagen que muestra todos los detalles de la cabeza o de las pieles, que permite su ilustrar mejor las diferencias entre las especies de cocodrilos.

Introduction

In the 1970s, all 23 crocodiles species were threatened or endangered (Thorbjarnarson 1992). The principal reason of this situation was overexploitation, illegal trade and uncontrolled harvest program (Velasco 2008). With the appearance and activation of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), that controls and design mechanisms for international trade and the Crocodile Specialist Group of the IUCN-SSC, that promotes the sustainable use of all crocodilians; appear guidelines to reduce the illegal trade, design strategies or tools to recover the wild populations and mechanism to control de international trade (Velasco 2005).

Those events were traduced in species recuperation, to the level that some of them begun to be used under sustainable programs, through wild harvest, ranching or captive breeding programs around the world. And also hunting programs, where the hunters export trophies to their countries.

One important point is how the customers in importing countries identify what species or sub-product are and if this specie is permitted to international trade. One of the most important document that permit to know and identify crocodiles species and its characteristics, is the CITES Identification Guide - Crocodiles (1995) published with the support of Canadian Ministery of Environment. Trutnau and Sommerlad (2006) have a large explanation of crocodile systematics, and reproduce the identification keys for crocodilians of Wermuth and Fuchs (1983). Also, Trutnau and Sommerlad (2006) include another key to identify belly skins of Alligatorinae, Crocodylinae and Tomistominae.

The most complete identification manual for crocodile skins was by Fuchs (2006). This book is so useful in all points of export; import and re-export for identify crocodile skins, through the images showed the characteristics for each species. The first crocodile head drawn was in 1953 by G. Richter (see Wermuth 1953). Those illustrations are excellent and are the inspiration for this work.

Methods

The basis is a high quality photograph, which when zoomed in on, does not lose focus, pixels, and all details of the head or skin can be seen. I used Adobe Illustrator CS5, a graphic design program. It permits to vectorize or digitalize all characteristic of the image in different layers. The result is an image with all detail of head or skins. Each layer permits to use different thickness lines, to separate and identify any particular detail.

For crocodile heads, we used two different images. One is a dorsal (Image 1A) and other is a lateral view (Image 1B). All crocodile photographs used in this work were juveniles.

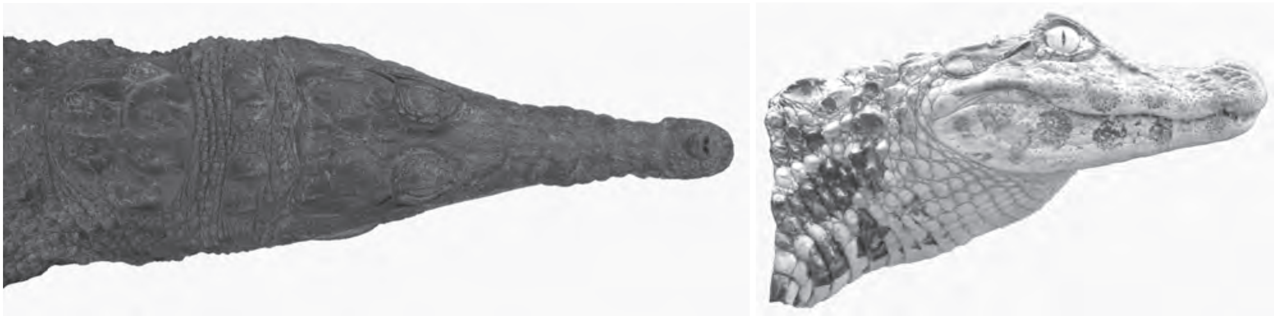


Figure 1A. (left) dorsal view *C. intermedius* head (Photograph: A. Velasco); 1B. (right) lateral view of *C. latirostris* head (Photograph: P. Siroski).

For crocodile skins and flanks, I used three skin types: belly cut (Fig. 2A), hornback cut (Fig. 2B), and flanks (Fig. 2C). The skins or flanks could be tanned or salted.

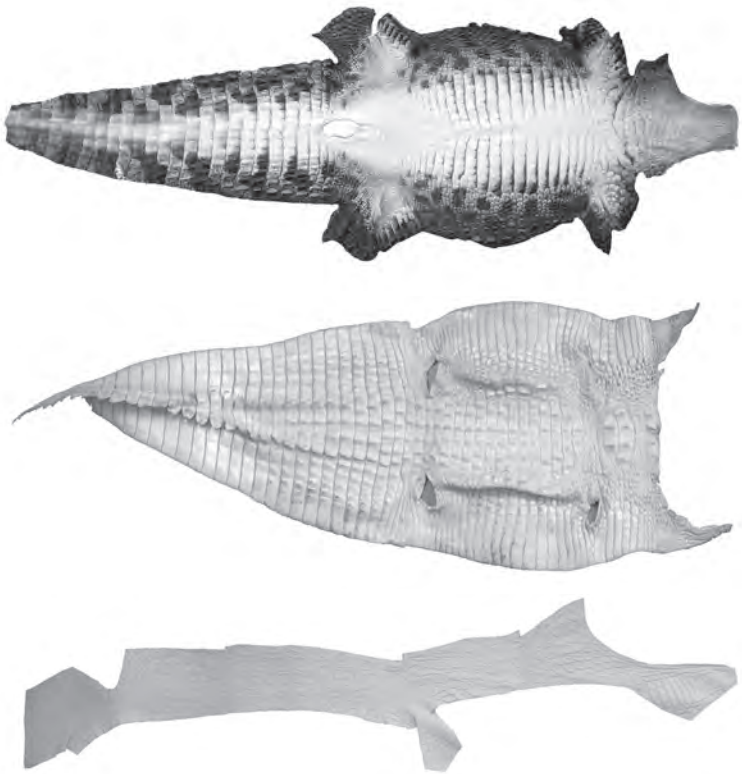


Figure 2A (top) raw *C. siamensis* belly skin (Photograph: Y. Temsiripong; 2B. (middle) tanned *C. intermedius* hornback skin (Photograph: A. Velasco); 2C. (bottom) tanned *C. crocodilus* flank (Photograph: A. Velasco).

The goals of this work is to develop a document that shows all differences of crocodilian species' heads and all commercial skins.

Results

At the time of writing of this paper, I had digitized or vectorized 15 of the 23 crocodilian species in lateral and dorsal head (*Alligator mississippiensis, Caiman crocodilus crocodilus, C. latirostris, C. yacare, Crocodylus intermedius, C. johnstoni, C. mindorensis, C. moreletii, C. novaeguineae* (only dorsal)*, C. palustris, C. porosus, Gavialis gangeticus, Melanosuchus niger, Paleosuchus palpebrosus and P. trigonatus*). Figure 3 shows the digital dorsal head view, Figure 4 the digital lateral view.

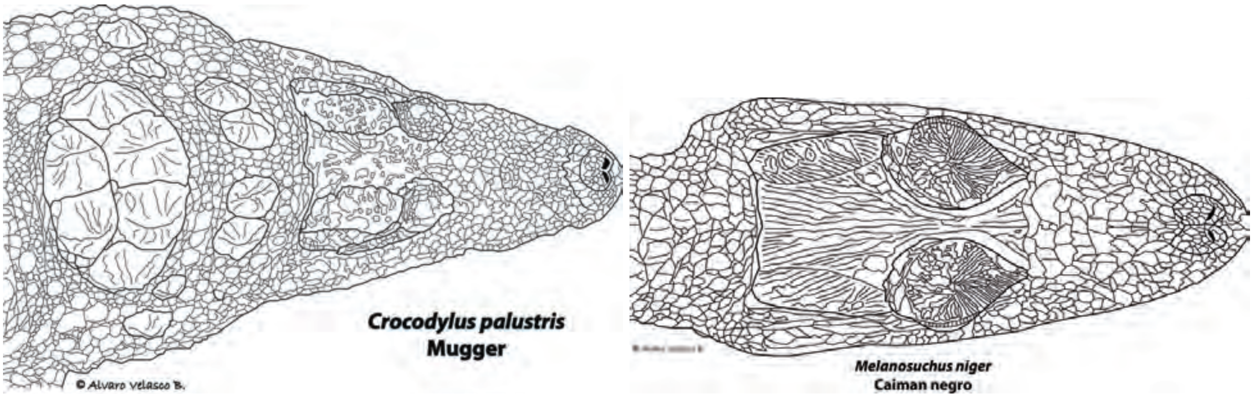


Figure 3A. (left) digital dorsal image of *Crocodylus palustris*. 3B. (right) digital dorsal image of *Melanosuchus niger*.

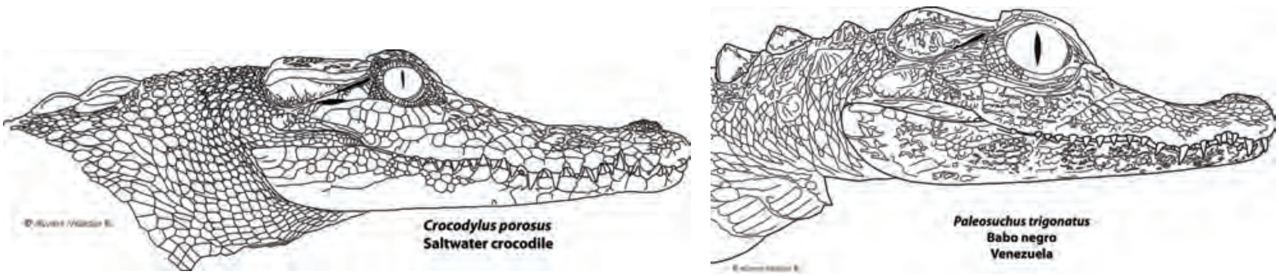


Figure 4A. (left) digital lateral image of *Crocodylus porosus*. 4B. (right) digital lateral image of *Paleosuchus trigonatus*.

Each pair of images allows heads differences between species to be seen. The Crocodylinae are long-snouted against the Alligatorinae that are short-snouted. This characteristic is easy to see in lateral digital image. Also, the presence outside the jaw of the 4th tooth. The dorsal digital image illustrates the neck scales distribution, which is characteristic of each crocodilian species.

The digital or vectorize image, maintain the scale of head. The program permits using the rule tools, determine the rate of any dimensions and proportions of any head parts.

For skins, I have digitized or vectorized *Alligator mississippiensis, C. yacare, C. niloticus, C. siamensis* in belly and hornback; *C. c. fuscus, C. latirostris* (from Argentina and Brazil), *C. porosus* in belly; and, *C. intermedius* and *C. johnstoni* in hornback. Figure 5 shows the digital belly and hornback skins, and Figure 6 flanks.

Those images allow identifying the differences between classic versus non-classic skins. Those differences are based in patrol scales distribution and osteoderm presences. On the other hand, this methodology could permit identify differences between captive or ranching versus wild skins or flanks, based on characteristics of each species.

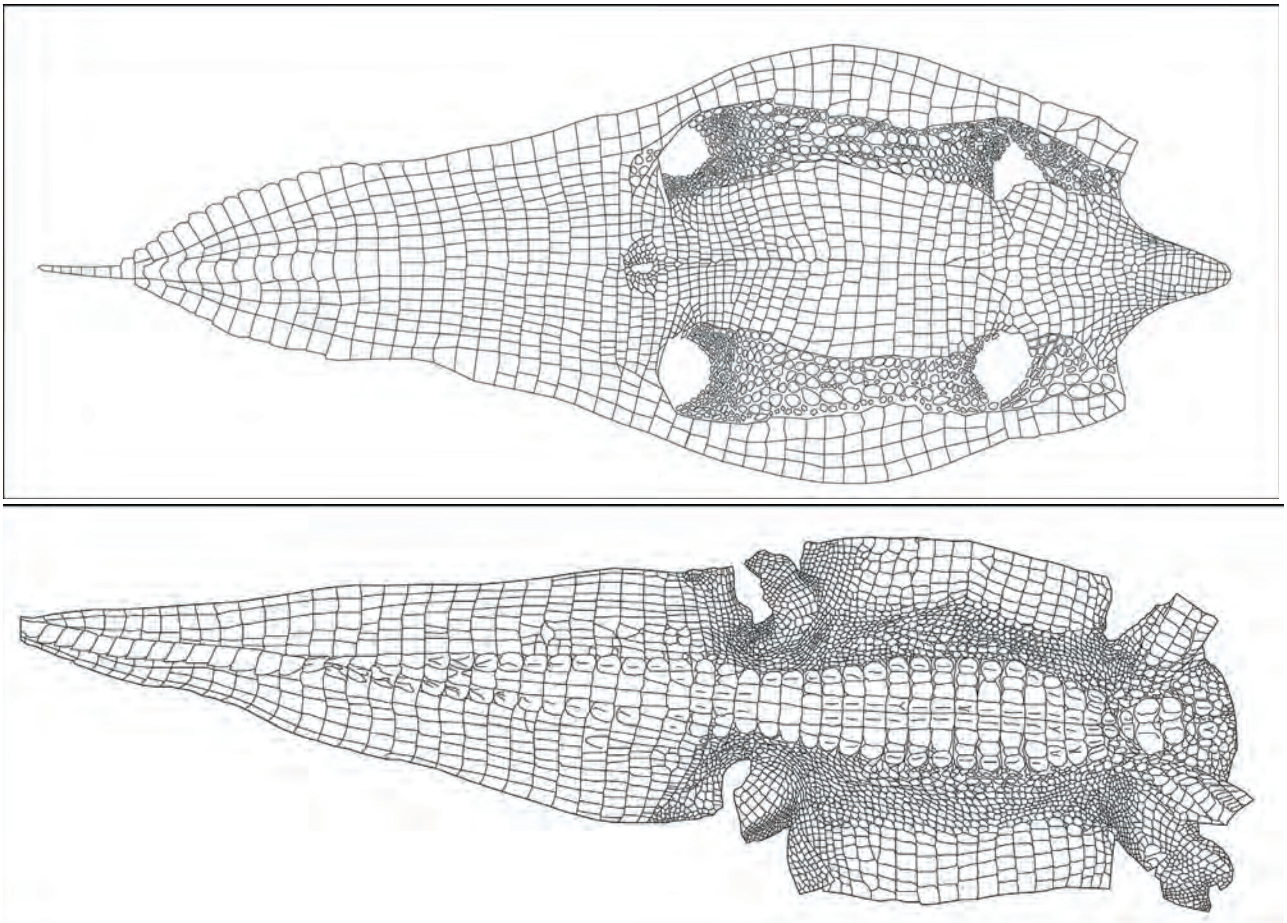


Figure 5A. (top) *Caiman latirostris* digital belly skin 5B. *Alligator mississippiensis* digital hornback skin.

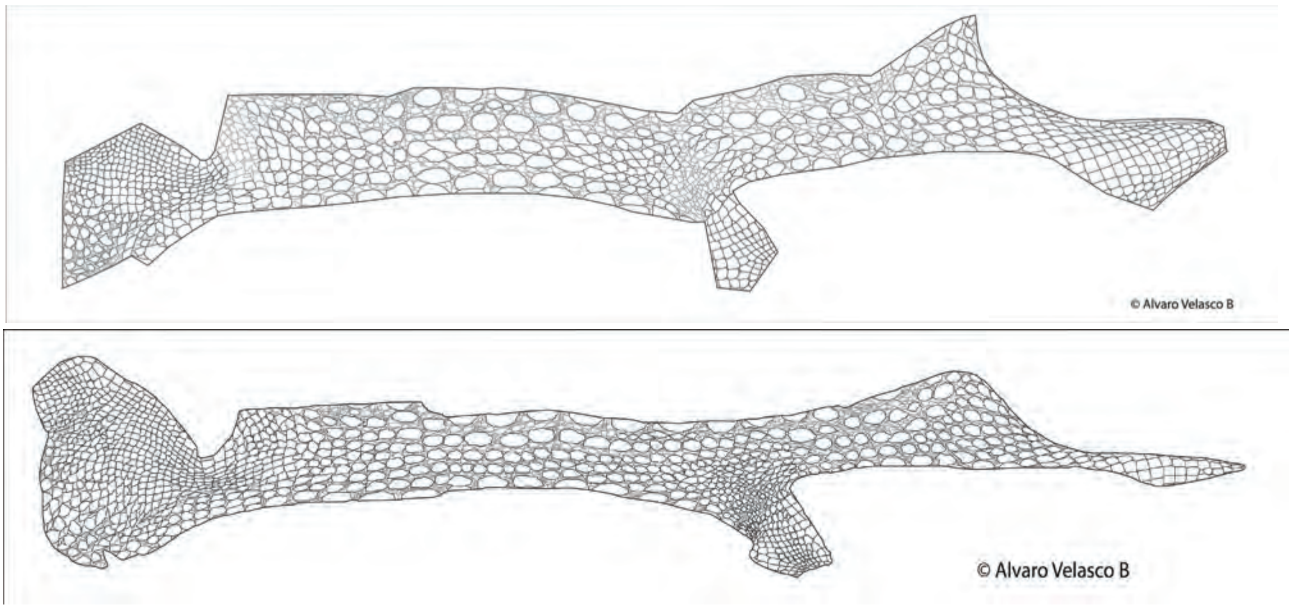


Figure 6A. (top) *Caiman crocodilus crocodilus* digital flank; 6B. (bottom) *Caiman yacare* digital flank.

Acknowledgments

This work was possible with a lot of help of many friends around the world, who allowed me to use their photos: Pablo Siroski, Colen Stevenson, Kadambari Devarajan, Grahame Webb, Robinson Botero, Godfrid Solmu, Merlijn van Weerd, Ruth Elsey, Enrico Chiesa, Gianni Rognoni, Luis Bassetti, Nina Collard, Yosapong Temsiripong and Armando Rubio.

Literature Cited

CITES (1995). CITES Identification Guide - Crocodiles: guide to identification of Crocodilians species controlled under The Convention on International trade in endangered species of wild fauna and flora. Minister of Environment Canada. 148 p.

Fuchs, K.H. (2006). The Crocodile Skin: Important Characteristics in Identifying Crocodilians Species. Edition Chimaira: Frankfurt am Main.

Thorbjarnarson, J. (1992). Crocodiles: An Action Plan for their Conservation. Ed. by H. Messel, F.W. King and J.P. Ross. IUCN: Gland, Switzerland.

Trutnau, L. and Sommerlad, R. (2006). Crocodilians. Their Natural history and Captive Husbandry. Edition Chimaira: Frankfurt am Main.

Velasco, A. (2005). La conservación de los cocodrilos en Latino América y el Caribe. Pp. 75-86 *in* Reunión Regional de América Latina y el Caribe del Grupo de Especialistas en Cocodrilos (CSG/SSC/IUCN) 17 al 20 de Mayo 2005, Santa Fe, Argentina. IUCN: Gland, Switzerland.

Velasco, A. (2008). Crocodile management, conservation and sustainable use in Latin America. Pp. 72-88 *in* Crocodiles. Proceedings of the 19th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Wermuth, H. (1953). Die Systematik der rezenten Krokodile. Mitt. Zool. Mus. Berlin, 29(2): 375-514.

Shedding Light on the Heart of Darkness - Comparative Phylogeography Clarifies Taxonomic Uncertainty in African Crocodiles

Matthew H. Shirley

Department of Wildlife Ecology and Conservation University of Florida, 110 Newins-Ziegler Hall Gainesville, FL 32611-0430, USA

Abstract

Recent molecular phylogenetic studies have shown that the three traditionally recognized extant African crocodilian taxa (*Crocodylus niloticus, Mecistops cataphractus* and *Osteolaemus tetraspis*) are each comprised of highly divergent, cryptic lineages. Interpreting these results in light of continent-scale biogeographic events indicated several common, putatively vicariant, patterns. Our study represents the first comparative study across Africa crocodilian taxa. Cryptic African crocodile complexes provide a unique opportunity for comparison because they are of different evolutionary age yet display similar levels of distributional stability. Despite being broadly sympatric throughout western Africa, they each exhibit significant niche partitioning and life history differences, as well as different capacity for dispersal. Comparative phylogeographic analyses provide a framework under which genealogical concordance between sympatric species is used to test the strength of geographic features in structuring regional biotas. Comparing phylogeographic structure between these crocodile species complexes will produce significant insights into the relative role of vicariance, notably basin entrapment, and the effects of paleoclimatic change on forest distribution and desertification.

Individuals of all three crocodile species were sampled from throughout their known distributions from both wild populations and museum collections and sequenced at up to five homologous gene regions including both mitochondrial and nuclear markers. Sequence data for all three species was analyzed under a comparative, statistical phylogeographic framework to test congruent vicariance and divergence timing between the Congo and Ogooué Basins, as well as across the Cameroon Volcanic Line. Preliminary results show congruent patterns of high interbasin differentiation, though not for all species complex pairs, with relatively low intrabasin structure. This study presents the first such data for the remaining, unevaluated African crocodile - *Mecistops cataphractus*. Our results support the importance of both species specific and landscape-level factors in driving the evolution of faunas across regions over time. Recognition of new African crocodile species has significant implications for the conservation status, and conservation strategies, of each newly recognized taxon in different regions of the continent.

Detecting American and Morelet's Crocodile Introgressive Hybridization Using a Large Number of Microsatellites

Brandon A. Gross, Miryam Venegas-Anaya, Jeremy P. Weaver, Ashish Bashyal and Llewellyn D. Densmore III

Department of Biological Sciences, Texas Tech University, Lubbock, Texas 79409-3131, USA (brandon.gross@ttu.edu)

Abstract

Introgressive hybridization is considered extremely uncommon and difficult to prove in animal speciation. However, hybridization is considered to be a very significant aspect in the conservation of biodiversity, when it comes to conserving natural populations of charismatic fauna, such as crocodilians. Molecular genetics provides tools for testing ancient and current hybridization events in many taxa, including crocodilians. Our study focuses on testing 40 microsatellite loci isolated and characterized from the Saltwater Crocodile (*Crocodylus porosus*), for cross-species amplification and polymorphism in American (*C. acutus*) and Morelet's (*C. moreletii*) Crocodiles collected throughout Mexico. Using a large set of multi-locus markers, will not only help us to better understand the evolutionary history of Neotropical crocodilians, but also contribute to our knowledge of current population dynamics. This will ultimately lead to the development of better management and conservation programs. Our preliminary results have found consistent cross-species amplification for 20 out of the 40 markers in both pure and "hybrid" species and indicate differing degrees of genetic variation. From the 20 microsatellites, 10 markers showed different grades of inter-specific genetic variation and two microsatellites appear to be monophyletic. We are currently testing these 20 markers on 17 individuals chosen randomly (5 *C. acutus*, 7 *C. moreletii*, and 5 hybrids) from 9 different localities within the Yucatan Peninsula, Mexico.

Introduction

Within the genus *Crocodylus*, many microsatellite loci are conserved across species and are useful in interspecific and intraspecific marker comparisons (Glenn *et al*. 1998). Such conservation allows for descriptions of genetic diversity and admixture analyses (Miles *et al*. 2009a); to date, microsatellites (msats) have been isolated or cross-species amplified in almost all species of crocodilians (Glenn *et al*. 1998; FitzSimmons *et al*. 2001; Dever and Densmore 2001; Miles *et al*. 2009b; Weaver *et al*. 2008; Zucoloto *et al*. 2002). Multi-locus genetic markers, including microsatellites can be used as tools for a variety of fields of study, such as in phylogenetics, population genetics, and for forensic analyses such as parentage testing (Anmarkrud *et al*. 2008). Microsatellites have been utilized in *Crocodylus* to identify ancient and current hybridization and introgression events (Zucoloto *et al*. 2002; Milian-Garcia *et al*. 2011; Rodriguez *et al*. 2008). While microsatellite markers are considered to be useful genetic tools, their molecular evolution and mutation is not fully understood (Anmarkrud *et al*. 2008). The first objective of this study is to characterize *C. acutus* (American Crocodile), and *C. moreletii* (Morelet's Crocodile), utilizing microsatellites described by Miles *et al*. (2009a) in order to ultimately test for admixture between the two species. Given recent studies using microsatellites in crocodilians and the high amount of inter-specific and intra-specific admixing that has been suggested, increasing the number of microsatellite markers should give better resolution in characterizing species relationships as well as help in decreasing effects of homoplasy. Our aim is to test whether increasing the number of microsatellites will show a higher level of resolution in detecting hybrid animals and establishing zones of potential admixture.

Methods and Materials

Samples and microsatellite genotyping:

- Utilized 17 individuals characterized genetically and morphologically previously by Cedeno *et al*. (2008) and Rodriguez *et al*. (2008): 7 *C. moreletii*, 5 *C. acutus* and 5 *C. moreletii* x *C. acutus* hybrids.
- Total genomic DNA was extracted using the PureGene isolation kit (Gentra Systems, Minneapolis, MN).
- 40 msats are currently being tested for cross species amplification using a modified 3-Primer Competition PCR (Polymerase chain reaction) using forward, reverse, and m-13 labeled primers (FAM and NED) and protocols TD65 and TD55 described by Miles *et al*. (2009a).
- Fragments were sized using GS500 Rox size standard on an ABI 3100-Avant Genetic Analyzer and visualized using GeneMapper v3.7.

Microsatellite analyses:

- STRUCTURE was run to examine the overall genetic subdivision between *C. acutus* and *C. moreletii* using 10 msats previously used on the same individuals by Rodriguez *et al*. (2008), 40 msats isolated by Miles *et al*. (2009a), and the two combined (Fig. 1).

- POPULATIONS was utilized to construct an exploratory neighbor-joining tree for all msats combined (Fig. 2).
- CERVUS was used to estimate measures of msat diversity (Fig. 3) for *C. acutus* and *C. moreletii* individually (after the removal of hybrid individuals).

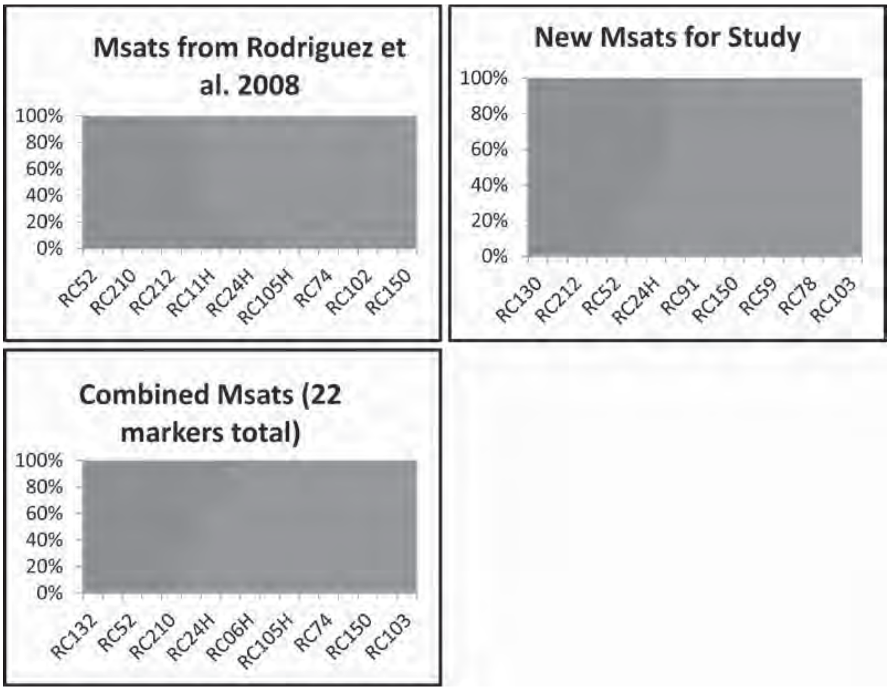


Figure 1. A barplot of posterior probability assignments (K constrained to 2) to species groups generated in STRUCTURE. [*C. acutus* individuals are represented in dark colouration (left side) and *C. moreletii* individuals are represented in lighter colouration (right side)]. Inferred hybrids are designated by an H.

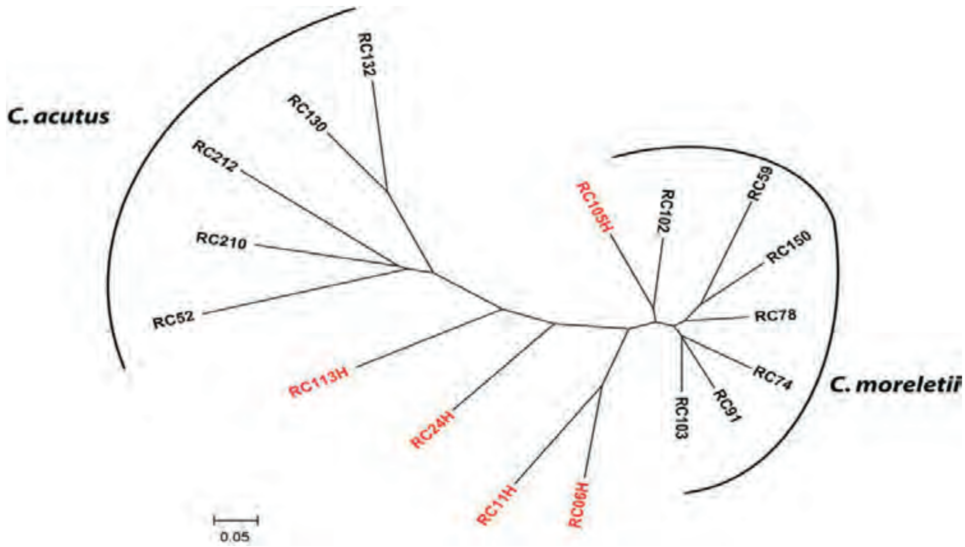


Figure 2. An exploratory neighbor-joining tree based on Dc distances constructed in POPULATIONS for 22 msat loci from pure *C. acutus* and *C. moreletii* as well as previously identified hybrids. Hybrids are identified with an (H).

Results

- 12 of the 40 msats tested have shown consistent amplification in *C. acutus* and *C. moreletii*.
- Measures of msat diversity (Fig. 3) show two markers are fixed and identical for both species and therefore relatively uninformative at this scale. Ten markers are variable and preliminary results show a range of species specific alleles.
- Analyses of population structure show similar assignments of individuals to specific genotypic classes and when all datasets are combined the probability of that assignment increases.

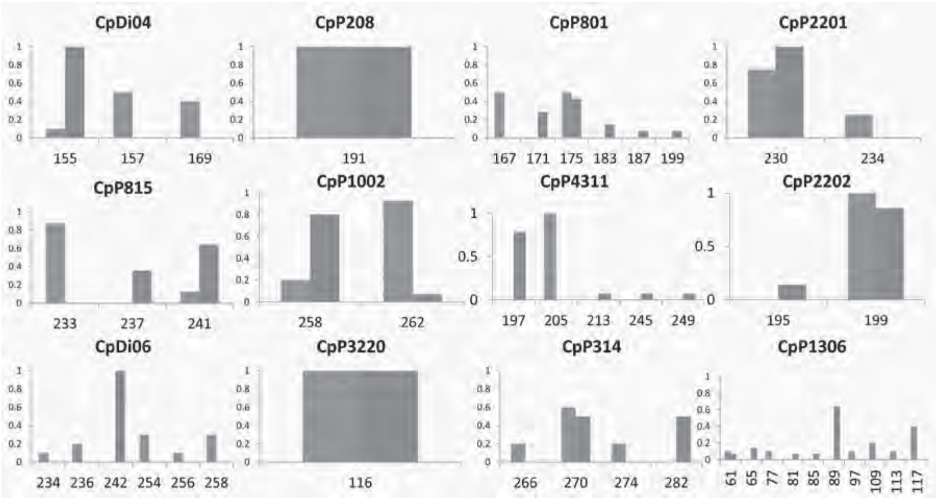


Figure 3. Distribution of allele frequencies for two genetic clusters (with hybrids removed) inferred by model clustering methods (Fig. 1). light colouration (left bars) = *C. acutus*; dark colouration (right bars) = *C.moreletii*.

Conclusions

Miles *et al*. (2009a) described 253 novel polymorphic msats from the Saltwater Crocodile (*C. porosus*), 82 have been tested for cross-species amplification with emphasis on Old World *Crocodylus* (Miles *et al*. 2009b). These markers have yet to be tested thoroughly in New World *Crocodylus*. Twelve of the 40 msat markers tested in this study show consistent amplification for *C. acutus* and *C. moreletii*. Of the 12 msats, 10 appear to be variable enough to discriminate between both species and possess an array of species-specific alleles while 2 msats appear to be monophyletic between the two species. When combining these msats with past studies (Rodriguez *et al*. 2008), we see an increase in the resolution of assigning individuals into specific genotypic classes, which is suggestive of the need to utilize a large array of msat markers when looking at species relationships. With these larger datasets there is a need to repetitively test each msat and use the standard deviation to verify alleles in an effort to reduce possible error arising from non-specific amplification. The utilization of a large set of multi-locus markers will not only help to understand the evolutionary history of Neotropical *Crocodylus*, but to also increase our knowledge of current population dynamics that ultimately lead to the development of better management and conservation plans.

Acknowledgements

We thank the people in Robert Bradley and Robert Baker's laboratory at Texas Tech University for their assistance and advice. This research was supported in part by a Howard Hughes Medical Institute Grant through the Undergraduate Science Education Program to Texas Tech University.

Literature Cited

Anmarkrud, J.A., Kleven, O., Bachmann, L. and Lifjeld, J.T. (2008). Microsatellite evolution: Mutations, sequence variation, and homoplasy in hypervariable avian microsatellite locus HrUI0. BMC Evolutionary Biology 8: 138.

Cedeño-Vázquez, J.R., Rodriguez, D., Calmé, S., Ross, J.P., Densmore III, L.D. and Thorbjarnarson, J.B. (2008). Hybridization between *Crocodylus acutus* and *Crocodylus moreletii* in the Yucatan Peninsula: I. Evidence from mitochondrial DNA and morphology. J. Exp. Zool. 309A: 661-673.

Dever, J.A. and Densmore III, L.D. (2001). Microsatellites in Morelet's crocodile (*Crocodylus moreletii*) and their utility in addressing crocodilian population genetics questions. J. Herpetol. 35: 541-544.

Fitzsimmons, N., Tanksley, S., Forstner, M.R., Louis, E.E., Daglish, R., Gratten, J. and Davis, S. (2001). Microsatellite markers for *Crocodylus*: New genetic tools for population genetics, mating system studies and forensics. Pp. 51-56 *in* Crocodilian Biology and Evolution, ed. by G. Grigg, F. Seebacher and C. Franklin. Surrey Beatty & Sons: Chipping Norton.

Glenn, T.C., Dessauer, H.C. and Braun, M.J. (1998). Characterization of microsatellite DNA loci in American alligators. Copeia 3: 591-601.

Miles, L.G., Isberg, S.R., Moran, C., Hagen, C. and Glenn, T.C. (2009a). 253 novel polymorphic microsatellites for the saltwater crocodile (*Crocodylus porosus*). Conserv. Genet. 10: 963-980.

Miles, L.G., Lance, S.L., Isberg, S.R., Moran, C. and Glenn, T.C. (2009b). Cross-species amplification of microsatellites in crocodilians: assessment and applications for the future. Conserv. Genet. 10: 935-954.

Milian-Garcia, Y., Venegas-Anaya, M., Frias-Soler, R., Crawford, A.J., Ramos-Targarona, R., Soberon, R., Alonso-Tabet, M., Thorbjarnarson, J., Sanjur, O.I., Espinosa-Lopez, G. and Bermingham, E. (2011). Evolutionary history of Cuban crocodiles *Crocodylus rhombifer* and *Crocodylus acutus* inferred from multilocus markers. J. Exp. Biol. 315: 358-375.

Rodriguez, D., Cedeño-Vázquez, J.R., Forstner, M.R.J. and Densmore III, L.D. (2008). Hybridization between *Crocodylus acutus* and *Crocodylus moreletii* in the Yucatan Peninsula: II. Evidence from microsatellites. J. Exp. Zool. 309A: 674-686.

Weaver, J.P., Rodriguez, D., Venegas-Anaya, M., Cedeño-Vázquez, J.R., Forstner, M.R.L. and Densmore III, L.D. (2008). Genetic characterization of captive Cuban crocodiles (*Crocodylus rhombifer*) and evidence of hybridization with the American crocodile (*Crocodylus acutus*). J. Exp. Zool. 309A: 649-660.

Zucoloto, R., Verdade, L. and Coutinho, L. (2002). Microsatellite DNA library for *Caiman latirostris*. Exp. Zool. (Mol. Dev. Evol.) 294: 346-351.

Population Genetics and Conservation of the Philippine Crocodile

Rheyda Penetrante Hinlo

Foundation for Philippine Environment

Abstract

The endemic Philippine Crocodile (*Crocodylus mindorensis*) is considered to be one of the most highly threatened crocodilians in the world. Historically known to occur throughout the Philippine archipelago, wild populations are now confined to small and isolated populations on the islands of Luzon and Mindanao. Reintroduction is seen as an important element in the recovery of this species. Successful captive breeding programs initiated in the 1980s increased the number to hundreds of captive Philippine Crocodiles, many of which are candidates for reintroduction to suitable habitats. Preliminary genetic studies based on mtDNA found *C. porosus-C. mindorensis* hybrids in the biggest captive population which raises concerns on species integrity and suitability of the captive population for the reintroduction program. In addition, unresolved issues on the extent of genetic differentiation among extant populations hampered recovery plans for many years. To resolve these issues, a total of 618 wild and captive Philippine crocodiles were genotyped at 11 microsatellite loci to investigate genetic diversity and population structure. In addition, information from an existing mtDNA study was combined with the results from a Bayesian assignment test based on microsatellite loci to find evidence of hybridisation. A high degree of genetic differentiation across all populations was observed (FST= 0.29. Genetic differentiation reflected geographic structuring, with the highest FST values recorded between populations from the northern Philippines (Luzon) and southern Philippines (Mindanao). Moderate levels of genetic diversity were seen in all captive and wild populations included in the sampling, except for one captive population in Abra. A total of 92 hybrids were identified from two captive facilities. Three of the identified hybrids in this study were part of the group released into the wild during the first reintroduction program in 2009. These three individuals did not exhibit obvious morphological anomalies and were thought to be pure *C. mindorensis*. The results of this study have important conservation implications and will influence the management of captive and wild populations of Philippine Crocodiles and the design of future reintroductions.

Evaluation of Genotoxicity in *Caiman latirostris* Hatchlings Exposed *In Vivo* to Roundup®(Glyphosate) Using the Micronucleus Test

Evelyn C. López González[1,3], Maria A. Latorre[1,3], Gisela L. Poletta[1,2,3] and Pablo A. Siroski[1,3]

[1] Proyecto Yacaé - Laboratorio de Zoología Aplicada: Anexo Vertebrados, Facultad de Humanidades y Ciencias, UNL/Ministerio de Aguas, Servicios Públicos y Medio Ambiente, Argentina (evelynclg@hotmail.com)
[2] Cátedra de Toxicología y Bioquímica Legal, Facultad de Bioquímica y Ciencias Biológicas, UNL/FCEyN, UBA-CONICET, Argentina
[3] Laboratorio de Biología Celular y Molecular-FCV-UNL-CONICET, Argentina

Introduction

Caiman latirostris (Broad-snouted Caiman) is the crocodilian species with the southern-most distribution in South America, extending to Santa Fe Province, Argentina (Siroski 2004). As a result of agricultural expansion produced in recent years in Argentina, mainly associated with transgenic soy, *C. latirostris* populations are exposed to continuous pesticide discharges in their natural environment because of overlap with areas of intensive agriculture (Poletta *et al*. 2011). Pesticides are often very reactive compounds that can disrupt normal cellular processes and interact directly or indirectly with DNA, causing genetic instability (Ecobichon 2005; Gluczac *et al*. 2006). The micronucleus (MN) test is a biomarker to detect genotoxic effects of mutagenic agents that modify the structure and/or segregation of chromosomes, allowing the detection of early biological responses, before the damage is irreversible and imbalances the organism's health (Carballo and Mudry 2006).

The aim of this study was to evaluate the potential genotoxicity and effects on growth of *C. latirostris* hatchlings exposed *in vivo* to sub-lethal concentrations of Roundup® (RU; glyphosate based formulation), and to provide further information on pesticide effects in this species, studying a route of exposure and a biological stage not previously evaluated.

Materials and Methods

We used 72 *C. latirostris* specimens, 20 days of age, hatched from eggs harvested in the Natural Managed Reserve "El Fisco" (Santa Fe, Argentina), under the Proyecto Yacaré ranching program. Animals were distributed into three experimental groups of 24 specimens each, with two replicates of 12 animals per group: a negative control without exposure and two treatments exposed to different concentrations of RU. Sub-chronic exposure (60 days) was performed by immersion (Eaton and Klassen 2005) in plastic pens tilted to provide a dry surface. Water was renewed every three days and concentration of RU progressively decreased through time, taking into account glyphosate metabolism previously determined by HPLC. The ranges of exposure concentrations were as follows: Treatment 1 (RU1): 11mg/l (initial concentration) to 2.5mg/l (final concentration) and Treatment 2 (RU2): 21 mg/l (initial) to 5 mg/l (final), while a third group was maintained as a control (NC). Animals were measured in total length (TL) and weighed at the beginning and at the end of the experiment to determine growth of the animals in each experimental group. Blood samples (0.5 ml) were taken from the spinal vein (Olson *et al*. 1977) for the application of the Micronucleus (MN) test in erythrocytes (Poletta *et al*. 2008), as a biomarker of genotoxicity. Two smears were made for each animal, fixed and stained with Giemsa.

For each sample, 1000 erythrocytes were analyzed under an optic microscope with a magnification of 1000X and the MN frequency determined (MNF: number of cells with MN/1000 cells counted).

Results

Results demonstrated an induction of genotoxic damage caused by exposure to RU. There was a significant increase in the MNF in RU1 (1.83 ± 0.27) and RU2 (2.09 ± 0.27) compared with the NC (0.43 ± 0.13, $p<0.0016$), but no difference was observed between RU1and RU2 ($p>0.016$) (Fig. 1).

Results of growth showed that hatchlings exposed to RU2 grew less in TL (5.64 ± 0.89 cm) and weight (54.13 ± 6.80 g) than those of the NC (8.23 ± 0.61 cm and 69.44 ± 6.02 g, respectively), but this was not statistically significant ($p>0.05$). No differences were observed between RU1 (8.53 ± 0.40 cm and 82.16 ± 5.11 g) and NC ($p>0.05$) (Fig. 2).

There were no differences between clutches in the MNF, weight or length of the animals ($p>0.05$), and no relationship between animal size and DNA damage evidenced by the MNF ($p>0.05$).

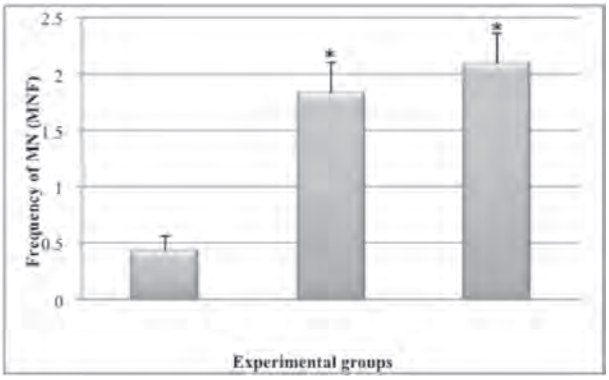


Figure 1. Micronucleus frequency(mean ± standard error) observed in the different experimental groups. NC: negative control; RU1 and RU2: groups exposed to different concentrations of Roundup®. *Significantly different compared to the negative control (Mann-Whitney test).

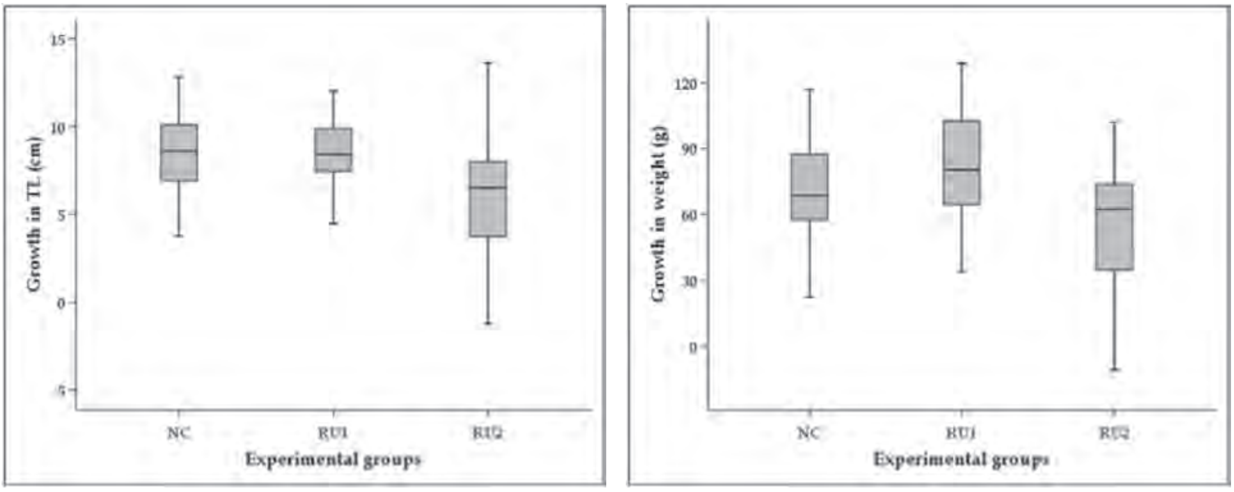


Figure 2. Growth in total length (TL; left) and bodyweight (right) of experimental groups. NC: negative control; RU1and RU2: groups exposed to different concentrations of Roundup®.

Discussion and Conclusions

In recent years, several studies evaluated the impact of glyphosate formulations on non-target organisms. In studies using concentrations commonly applied in agriculture, adverse effects were observed in different wildlife species (Sparling *et al*. 2006; Cavas and Könen 2007; Poletta *et al*. 2009; Lajmanovich *et al*. 2010; Bosch *et al*. 2011).In our region, previous studies demonstrated the genotoxic effect of RU and its combination with Endosulfan and Cypermethrin formulations on Broad-snouted Caiman neonates after exposure during the incubation period to pesticide concentrations commonly applied in the field (Poletta *et al*. 2011). Hatchlings are particularly susceptible because they spend most of the time in small waterbodies, many of which receive and concentrate pesticides discharges from neighboring crops. The results of this study demonstrated that RU formulation also induces genotoxic effects and a trend to lower growth in *C. latirostris* hatchlings exposed *in vivo* during the first months of life. This could imply a serious risk for hatchlings in natural environments, because in this period they are extremely vulnerable to climate conditions, which is clearly dependent on body size.

The biological consequences of these alterations is uncertain, but they could affect the normal function of physiological processes at the cellular and individual level, warning about the effect that wild populations of *C. latirostris* continuously exposed to low concentrations of these and other pesticides, might be suffering.

Acknowledgements

This study was supported by Proyecto Yacaré and Yacarés Santafesinos (Gob. Sta. Fe/MUPCN), and was part of an ELG's undergraduate thesis to obtain a Bachelor of Science degree.

Literature Cited

Bosch, B., Mañas, F., Gorla, N. and Aiassa, D. (2011). Micronucleus test in post metamorphic *Odontophrynus cordobae* and *Rhinella arenarum* (Amphibia: Anura) for environmental monitoring. J. Toxicol. Environ. Health Sc. 3: 155-163.

Carballo, M.A. and Mudry, M.D. (2006). Indicadores y marcadores biológicos. Pp. 83-108 *in* Genética Toxicológica, ed. by M.D. Mudry and M.A. Carballo. De los Cuatro Vientos Editorial: Buenos Aires.

Cavas, T. and Könen, S. (2007). Detection of cytogenetic and DNA damage in peripheral erythrocytes of goldfish (*Carassius auratus*) exposed to a glyphosate formulation using the micronucleus test and the comet assay. Mutagenesis 22: 263-268.

Eaton, D.L. and Klassen, C.D. (2005). Principios de toxicología. Pp. 7-22 *in* Fundamentos de Toxicología, ed. by C.D. Klassen and J.B. Watkins III. McGraw-Hill/Interamericana: Madrid.

Ecobichon D.J. (2005). Efectos tóxicos de los pesticidas, Pp. 339-353 *in* Fundamentos de Toxicología, ed. by C.D. Klaassen and J.B. Watkins. McGraw-Hill/Interamericana: Madrid.

Glusczak, L., dos Santos Miron, E., Crestani, M., Braga de Fonseca, M., de Araujó-Pedron, F., Frescura Durate, M.Y. and Pimentel Vieira, V.L. (2006). Effect of glyphosate herbicide on acetylcholinesterase activity metabolic and hematological parameters in piava (*Leporinus obtusidens*). Ecotoxicol. Environm. Saf. 65: 237-241.

Lajmanovich, R.C., Attademo, A.M., Peltzer, P.M., Junges, C.M. and Cabagna, M.C. (2010). Toxicity of four herbicide formulations with glyphosate on *Rhinella arenarum* (Anura: Bufonidae) tadpoles: B-esterases and glutathione S-transferase inhibitors. Arch. Environ. Contam. Toxicol. 60: 681-689.

Olson, G., Hessler, J. and Faith, R. (1977). Techniques for the blood collection and intravascular infusion of reptiles. Lab. Anim. Sci. 25: 783-786.

Poletta, G., Kleinsorge, E., Mudry, M.D. and Larriera, A. (2009). Genotoxicity of the herbicide formulation Roundup® (glyphosate) in broad-snouted caiman (*Caiman latirostris*) evidenced by the Comet assay and the Micronucleus test. Mutat. Res. 672: 95-102.

Poletta, G.L., Larriera, A., Kleinsorge, E. and Mudry, M.D. (2008). *Caiman latirostris* (Broad-snouted caiman) as a sentinel organism for genotoxic monitoring: Basal values determination of micronucleus and comet assay. Mutat. Res. 650: 202-209.

Poletta, G.L., Kleinsorge, E., Paonessa, A., Mudry, M.D., Larriera, A. and Siroski, P.A. (2011a). Genetic enzymatic and developmental alterations observed in *Caiman latirostris* exposed *in ovo* to pesticide formulations and mixtures in an experiment simulating environmental exposure. Ecotoxicol. Environ. Saf. 74: 852-859.

Poletta, G.L., Larriera, A., Siroski, P., Kleinsorge, E. and Mudry, M.D. (2011b). Integral approach of glyphosate-induced alterations in a South American caiman species. *In* Herbicides: Properties, Crop Protection and Environmental Hazards, ed. by K.D. Piotrowski. Nova Science Publishers: New York.

Siroski, P. (2004). *Caiman latirostris* and *Caiman yacare* population surveys in Formosa Province, Argentina. Pp. 443-446 *in* Crocodiles. Proceedings of the 17th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Schmid, W. (1975). The micronucleus test. Mutat. Res. 31: 9-15.

Sparling, D.W., Matson, C., Bickham, J. and Doelling-Brown, P. (2006). Toxicity of Glyphosate as Glypro® and LI700 to Red-eared slider (*Trachemys scripta elegans*) embryos and early hatchlings. Environm. Toxicol. Chem. 25: 2768-2774.

SPSS for Windows. Version 14.0. (2005). SPSS Inc.: Chicago.

Mating System and Population Genetics Analysis of the Broad-Snouted Caiman (*Caiman latirostris*)

Patricia Susana Amavet[1,3,4], Juan César Vilardi[2,4], Eva Carolina Rueda[1,4], Alejandro Larriera[1,3] and Beatriz Ofelia Saidman[2,4]

[1] Departamento de Ciencias Naturales, Facultad de Humanidades y Ciencias, Universidad Nacional del Litoral, Ciudad Universitaria, Santa Fe, 3000, Argentina (pamavet@fhuc.unl.edu.ar)
[2] IEGEBA-Departamento Ecología, Genética y Evolución, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Buenos Aires 1428, Argentina
[3] Proyecto Yacaré-Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUCUNL/MASPyMA), A. del Valle 8700, Santa Fe 3000, Argentina
[4] Carrera del Investigador Científico, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina

Abstract

Multiple paternity is a behavior increasing effective population size, which could increase genetic diversity particularly in populations submitted to bottlenecks events. In Argentina, wild populations of *Caiman latirostris* are subject of a management plan started in response to the evident numeric reduction of the populations, as a consequence of hunting pressure and habitat modification. The program had a remarkable success in population recovery allowing the commercial use of *C. latirostris*. Data on reproductive behavior of *C. latirostris* are limited and the information about genetic diversity is scarce too. Our specific aims were to study the genetic structure and mating system applying microsatellite markers in 12 *C. latirostris* families from 8 populations. The obtained results showed highly significant difference among populations and a lack of correspondence between geographical distance and genetic differentiation suggesting that populations of *C. latirostris* represent unstable metapopulations. In the paternity analysis more than one father was detected in two nests, which could be explained by female ability to sperm storage, as proposed in related species. Multipaternity could contribute to preserve viable populations of *C. latirostris*, since the maintenance of genetic variability within populations could help increase their capacity to respond to selective pressure.

Symbiosis between Long Legged Wading Birds (Ciconiiformes) and Alligators (*Alligator mississippiensis*)? Testing the 'Nest Protector' Hypothesis

Brittany Burtner[1], Peter C. Frederick[2] and Frank J. Mazzotti[3]

[1] School of Natural Resources and Environment, University of Florida, Gainesville, FL 32611, USA (bburtner@ufl.edu)
[2] Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32611, USA
[3] Fort Lauderdale Research and Education Center, University of Florida, Davie, FL 33314, USA

Abstract

Wading birds (Ciconiiformes) appear to preferentially nest above alligators and alligator habitat. Alligators could benefit nesting birds by deterring mammalian predators. Chicks or food dropped from the bird nests could provide alligators with food. We tested selected predictions of this hypothesis using small willow-dominated colonies of little blue herons (*Egretta caerulea*), tricolored herons (*Egretta tricolor*), and snowy egrets (*Egretta thula*) in the central Everglades as experimental units. We experimentally manipulated apparent densities of alligators and conspecific birds using alligator and white bird decoys to determine if wading birds were attracted to alligators via visual cues. Egretta herons showed a strong preference for sites with both alligator and bird decoys in 2010 [X2 (3, N= 45)= 17.133, p= 0.001] and 2011 [X2 (3, N= 261)= 72.452, p= 0.0001]. Utilizing throughfall traps, we estimated that a colony of 50 pairs has the potential to drop 102 g of food over a 60-day nesting cycle. This may be nutritionally important to alligators, particularly during the dry season when movements may be limited and food is harder to find. Our evidence suggests that there is a mutualism between *Egretta* herons and alligators; herons are attracted to nest near alligators, and alligators receive nontrivial food benefits from nesting birds.

Born to be Bad: Agonistic Conflict in Hatchling Saltwater Crocodiles (*Crocodylus porosus*)

Matthew L. Brien[1,2], Grahame J. Webb[1,2], Jeffrey W. Lang[2], Keith A. McGuinness[1] and Keith A. Christian[1]

[1]School for Environmental Research, Institute of Advanced Studies, Charles Darwin University, Darwin, NT 0909, Australia
[2]Wildlife Management International Pty. Limited, P.O. Box 530, Karama, NT 0813, Australia
[3]Dept. of Fisheries, Wildlife and Conservation Biology, University of Minnesota, Saint Paul, MN 55108, USA

Abstract

Saltwater Crocodiles (*Crocodylus porosus*) are considered one of the least tolerant of conspecifics of all crocodilians. Yet they begin their life living in groups (hatchling crèches) for around two months, suggesting ontogenetic changes in social behaviour may underpin the growing intolerance with increasing age and, or size. In this study, detailed observations on groups of captive *C. porosus* hatchlings, particularly in the first 6 weeks of life, demonstrated they exist with high levels of close contact and little aggression (tolerance). Yet this quiescent existence is interspersed with sporadic periods of agonistic events (signalling intolerance), with highly distinctive behaviours (N= 12), particularly in the morning (0600-0800 h) and evening (1700-2000 h). Of these behaviours, 5 were postures involving no movement, with 2 non-contact movements, and five contact movements that were considered either discrete (stereotypic; N= 4) or graded (not stereotypic; N= 8), based on whether the form or intensity of the display varied. Ontogenetic shifts in agonistic behaviour were quantified by examining 18 groups of hatchlings, 6 groups each at 1, 13 and 40 weeks of age. Agonistic events between hatchlings at 1 week of age varied in intensity (low, medium, high) and involved one (dominant) or both (combat) individuals. Almost all encounters involved actual contact, with a high number resulting in the instigator losing. At 13 and 40 weeks, a more formalized, hierarchal dominance relationship had established, based primarily on aggression-submission interactions. Conflict was high intensity and more frequent, with the subordinate individual fleeing in response to an approach by a dominant animal that often did not make contact. Social hierarchies among hatchling *C. porosus* may well underpin the high variability reported in individual growth rates, while the similarity of agonistic behaviours displayed by hatchlings and adults suggests a 'juvenile structured' pattern of behavioural ontogeny for this species.

Isolation and Characterization of Antimicrobial Peptides from the Leukocytes of the American Alligator (*Alligator mississippiensis*)

Mark Merchant[1], Lancia Darville[1] and Kermit Murray[2]

[1]Department of Chemistry, McNeese State University, Lake Charles, Louisiana, USA
[2]Department of Chemistry, Louisiana State University, Baton Rouge, Louisiana, USA

Abstract

We have isolated a 4746 Da peptide (39 amino acids), with antimicrobial activities, from the leukocytes of the American Alligator. The peptide was isolated by acid ultracentrifugation, reverse phase high performance liquid chromatography, and ion mobility chromatography. The mass was determined using matrix-assisted laser desorption ionization. The peptide has a net positive charge (+8), an isoelectric point of 9.5, an arginine and lysine content of 36%, and is extremely amphipathic. Another peptide of 4.9 kDa (43 amino acids) was isolated, and had a net charge of +13 with an arginine and lysine content of 32%. Both of these peptides have several cysteine residues, and show sequence homologies to mammalian b-defensins.

Host-Parasite Interaction of the Order Crocodylia

Marisa Tellez

UCLA, Department of Ecology and Evolutionary Biology, 621 Charles E. Young Drive South, P.O. Box 951606, Los Angeles, CA 90095-1606, USA

It is possible that parasites of crocodilians are highly host specific, the results of a relationship that began over 65 million years ago. Records of parasitism in crocodilians dates back to the early 1800s, distributed among published and unpublished manuscripts, and international parasite catalogs. Previously published checklists of vertebrate or reptilian parasites have included crocodilians, however many did not include all crocodilian species, or all crocodilian parasite species that had been found up to that date. Additionally, various species of crocodilians and their parasites have been through extensive taxonomic evaluation and past sources of data may not have identified host or parasite with its new systematic name. This can be confusing for scientists, researchers, students, or parasitologists and herpetologists interested in crocodilian parasitology. To decrease any ambiguity I have created a crocodilian parasite database to bring an up-to-date document of this particular host-parasite relationship in order to assist those pursuing investigations on the ecological, biological and veterinary significance of crocodilian parasites. In addition I have analyzed parasite distribution among crocodilian taxa, postulating host-parasite evolutionary and ecological interactions.

Crocodilians appear to be parasitized by a diverse array of parasitic phyla and species. Patterns of parasitism among crocodilian species can be described in two categories: generalist and host specialists. Generalists parasitize various crocodilian species, whereas host specialists or host-specific parasites infect a single host species. Overall, there are fewer host specific (~95) than generalist (~310) parasites (categorization did not include unidentified parasite species or parasites only identified to genus). Species-specific parasitism can be attributed to the lack of sympatry among crocodilian species and/or populations (Brooks 1979a,b; Brooks and O'Grady 1989; Huchzermeyer 2003). Many crocodilian species are isolated either due to geographic or anthropogenic barriers (Huchzermeyer 2003). Therefore a parasite must evolve strategies or life cycle patterns that minimizes or removes obstacles posed by vicariant barriers, enabling the capability of the parasitic species to infect multiple hosts throughout a geographic range. Three propositions are suggested that can assist in explaining the evolution of generalist parasites in crocodilian species: host dispersal, similar life-history traits and diets, and broad range of intermediate hosts. In evaluating the association of generalist parasites to geographic region, a pattern emerged reflecting three geographic regions: the Americas (includes North, Central, and South America), Africa, and Indo-Australia. The majority of generalist parasites shared amongst crocodilians within these regions was nematodes from the family Ascarididae.

Crocodilians are parasitized by several parasitic phyla, and are briefly discussed: Acanthocephala: Acanthocephalans infecting crocodilians are under the order Polyacanthorhynchida, represented by one species. *Polyacanthorhynchus rhopalorhynchus* parasitizes the intestines of all members of the genera *Caiman*, *Melanosuchus* and *Paleosuchus*. Although Bush *et al*. (2001) state that only acanthocephalans from the order Polyacanthorhynchida parasitize crocodilians, two other orders are documented to infect crocodilians. *Gorgorhynchoides* sp. from the order Echinorhynchida was found in *Crocodylus acutus* in Mexico, and *Polymorphus mutabilis* in the order Polymorphida was discovered in the small intestine of *Crocodylus rhombifer* in Cuba.

Apicomplexa: Seventeen (17) known species of coccidia (not including unidentified species) from four families under the order Eucoccidiorida parasitize crocodilians worldwide. Route of infection is most parsimoniously explained via horizontal transmission through contaminated water or food (Bush *et al*. 2001; Combes 2001; Huchzermeyer 2003). The majority of these protozoans (13 known species, 4 unidentified species) are from the family Eimeridae infecting 13 crocodilians.

Arthropoda: The order Porocephalida includes a group of parasites commonly known as tongue worms. This order includes the families Subtriquetridae, Sebekidae and Porocephalidae, that contain crocodilian specific parasites. The majority of these described pentastomids are adults found in the lungs and trachea of their host, but some are known to parasitize other parts of the body such as the nasal cavity and intestine.

Nematoda: Nematodes are the second largest group parasitizing crocodilians. Adult nematodes parasitize various organs and tissue in crocodilians, but most documentation of parasitism is described from the stomach. Besides inflammation caused by stomach nematodes (Huchzermeyer 2003) or scarring such as by *Paratrichosoma*, there are no ill effects unless the host is immunocompromised.

Platyhelminthes: Platyhelminthes is the most diverse and largest phylum parasitizing crocodilians, comprising of 5 orders, 16 families (not including one superfamily) and 125 species. Three orders of Platyhelminthes appear to have an ecological and/or evolutionary relationship with crocodilians. Parasites of the order Echinostomida are a diverse intestinal parasitic group of reptiles that are considered not to be host specific (Bush *et al*. 2001), yet the majority recorded in crocodilians are found in only one crocodilian taxon. Furthermore, most documentation of echinostomes are described from South American caimans, principally in the region of Matto Grosso, Brazil. Plagiorchiida is the second largest order of crocodilian platyhelminthes. Almost all plagiorchiids are described as intestinal parasites, yet few are found in other organs such as *Pseudotelorchis caimanis* discovered near the oviduct of *Caiman yacare*, and *Renivermis crocodyli* from the kidneys of *Crocodylus porosus*. The third largest order of platyhelminthes parasitizing crocodilians is also the most diverse in location of parasitism. Species of the order Strigeidida are documented from the buccal cavities, cloaca, major organs (including the brain), yet majority are found in the intestinal tract. Sarcomastigophora: Trypanosomes have an ancient evolutionary relationship with crocodilians, dating back to the late Cretaceous (Viola *et al*. 2009). Two species have been described from two crocodilians, *Trypanosoma cecili* from *Caiman crocodilus crocodilus*, and *Trypanosoma grayi* from *Crocodylus niloticus*. There are other parasites that have been documented in crocodilians, but considering these phyla are represented only by one parasite and were found in only one host within the crocodilian assemblage, it is hypothesized that these reports are examples of opportunistic parasitism.

It is probable that a unique mutualistic or commensal relationship between crocodilians and their parasites has developed over evolutionary time, allowing them to adapt to changing environments and novel pathogens. However, human conflict, climate change, and habitat loss, pose a threat to this dynamic, resulting in one of two negative outcomes. First, anthropogenic interactions can decrease parasitic prevalence and abundance in a host population by external factors hindering parasitic transmission or killing free-living stages of the parasite (Bush *et al*. 2001). As this may seem beneficial, parasites that are host-specific for crocodilians may have developed a commensal relationship over evolutionary time with their archosaurian host, contributing to crocodilians' ability to eradicate a broad spectrum of invasive pathogens over evolutionary time. Therefore the alteration of a beneficial coevolved dynamic may contribute to crocodilian populations inability to adjust to anthropogenic disturbances or novel pathogens. In contrast, ecosystem perturbations may enhance parasitic prevalence, intensity and abundance of a host population (Combes 2001; Lafferty and Holt 2003; Lafferty and Kuris 2008). Increase stress due to ecosystem disturbance, or accumulation of toxic metals can interfere with hosts' immune function (Sures 2006; Arkoosh *et al*. 2008; Lafferty and Kuris 2008; Rohr *et al*. 2008). Immunosuppression allows viral, bacterial and parasitic infections to proliferate, ultimately causing extreme morbidity, or mortality, of the host. Either alternative illustrates that a disruption in this reptilian-parasite system will have a detrimental outcome for the individual, population, or crocodilian species under investigation, resulting in a negative trophic cascade due to their role as keystone predators.

The purpose of this crocodilian-parasite database is to provide a foundation for future research on crocodilian parasitism. Data extrapolated from this study can be utilized to investigate coevolution and host phylogeny, as well as the role of crocodilian parasites in food webs, and ecosystems, and how external stressors may alter host-parasite dynamics. Previous ecological parasitology studies have linked predator reduction to reduced presence of trophically transmitted parasites, and an increase in other types of parasites of abundant hosts at lower trophic levels (Lafferty and Kuris 1999; Combes 2001; Bush *et al*. 2001; Lafferty *et al*. 2008). Moreover, the fundamental dependence of parasites on both host and environment make them biological indicators of the stability of the environment. Therefore, quantifying parasites of keystone predators, such as crocodilians, may enable analysis of ecosystem function. In a rapidly changing environment (due to climate change, land use practices, and direct exploitation of the environment), knowledge on the significance of crocodiles and their parasites is necessary to propose proper action for conservation and responsible stewardship of their environment.

Literature Cited

Arkoos, M.R., Casillas, E., Clemons, E., Kagley, A.N., Olsen, R., Ren, P. and Stein, J.E. (2008). Effect of pollution on fish diseases: potential impacts on salmonid populations. J. Aqua. Animal Health 10(2): 182-190.

Brooks, D.R. (1979a). Testing hypotheses of evolutionary relationships among parasites: The digeneans of crocodilians. Amer. Zool. 19: 1225-1238.

Brooks, D.R. (1979b). Testing the context and extent of host-parasite coevolution. Sys. Zool. 28(3): 299-307.

Brooks, D.R. and O'Grady, R.T. (1989). Crocodilians and their helminth parasites: macroevolutionary considerations. Amer. Zool. 29(3): 873-883.

Bush, A.O., Fernandez, J.C., Esch, G.W. and Seed, J.R. (2001). Parasitism: the Diversity and Ecology of Animal Parasites. Cambridge University Press: Cambridge.

Combes, C. (2001). Parasitism: The Ecology and Evolution of Intimate Interactions. The University of Chicago Press: Chicago.

Huchzermeyer, F. (2003). Crocodiles: Biology, Husbandry, and Diseases. CABI International: London.

Lafferty, K.D. (1997). Environmental parasitology: what can parasites tell us about human impacts on the environment? Parasit. Today 13(7): 251-255.

Lafferty, K.D. and Holt, R.D. (2003). How should environmental stress effect the population dynamics of disease? Eco. Letters 6: 654-664.

Lafferty, K.D. and Kuris, A. (1999). How environmental stress affects the impacts of parasites. Meth., Limno. and Oceano. Methods 44: 925-931.

Lafferty,K.D., Shaw, J.C. and Kuris, A. (2008). Reef fishes have higher parasite richness at unfished Palmyra Atoll compared to fished Kiritimati Island. Ecohealth 5: 338-345.

Rohr, J.R., Schotthoefer, A.M., Raffel,T.R., Carrick, H.J., Halstead, N., Hoverman, J.T., Johnson, C.M., Johnson, L.B., Lieske, C., Piwoni, M.D., Schoff, P.K. and Beasley, V.R. (2008). Agrochemicals increase trematode infections in a declining amphibian species. Nature 455: 1235-1239.

Schoeb T.R., Heaton-Jones, T.G., Clemmons, R.M., Carbonneau, D.A., Woodward, A.R., Shelton, D. and Poppenga, R.H. (2002). Clinical and necropsy findings associated with increased mortality among American Alligators of Lake Griffin, Florida. J. Wildlife Dis. 38(2): 320-337.

Sures, B. (2006). How parasitism and pollution affect the physiological homeostasis of aquatic hosts. J. Helminth. 80: 151-157.

Viola, L.B., Almeida, R.S., Ferreira, R.C., Campaner, M., Takata, C.S.A., Rodriguez, A.C., Paiva, F., Camargo, E.P. and Teixeira, M.M.G. (2009). Evolutionary history of trypanosomes from South American caiman (*Caiman yacare*) and African crocodiles inferred by phylogenetic analyses using SSu rDNA and gGAPDH genes. Parasit. 136: 55-65.

The Role of the American Alligator (*Alligator mississippiensis*) and American Crocodile (*Crocodylus acutus*) as Indicators of Ecological Change in Everglades Ecosystems

Frank J. Mazzotti[1], Brian M. Jeffery[1], Michael S. Cherkiss[2], Laura A. Brandt[3], Kristen M. Hart[2] and Ikuko Fujisaki[1]

[1] University of Florida, 3205 College Ave, Davie, FL 33317, USA
[2] U.S. Geological Survey, Southeast Ecological Science Center, 3205 College Ave, Davie, FL 33317, USA
[3] U.S. Fish and Wildlife Service, 3205 College Ave, Davie, FL 33317, USA

Abstract

The system-wide monitoring and assessment plan for the Comprehensive Everglades Restoration Plan identified indicators and established performance measures to monitor system responses and track progress toward meeting restoration goals. The crocodilian indicator uses monitoring parameters (performance measures) that have been shown to be both effective and efficient in tracking trends. The alligator component uses relative density (reported as an encounter rate), body condition, and occupancy rates of alligator holes; the crocodile component uses juvenile growth and hatchling survival. We hypothesize that these parameters are correlated with hydrologic conditions. Alligators and crocodiles are keystone and flagship species to which the public can relate. Additionally, the parameters used to track trends are easy to understand. These relationships are easy to communicate and mean something to managers, decisionmakers, and the public.

Using Critter-Cams to Compare Prey Capture and Success Rates of American Alligators (*Alligator mississippiensis*) from Two Florida Estuaries

James C. Nifong and Brian R. Silliman

Department of Biology, University of Florida, P.O. Box 118525, Gainesville, FL 32611, USA

Abstract

Recent advances in video processing and remote imaging have forged a new era in the study of animal behavior. The fast evolving field of Animal Born Imagery utilizes these technological advances to collect video data from the point-of-view (POV) of the animal. This non-intrusive, POV approach offers researchers a novel opportunity to observe and quantify natural, unobstructed patterns in animal behavior. Videographers in National Geographic Remote Imagining (NGRI) department are pioneers within this field and have developed a number of multifaceted video systems, collectively known as Crittercams. In 2010 and 2011, we partnered with NGRI to deploy Critter-cam systems on a wild American Alligators. Here we present findings from analyses of video data retrieved after deploying Critter-cams on 15 adult alligators (~90 hours of video) within the Merritt Island National Wildlife Refuge Cape Canaveral and Guana Lake Wildlife Management Area Florida. Video data collected has provided an intimate view of the foraging habits and behaviors alligator's exhibit in Florida estuaries. A common pattern revealed was that alligators primarily forage along the benthic substrate and often forage fully submerged. Additionally, the frequency of foraging events far surpassed our initial expectations and demonstrates alligators frequently attempt capture of smaller prey items.

Assessment of Nest Attendance of the American Alligator (*Alligator mississippiensis*) Using a Modified Motion-Sensitive Camera Trap

Mark Merchant[1], Dusty Savage[1], Amos Cooper[2], Monique Slaughter[2] and Chris Murray[3]

[1] Department of Chemistry, McNeese State University, Lake Charles, Louisiana, USA
[2] JD Murphree Wildlife Management Area, Texas Parks and Wildlife Department, Port Arthur, Texas, USA
[3] Biology Department, Southeastern Louisiana University, Hammond, Louisiana, USA

Abstract

Previous data from our laboratory has shown that motion-sensitive, infrared (IR)-based camera traps are not reliable for the quantitative capture of images of alligators. Therefore, we designed a camera trigger mechanism which included an electrical circuit board, coupled to a camera, which powered an IR Led light. The circuit was designed to turn the IR LED on for 2 seconds every 5 minutes. In the field, the IR LED was positioned such that the light was pointing directly into the IR detector of the camera. Therefore, the cameras were stimulated to take photos every five minutes, throughout the entire nesting period. The data revealed that alligators attend and maintain their nests more frequently during the first four to seven days after egg deposition, and then attendance is decreased. Nest attendance increased toward the end of the incubation period as eggs neared the hatching stage. In addition, 87.3% of alligator nest attendance occurred during the nighttime hours, between 8 pm and 6 am. In addition to nest visitation data, we also gained information concerning nest predation.

Ultrasound, a Powerful Tool for Health Assessment in Crocodilians

Paolo Martelli and Brian Chin Wing Kot

Veterinary Department, Ocean Park Hong Kong, Hong Kong

Abstract

Because of their peculiar and poorly understood anatomy, physiology and behavior, assessing the health of crocodilian is not straightforward. Observation, palpation, auscultation and blood analysis are not sufficient to form an accurate picture of the health status. Ultrasound allows visualization and recognition of size, shape and appearance of the visceral organs. This study presents in detail the ultrasonic approach and appearance of the various internal organs. Images are correlated with post mortem gross and microscopic appearance. The authors conclude that ultrasound is a useful and powerful tool that should be part of the health assessment of crocodilian individuals or populations.

Sexual Maturity in Male American Alligators in Southwest Louisiana

Valentine Lance[1], Ruth Elsey[2] and Phillip Trosclair III[2]

[1] San Diego State University; [2] Rockefeller Wildlife Refuge

Abstract

Very little is known about the attainment of puberty in reptiles. In the American Alligator (*Alligator mississippiensis*) males are assumed to be sexually mature at about 1.8 m total length, but it is not clear at what size they produce spermatozoa and mate successfully. The minimum size for sexual maturity is thought to be around 1.8 m, but social hierarchy favors breeding by male alligators over 2.2 m. We decided to re-examine this question by studying plasma testosterone levels in blood samples from a large sample of alligators (around 1500) collected in every month of the year and ranging in size from approximately 61 cm (2') to 360 cm (11.5'). In addition a number of testicular samples were taken for histology from alligators (close to, and equal to 1.8 m TL) during the mating season to assess degree of spermatogenesis and testicular maturation. Plasma testosterone values ranged from 0.05 ng/ml to 115.41 ng/ml. All size classes of alligators exhibited a seasonal cycle in testosterone levels, but the concentrations were size-dependent: the larger the alligator the higher the testosterone. In all alligators sampled testosterone reached a peak in the breeding season (March-May). Mean testosterone in the largest size class during breeding was 75 ng/ml whereas in the smallest size class peak testosterone was less than 3 ng/ml. The smallest size class (61-89 cm) showed an additional rise in testosterone in late summer. The attainment of sexual maturity in alligators appears to be closely associated with growth, and is a gradual process lasting several years. Sexually immature alligators show a seasonal pattern of testosterone secretion similar to that of adults, but the values are significantly lower.

Head-Starting as a Tool for Crocodile Conservation

Willem van de Ven, Marites Balbas, Dominic Rodriguez, Sammy Telan, Jessie Guerrero and Merlijn van Weerd

Mabuwaya Foundation Inc., CCVPED building, ISU Cabagan, 3328 Isabela, Philippines

Abstract

The critically endangered *Crocodylus mindorensis* is a freshwater species endemic to the Philippines. The wild population size is <250 adult individuals. In 1999 a conservation project started in the municipality of San Mariano, Isabela, targeting a very small population. Hatchling mortality is high, preventing a quick population recovery. Most suitable hatchling habitat has been converted into agricultural lands, consequently the crocodiles nest next to fast flowing rivers and hatchlings are swept downstream. In 2005 we started a head-start program to increase hatchling survival. We collect hatchlings from the wild and rear them in captivity for 18-24 months before releasing them back into the wild. Between 2007 and 2011, 162 hatchlings were collected and raised in a rearing station. 91 juveniles have been released into the wild and 39 individuals are at this time still at the rearing station, to be released in 2012 and 2013. Rearing strategies are evaluated and improved and growth rates are increasing. Survival rates of crocodiles in the rearing station are high and crocodiles adapt to wild conditions. Survival of released crocodiles is difficult to assess but indications are that survival rates after one year in the wild are at least 50%.

Influence of Natural and Artificial Light on Broad-Snouted Caiman (*Caiman latirostris*)

Lucía Fernández[1], Alba Imhof[1] and Pablo Siroski[1,2]

[1] Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASPyMA) - A. del Valle 8700, Santa Fe, Argentina
[2] Laboratorio de Biología Celular y Molecular (FCV-UNL), Argentina (la_lufernandez@hotmail.com)

Introduction

The UV spectrum irradiation on the planet surface is regulated by temporal, geographical and meteorological factors. Ultraviolet radiation (UVR) plays an important role to determinate the natural balance of the planet and also is an important factor in many physiological functions of organisms. The UVR are part of the electromagnetic spectrum and appear in three frequencies: A, B and C. (Diffey 1991). These radiations act in many biological processes. Ectothermic vertebrates use sunlight as a thermoregulatory mechanism (Johnson *et al*. 2008). Under natural conditions in the wild, many reptiles synthesize their own vitamin D3 from the UV component of sunlight. Certain wavelengths in the UV spectrum (290-320 nm) react with sterols (provitamina D) in the skin to produce pre-vitamin D3 that then is transformed in cholecalciferol, a previous form of the vitamin D3. This is in turn converted into vitamin D3 itself, based on a process which also depends upon heat. Reptiles get a high proportion of their vitamin D3 requirement from their food. Vitamin D3 is controlling the absorption, transport and deposit of calcium, and in minor proportion, phosphorus.

Objectives

To determine the effects of different time periods of natural and artificial light UV exposure on the growth of *Caiman latirostris* yearlings.

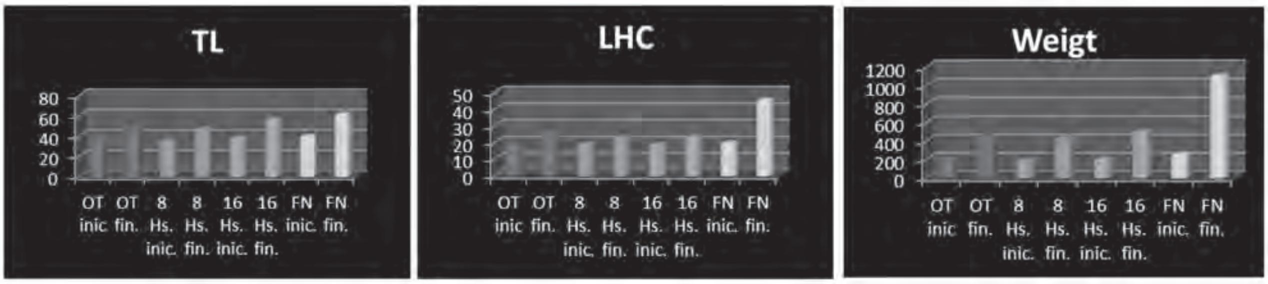
To determine the effects of different time periods of natural and artificial light UV exposure on calcium and phosphorus plasmatic concentrations in *Caiman latirostris* yearlings.

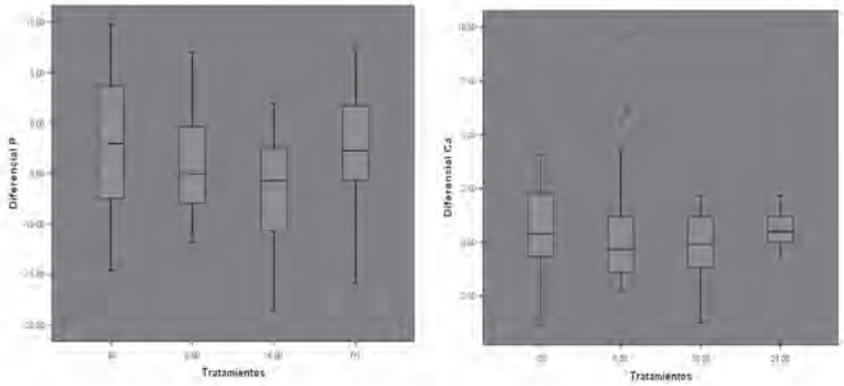
Materials and Methods

We used 96 4-month-old Broad-snouted Caiman (*Caiman latirostris*) from 4 wild-harvested and artifically incubated clutches. The animals were randomly separated in four duplicate groups of 12 individuals. Each animal was identified with a tag numbered (Natl. Band and Tag Co., Newport, Kentucky). At the beginning and at the end of the study, total length (TL, precision 0.5 cm), weight (BM, precision 0.1 g) and snout-vent length (SVL) were measured. Blood samples were taken from the spinal vein (Tourn *et al*. 1994; Zippel *et al*. 2003) using 25G x 5/8" needle and 5 ml syringe, and transferred to serum tubes. Animals were exposed to 4 treatments: total darkness (td); 8 hours of UVR (uva-uvb) (8 h); 16 hours of UVR (uva-uvb) (16 h); normal photoperiod of natural light (NP), in plastic pens over 90 days. Temperature was 31 ± 2°C, recorded with HOBO Dates Logger (ONSET Computer Corp., Pocasset, MA, USA). Food was offered three times a week ad libitum with a mixture of 60% minced chicken heads and 40% dry pellets. Cleanup was done the following day. Calcium (Ca) concentrations were determined by colorimetric method; and phosphorous (P) concentrations were determined by direct UV method. Changes in BM, SVL, TL, Ca and P concentrations were analyzed by ANOVA, with UV-exposed period and clutch as grouping variable.

Results

The animals exposed to FN showed the highest increases in TL, LHC and BM ($p<0.05$). There was no significant difference in calcium concentration in any of the treatments. However, P concentration in animals exposed to UV radiation (16 hours) ($p<0.05$) dropped significantly. Finally, the effect of nest-of-origin was considered, and resulted in significant differences for all initial differential variables, in growth and Ca and P concentrations. All animals survived in all treatments and none presented external injuries.





Discussion

The results showed that a FN would be ideal for the captive organisms to increase their growth. As it was demonstrated by Ferguson *et al*. (2005) in *Anolis lineotopus merope* and *Anolis sagrei*, and Karsten *et al*. (2009) *Furcifer pardalis*, sun radiation would provide the necessary quantity and quality of UV radiation so as the organisms effectively develop life cycles. Calcium concentrations (final results), were similar to those reported for *C. latirostris* but they were higher in sub-adult animals exposed to FN (Barboza *et al*. 2008) and in other crocodile species captive in farms (*C. niloticus*, Watson 1990; *A. mississippiensis*, Schoeb *et al*. 2002; *C. porosus,* Millan *et al*. 1997; *C. moreletii*, Sigler 1991; *T. schlegelii*, Siruntawineti and Ratanakorn 1994; *C. yacare*, Barboza 2006). In the same species and other captive crocodile species the P values were higher than in Barboza *et al*. (2008). *C. porosus*, Millan *et al*. 1997; *C. moreletii*, Sigler 1991; *T. schlegelii*; Siruntawineti and Ratanakorn 1994; *C. yacare*, Barboza *et al*. 2006). But in others, the concentrations were higher than in our own research. (*A. mississippiensis*, Schoeb *et al*. 2002). The organisms may have been under a stressful situation influencing on the final serum values of P and Ca, and a as result provoking a remarkable fall. Regardless the kind of diet, temperature, etc. provided, the absorption of minerals will not be optimum (Brames 2007) if UV radiation is not properly provided. Taking into account that all the animals are exposed to natural UV radiation, and based on the results of the research, the concentration values could show some deficiency or difference in the minerals included in the diet (Coppo 2001). Based on the importance of UV radiation for phosphorous metabolism, we can assume that the periods of exposure were not enough for presenting a change in such metabolism. However, it was enough to notice a less growth in the animals that could be related to alteration in the absorption of minerals related by an inappropriate synthesis of vitamin D.

Literature Cited

Barboza, N.N., Mussart, N.B., Ortiz, L., Prado, W. and Coppo, J. (2006). Influencia de la especie, sexo, edad, alimentación y temperatura ambiental sobre los electrolitos séricos de caimanes autóctonos. Sitio Argentino de Producción Animal. Universidad Nacional del Nordeste. Comunicaciones Científicas y Tecnológicas. Resumen: V-005. Pp. 1-4.

Barboza, N.N., Mussart, N.B., Coppo, J.A., Fioranelli, S.A. and Koza, G.A. (2008). El medio interno de *Caiman latirostris* en cautiverio. Influencia del sexo, crecimiento y estación del año. Revista Veterinaria 19(1): 33-41.

Brames, H. (2007). Aspects of light and reptile immunity. Iguana 14: 18-23.

Coppo, J.A. (2001). Fisiología Comparada del Medio Interno. Ed Dunken: Buenos Aires. Pp. 212-216.

Diffey, B.L. (1991). Solar ultraviolet radiation effects on biological systems. Physics in Medicine and Biology 36(3): 299-328.

Ferguson, G.W., Gehrmann, W. H., Karsten, K.B., Landwer, A.J., Carman, E.N., Chen, T. C. and Holick, M.F. (2005). Ultraviolet exposure and vitamin D synthesis in a sun-dwelling and a shade-dwelling species of *Anolis*: are there adaptions for lower ultraviolet B and dietary vitamin D3, availability in the shade? Physiological and Biochemical Zoology 78: 193-200.

Johnson, C.R., Voigt, W.G. and Smith, E.N. (2008). Thermoregulation in crocodilians. III. Thermal preferenda, voluntary maxima, and heating and cooling rates in the American alligator, *Alligator mississipiensis*. Zool. J. Linn. Soc. 62: 179-188.

Karsten, K.B., Ferguson, G.W., Chan T.C. and Holick, M.F. (2009). Panther Chameleons, *Furcifer pardalis*, behaviorally regulate optimal exposure to UV depending on dietary Vitamin D3 status. Physiological and Biochemical Zoology 82(3): 218-225.

Millan, J.M., Janmaat, A., Richardson, K.C., Chambers, L.K. and Fomiatti, K.R. (1997a). Reference ranges for biochemical and haematological values in farmed saltwater crocodile (*Crocodylus porosus*) yearlings. Australian Veterinary Journal 75: 814-817.

Schoeb, T.R., Heaton-Jones, T.G., Clemmons, R.M., Carbonneau, D.A., Woodward, A.R., Shelton, D. and Poppenga, R.H. (2002). Clinical and necropsy findings associated with increased mortality among American alligators of Lake Griffin, Florida. J. Wildl. Dis. 38: 320-337.

Sigler, L. (1991). Constantes fisiológicas y valores hemáticos de cocodrilianos mexicanos en cautiverio en los Estados de Chiapas, Quintana Roo y Yucatán. Veterinaria México 22: 99.

Siruntawineti, J. and Ratanakorn, P. (1994). Hematology and serum chemistry values of captive False Gharial (*Tomistoma schlegelii*) in Thailand. Pp. 279-286 *in* Crocodiles. Proceeding of the 12th Working Meeting of the IUCN-SSC Crocodile Specialist Group, Vol. 2. IUCN: Gland, Switzerland.

Tourn, S., Imhof, A., Costa, A., Von Finck, C. and Larriera, A. (1994). Colecta de sangre y procesamiento de muestras en *Caiman latirostris*. Pp. 25-30 *in* Memorias del IV Workshop sobre Conservación y Manejo del Yacaré Overo (*Caiman latirostris*). "La Región" - Fundación Banco Bica - Santo Tomé: Santa Fe, Argentina.

Watson, P.A. (1990). Effects of blasting on Nile crocodiles, *Crocodylus niloticus*. Pp. 240-252 *in* Crocodiles. Proceedings of the 10th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland, Switzerland.

Zippel, K.C., Lillywhite, H.B. and Mladnich, C.R. (2003). Anatomy of the crocodilian spinal vein. Journal of Morphology 258: 327-335.

Deficiencies of Crocodilian Husbandry in Large Head-Starting Facilities and a Proposal for an Alternative Concept

Geoff McClure

PO Box 44, Clifton Beach, Queensland 4879, Australia (crocconsult@bigpond.com)

Abstract

The supplementation of depleted populations of wild crocodilians is frequently initiated in large head-starting facilities or breeding centres based on a farming model of husbandry. This paper discusses conditioning of crocodilians in zoos and farms and how it may produce crocodiles that have limited survival skills when released. This conditioning process is exacerbated by deficiencies in pen design. A typical nursery pen in a large (unnamed) breeding centre is discussed, and how its deficiencies contribute to high mortality rates. An alternative proposal based on developing local or villager based aquaculture skills is proposed as a solution to producing crocodiles that are better equipped for survival after release, and as part of a solution to addressing significant socio-economic pressures on freshwater ecosystems for which crocodiles are frequently an icon.

Introduction

This paper is based on personal experience of crocodile husbandry in both zoos and farms, with some observation of various methods of head-starting crocodilians in South and Southeast Asia. Head-starting is the most commonly used method for supplementing or reinforcing depleted populations of wild crocodilians. It is often perceived as a simple process but in reality is very complex, often including species-specific issues associated with husbandry of endangered crocodilians, while habitat health and complicated socio-economic pressures impact on survival rates of released animals. Various methods have evolved to overcome these issues including paying villagers to guard hatchlings in village ponds, guarding natural nests and collecting hatchlings for captive rearing, or incubation of eggs from wild or captive breeders with captive rearing and release of suitably sized juveniles. This latter process usually occurs in larger rearing facilities or breeding centres similar to crocodile farms and is the subject of this paper.

Chabreck *et al*. (1998) state that survival rates of farm-raised or hand-reared animals is generally lower than wild conspecifics, and refer to Blake and Loveridge (1975) who report very low survival rates of farm-raised Nile Crocodile hatchlings. In Zimbabwe Ferguson (1998) found that released farm-raised Nile Crocodiles had better body condition than wild crocodiles at the time of release but this situation deteriorated to inferior condition after their first non-growing season, and that survival of released crocodiles was lower than wild conspecifics. Released farmed American Alligators in Louisiana at 1.2 m total length are subject to higher rates of cannibalism than wild conspecifics, and are easier to approach during recapture (Chabreck *et al*. 1998).

This is not to say that supplementation programs are failures. The IUCN Re-Introduction Specialist Group rates supplementation programs on a scale from highly successful to successful, partially successful, or as failure. Soorae (2008) notes that van Weerd and van der Ploeg (2008) had 'partial success' in supplementing Philippines Crocodiles in Luzon, and Rao states 'partial success' in supplementing wild Gharial in the Chambal River in India. Elsey and Kinler (2011) found that a reintroduction program using farm raised alligators in Louisiana is 'highly successful' with released animals attaining adulthood and reproducing.

Thus only one of these programs is rated as highly successful. As a result of these issues and personal experience this paper is critical of large head-starting facilities based on a farming model, and proposes a simpler alternative particularly suitable for lesser developed countries. In this context the term 'husbandry' includes both management (eg daily routines, diet, and collecting data) and pen design, while conditioning is defined as simple learning. The relevant issues discussed below are divided into three sections:

1. Conditioning of captive-reared hatchling and juvenile stock

   The behaviour of various species of wild crocodilians is noted by their similarities rather than by their differences. However their degree of tolerance, as shown in Figure 1 by Lang (1987) varies, and has a marked influence on captive husbandry. In captivity tolerance also varies between individuals and is subject to conditioning. To give an example with supposedly intolerant saltwater crocodiles (*C. porosus*): In a farming situation it is common practice for one keeper to be responsible for the daily routines of a given group of hatchlings. Hatchlings become conditioned to a particular routine and a particular keeper, to the extent that they may be imprinted on him/her and will even hand feed if the keeper is silly enough to attempt it. On one occasion a change of keeper caused a reduction in food consumption by up to a third despite the same standard feeding routine being adhered to.

Some of these hatchlings were maintained as future breeding stock. At a total length of approximately 3 m they were fed from a wheel barrow (trolley), and on two occasions some of them crawled under the barrow and stopped within a few centimetres of the keeper's feet waiting for their dinner. They showed no aggression and simply waited to be fed.

This conditioning process can vary between zoos and crocodile farms because they have different objectives which impact on behaviour and thus have direct implications for conservation programs that use captive crocodilians to supplement wild populations.

Zoos are contemporary Noah's Arks. Zoo-keepers value their animals by an educational value for presentation and interpretative initiatives. Their husbandry is often anthropomorphic, by caring for the welfare and maintenance of individual animals in perpetuity. This type of care and conditioning rarely promotes those survival skills that are necessary for release into the wild and if animals are raised in isolation they may even lack social skills for attaining compatibility which (at least) in captivity is a prerequisite of reproduction.

Crocodile farmers place an economic value on their stock as skins and meat, and develop intensive systems of husbandry based on productivity, caring for the welfare of animals in homogeneous groups rather than as individuals. It is also possible that hatchlings are imprinted on keepers (note example above), and that the accepted method of rearing young stock in densities that promote tolerance by removing personal space to limit physical damage to skins is reinforcing a form of conditioning that is not conducive to survival if released into the wild. Some large head start facilities also use stocking density to condition crocodiles for tolerance as a means of avoiding injuries that may preclude survival after release. It is possible that this form of management is counter-productive to the survival of all individuals in the cohort. It is also probable that crocodiles raised in groups of homogeneous size are unable to recognise dominant animals as a threat.

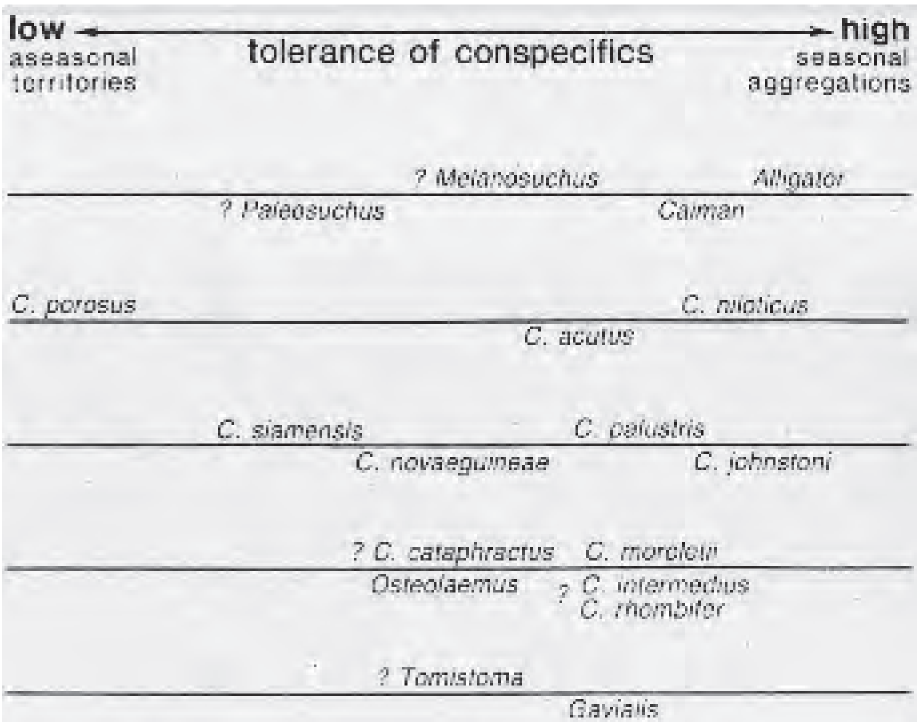


Figure 1. Tolerance of conspecifics by wild crocodilians (Lang 1987). This diagram may be used as a basis for husbandry, and in particular for designing breeding pens.

Many wild hatchling and juvenile crocodilians (eg Gharials) cohabit with their parents and parental guidance may be important. The author has observed a captive juvenile Saltwater Crocodile (NB: intolerant species) coexisting with its parents in a relatively small 1:1 breeding pen, while Brueggen (2002) has observed parental guidance with captive Siamese Crocodiles over a two-year period and suggests that we should not be dismissive of poorly understood crocodilian behaviour because they are often considered as primitive. Care should be taken in citing these observations because captive behaviour may not necessarily be the same as that in the wild.

2. Inherent problems in the design of head start facilities

   Figure 2 shows a typical hatchery pen in a large head start facility or breeding centre. Presentation is very good - it is clean and generally well maintained. This is an indication of keeper's respect for their livestock.

   On crocodile farms the contribution of a pen to overall productivity is measured by what comes out of it. Unfortunately in this pen (Fig. 2) fungal infection causes mortality rates up to 60% or more so it contributes very little to productivity. On small closed-cycle crocodile farms mortality rates should be approximately 5%, and marginally higher on large farms. The very high mortality rates in this pen are rationalised by management by comparing them to wild mortality rates. This approach can not be justified. Problems with livestock in captivity are managerial problems and should not be attributed to deficiencies of animals, particularly when critically endangered species of high biological value are concerned. Below are some aspects of the pen in Figure 2 which detract from high productivity:

- Wild hatchlings use micro-climate (eg mud and rocks) to thermoregulate but this building does not collect or store heat. This can easily be achieved by orientating the building to early morning sun, installing a plastic cover on the roof, using building materials with high thermal mass, passing pond refill water through small diameter poly pipe, using a 10-20% flush rather than feed and drop 100% of pond water (water exchange), and incorporating a heat box into hideboards. Most of these ideas could be incorporated after construction.
- Porous building materials such as timber and sand substrate may harbour high pathogen loads. Initially river sand may be relatively clean but over time pathogen loads will increase. Therefore it is important that sand used in artificial incubation or as a pen substrate is changed regularly. Timber is porous and also harbours pathogens, particularly when used for hide boards. In this instance it should at least be painted.
- Controls for all plumbing should be external to the pen to reduce disturbance.

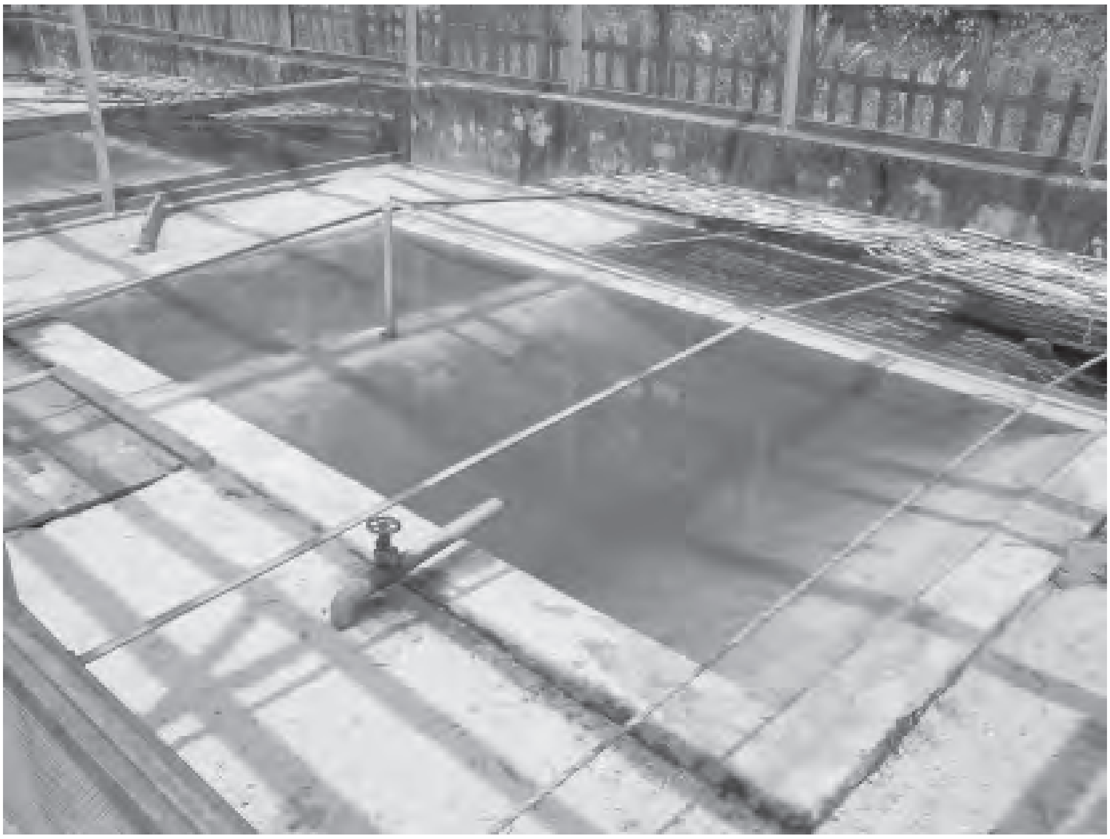


Figure 2. An example of a hatchery/nursery pen built in 2006 in a head-start facility which uses husbandry techniques based on farm husbandry. This system of husbandry and poor pen design creates a number of issues including a compromised ability to thermoregulate and increased pathogen loads in porous building materials such as sand substrate and timber in walls and hideboards. Hatchling mortality frequently reaches 60% or more. Note: Crocodiles have been edited out to maintain confidentiality.

High mortality rates in the pen shown in Figure 2 are the result of a sequence of events during incubation and predetermined by pen design. This sequence is as follows:

- Possible infection during incubation. Captive and wild-laid eggs are collected and incubated in artificial sand banks.

Thomas (2001) found that *Fusarium* and *Paecilimyces* spp. of fungi occur naturally in sand and nesting media in Queensland (Australia) and caused the most fatalities of embryos and hatchlings. These fungi may invade eggs and infect embryos during incubation. Infected hatchlings may die three or more months later (Thomas 2004) from massive growth of fungus in the liver. It is possible that hatchlings at this facility are infected during incubation but pathogen loads in sand banks have not been assessed.

- Falling temperature favours fungi and causes thermal stress. Crocodilian immune systems and metabolism are temperature dependent. Crocodiles have a preferred body temperature of 32 to 33°C (Huchzermeyer 2003) while Johnson *et al*. in 1976 (cited in Mayer 1995) found that Saltwater and Australian Freshwater Crocodiles have a Preferred Optimum Temperature Zone (POTZ) of 25.5 to 35°C. Hatchlings released into this pen have a compromised ability to thermoregulate as winter water temperatures eventually fall to 17°C. Thermal stress and the onset of cooler weather favour fungus - for example *Fusarium* and *Paecilimyces* spp. of fungi prefer an optimal temperature range of 26°C (most favourable temperature) to 31°C (Thomas 2004).
- Failure to initiate feeding. In this pen the majority of hatchlings fail to initiate feeding and are subjected to further stress from force feeding - it should be noted that the stimulus to feed in many species is poorly understood but this pen does not provide flexibility for trialling various methods.
- Depletion of antibodies and onset of infection. Within a few weeks an inability to thermoregulate coincides with a depletion of yolk sack antibodies and more stress caused by individual medication for fungal infection.
- Pathogen loads. Because of pathogen loads in sand and timber any crocodiles washed or medicated for disease such as fungus are reinfected.

Further to the above the importance of collecting and collating data in any facility can not be over emphasised - 'you can't manage what you don't measure'. Professional managers collate appropriate data to reveal deficiencies in husbandry and act accordingly, while those managers that do not are generally ignorant of deficiencies in their husbandry. They are letting the crocodiles manage the facility and rationalise their deficiencies in husbandry by blaming their animals.

3. General logistics associated with large head start facilities

Crocodiles are an icon or keystone species for freshwater ecosystems so many head starting initiatives in lesser developed countries are part of a far more complex program addressing socio-economic issues related to the wider community and particularly overfishing by local villagers. Generally larger facilities or breeding centres create larger problems, including: -

- They are cost and labour intensive compared to other methods.
- They need considerably more managerial skill.
- In the absence of refrigeration the practicalities of supplying large quantities of fresh fish are difficult. This may contribute to dietary disease which can have long-term implications.
- They may be seen as competing with local people for limited supplies of protein.
- They tend to release large numbers of juveniles of similar size class in a limited area. This may exceed habitat carrying capacity, distort the social balance of wild populations, and may increase cannibalism.
- They may discharge relatively higher loads of nutrients.

Developing an Alternative Concept

In an attempt to solve some of the issues noted above an alternative system of head starting crocodilians is proposed (see Fig. 3). This proposal has evolved from a Captive Breeding Project at Pagasa Farms, which is a joint venture with the Protected Areas and Wildlife Bureau (PAWB-DENR) and the Silliman University in Dumaguete City, Philippines. Three male and four female (3:4) Philippine Crocodiles (*C. mindorensis*) are accommodated in a small fenced lagoon approximately 28 m x 39 m. No supplementary food has been offered since March 2007 and production to date is three juveniles and 36 hatchlings.

This concept has been further enhanced as a conceptual drawing in Figure 3. There are four components shown in the diagram:

Pond A. This pond is a dedicated aquaculture pond for the production of food for adult crocodiles and their progeny. It is important that selected species should be endemic to local freshwater ecosystems so captive-bred crocodiles will become conditioned to hunting them. Undesirable species should be avoided (eg *Tilapia* and *Gambusia* spp.) because there will be escapees. Excess production can be used by local villagers and thus reduce socio-economic pressure on freshwater ecosystems. At the very least this pond could be used as a training facility with the objective of establishing local aquaculture. Ponds are separated by a series of suitably sized mesh screens as drop gates to preclude the movement of larger fish and crocodiles. Pond B is included to demonstrate that any number of ponds may be incorporated to specifically cultivate small fish, crustaceans, endangered species of turtles, juvenile crocodiles of mixed ages, or future breeding stock. Pond C is a crocodile breeding pond/s. The design should be species and climate specific, and must include ample shallow water for hatchling security and feeding. Pond D is a trap to assist in measuring production, and assessing suitability of stock for release - eg biosecurity issues such as deformity and disease.

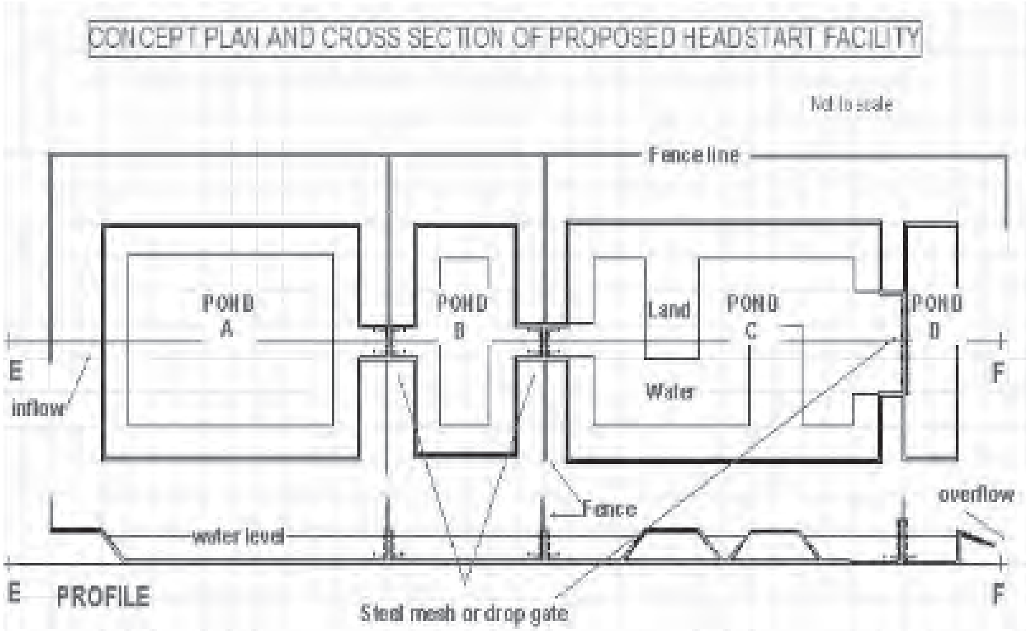


Figure 3. Concept plan for an alternative head-starting facility or breeding centre. In lesser developed countries this system should produce protein for local villagers and contribute to reducing socio-economic pressure on freshwater ecosystems. Juvenile crocodiles for release should have improved survival skills.

Some general notes:

- The site must have impermeable soil. Initially the only machinery needed is a pump to lift river water.
- The site should be in proximity of good juvenile crocodile habitat.
- A food pyramid should be established in each pond. It will need to be created over a period of months starting with hay or straw, followed by endemic aquatic plants and smaller prey species of fish.
- This facility will remove nutrients and not dump excessive nutrient loads.
- As a breeding centre this system should be cost-effective and could possibly be used for integrated farming.
- Local people should be involved in planning and construction. This will help develop a sense of ownership and is a prerequisite to their commitment and success of the project.
- A number of smaller breeding groups are considered superior to one large breeding centre. This avoids release of large numbers of juveniles in one place, will be beneficial if site fidelity is an issue, improves biosecurity, and will reach a broader community of people.

Where there is life there is death but at least in this proposed system mortality will occur as part of the process of learning survival techniques rather than poor husbandry such as that discussed above.

Conclusions

Releasing a few crocodiles is simple, but head-starting crocodilians deals with many complex issues that vary between species, catchments and cultures. It is often a necessary and expensive bandaid which remains important not only because of the intrinsic value of the species, but because they are iconic to many freshwater ecosystems that are among the most threatened in the world. These threats will be exacerbated by increasing socio-economic pressures and climatic influences in forthcoming decades.

Conservationists are competing for limited sponsorship that demands success. They need to think in business terms such as 'do we have a product to sell?' and develop a sense of cost benefit analysis by asking 'is crocodile conservation getting a bang for its buck?' Essentially this involves a professional approach to improving productivity. Managers of head-start facilities should be able to define what they want to produce as an objective, and then set about adopting a system that will achieve their objectives.

One of the areas in which this may occur is by taking the next step in pen design. It is no longer satisfactory to design a pen with a surrounding fence and central pond and then add a substrate. Certainly crocodile husbandry is part of a young emerging industry but this type of thinking is a relic of the past. Professional farmers have realised the benefit of experience and consultation, and the use of collated data to reveal deficiencies in husbandry and lateral thinking to provide solutions. Conservationists that are head-starting crocodiles of high biological value need to follow suite.

Acknowledgements

I would like to thank Vic Mercado and Michael Cruz of Pagasa Farms for their assistance.

Literature Cited

Bajomi, B. (2010). Reintroduction of endangered animal species: complementing the IUCN guidelines, Systematic review No. 86, Centre for Environmental Science, Eötvös Loránd, University of Sciences: Budapest. (published at http://www.iucnsscrsg.org/rsg_book.php).

Brueggen, J. (2002). Crocodilians: fact vs. fiction. *In* Crocodiles. Proceedings of the 16th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Chabreck, R.H., Wright, V.L. and Addison, B.G. (1998). Survival indices for farm-released American alligators in a freshwater marsh. *In* Crocodiles. Proceedings of the 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Elsey, R.M. and Kinler, N. (2011). Supplementation of juvenile American alligators in Louisiana, USA. IUCN/SSC Re-introduction Specialist Group, Retrieved from: http://www.iucnsscrsg.org/rsg_book.php

Ferguson, R. (1998). Reintroduction of Nile Crocodiles to Lake Kariba, Zimbabwe. *In* Crocodiles. Proceedings of the 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Huchzermeyer, F.W. (2003). Crocodiles, Biology, Husbandry and Disease. CABI Publishing: Oxon, UK.

IUCN/SSC (1995) Guidelines for Re-Introductions, SSC Re-introduction Specialist Group, 41st Meeting of the IUCN Council, Gland, Switzerland. Retrieved from: http://intranet.iucn.org/webfiles/doc/SSC/SSCwebsite/Policy_statements/Reintroduction_guidelines.pdf

Lang, J.W. (1987). Crocodilian behaviour: implications for management. *In* Wildlife Management: Crocodiles and Alligators, ed. by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty and Sons: Chipping Norton.

Mayer, B. (1995). Temperature trial on two month old juveniles, Crocodile Research and Development Bulletin, Volume 1, 1 June 1995. QDPI&F: Brisbane.

Rao, R.J. (2008). Supplementation of Indian Gharial in protected areas of Madhya Pradesh, India. *In* Global Re-Introduction Perspectives, Re-introduction Case-studies from around the Globe. IUCN/SSC Re-introduction Specialist Group, Retrieved from: http://www.iucnsscrsg.org/rsg_book.php.

Soorae, P.S. and Stanley Price, M.R. (1998). General introduction to re-introductions. *In* Crocodiles. Proceedings of the 14th Working Meeting of the IUCN-SSC Crocodile Specialist Group. IUCN: Gland.

Soorae, P.S. (ed.) (2008). Global Re-Introduction Perspectives, Re-introduction Case-studies from around the Globe. IUCN/SSC Re-introduction Specialist Group. Retrieved from: http://www.iucnsscrsg.org/rsg_book.php.

Thomas, A. (2001). Some fungal contaminants of the Estuarine Crocodile. Crocodile Research and Development Bulletin Volume 3. QDPIF: Brisbane.

Thomas, A. (2004). Observations on bacterial and fungal contamination of farmed Freshwater Crocodile eggs. Crocodile Capers 1(9): 7-9.

van Weerd, M. and van der Ploeg, J. (2008). Philippine crocodile hatchling head-start and re-inforcement program in San Mariano, Isabela Province, Luzon, the Philippines. *In* Global Re-Introduction Perspectives, Re-introduction Case-studies from around the Globe. IUCN/SSC Re-introduction Specialist Group, Retrieved from: http://www.iucnsscrsg.org/rsg_book.php.

Research Influences a Conservation Breeding Program - The European StudBook for African Dwarf Crocodiles (*Osteolaemus tetraspis*)

Fabian Schmidt

Zoo Leipzig, Pfaffendorfer Str. 29, D-04105 Germany (fschmidt@zoo-leipzig.de)

Abstract

The endangered African Dwarf Crocodile (*Osteolaemus tetraspis*) is distributed in central and Western Africa. Traditionally two subspecies are described (*tetraspis* and *osborni*), which can be distinguished only on minor morphological differences. Recent molecular studies suggest the existence of thee allopatric taxa which occur in the Congo Basin, the Ogooue Basin and West Africa. African Dwarf Crocodiles are regularly kept in European Zoos. The collection is managed by a European Studbook coordinated at Leipzig Zoo since 2007. For conservation reasons it is important to know the provenance of these animals registered. Hence in cooperation with the University of Leipzig a genetic screening of the studbook population was conducted The results confirmed the existence of at least three different lineages of *Osteolaemus* as recently postulated, but also revealed hints of the existence of a fourth evolutionary lineage. A majority of the animals originate from the Ogooue basin. Unfortunately also hybrids between these lineages were detected, all of them bred in zoological institutions. This case study shows the importance to reflect results from research in breeding programs to ensure the survival of genetically viable and taxonomically pure *ex-situ* populations.

Community Conservation Initiative by the Sepik Wetland Management Initiative

Godfrid C. Solmu[1], Matt Plummer[1] and Jerry Wana[2]

[1] Mainland Holdings Limited, P.O. Box 196, Lae, Morobe Province, Papua New Guinea (crocresearch@mainland.com.pg, crocgm@mainland.com.pg)
[2] Sepik Wetlands Management Initiative, P.O. Box 81, Ambunti, ESP, Papua New Guinea

Abstract

The Sepik Wetland Management Initiative (SWMI) was set up locally as a consultative Community-based organisation (CBO) in Ambunti, East Sepik Province, Papua New Guinea. As a result of the changing dynamics of the Sepik River System, the remnant prime nesting habitats for the two PNG crocodile species, *Crocodylus porosus* and *C. novaeguineae*, are being afforded the protection to enhance wild population sustainability. SWMI's vision is to ensure that both crocodiles are used as flagship species to augment better appreciation and community based management/conservation for the wetlands as a result of sustainable harvest of eggs, juveniles and skins. Sustainable use in this area provides all important school fees, fuel for river transport and other goods and services otherwise unobtainable. SWMI, in collaboration with MHL, also noted that terrestrial and aquatic wetlands are managed holistically, providing a benchmark for conservation of inland wetlands. Through consultation with government and other local stakeholders the ultimate aim is to influence the legislative process to improve socio-economic development in these very remote communities as well as improving the management of the entire Upper Sepik Wetlands system.

Gastric Nematode Community of *Crocodylus acutus*, *Crocodylus moreletii* and *Caiman crocodilus chiapsius* from Southern Mexico

Marisa Tellez, Dhithya Ramsawamy and Nicole Sarimiento

UCLA, Department of Ecology and Evolutionary Biology, 621 Charles E. Young Drive South, P.O. Box 951606, Los Angeles, CA 90095-1606, USA

Abstract

Stomach nematode prevalence, intensity, abundance and species richness were evaluated and identified in *Caiman crocodilus chiapsius* (n= 3), *Crocodylus moreletii* (n= 12), and *C. acutus* (n= 1) from Lagoon Illusion (Tabasco), Rio Hondo (Chetumal) and and Puerta de Arisa and Boca del Cielo (Chiapas), in Mexico. Stomach nematodes were collected via stomach flushing during night surveys, stunned with hot alcohol, and put in labeled vials of 70% glycerin alcohol. Three nematode genera from the family Ascarididae made up the parasite species richness: *Dujardinascaris helicina* (n= 26), larval *Dujardinascaris* sp. (n= 6), *Terranova lanceolata* (n= 1), *Brevimulticaecum* sp. (n= 1). *Dujardinascaris helicina* was the most abundant stomach nematode species found, particularly in *C. moreletii*. This study records the first host record of *Terranova lanceolata* parasitizing *C. moreletii*, and documents the first parasite ever recorded in *C. c. chiapsius*. The parasite discovered in *C. c. chiapsius* was identified to the genus *Brevimulticaecum*, but was not identified to species as it has characteristics unique from its congenerics parasitizing other crocodilians. To date, we consider this specimen as a new species, but more parasite specimens are needed for verification.

Statistical analysis of parasitic prevalence (44%), intensity (2.1) and abundance (2.1) was performed via a Wilcox t-test. Comparative analysis of *C. moreletii* between urban and non-urban populations in Mexico illustrates a significant difference in nematode intensity (P= 0.016). A plausible explanation for the difference in nematode intensity among urban and non-urban areas could be crocodilian immunosuppression via anthropogenic impacts such as heavy metal pollution. Production, maturation, and function of monocytes, and the humoral immune response of vertebrates are hindered upon the disruption of internal heavy metal homeostasis (Rink and Gabriel 2000; Crossgrove and Zheng 2004; Kannan *et al*. 2006). This increases the susceptibility of an individual or population to pathogens that normally would be exacerbated by the immune system. Therefore, if a pollutant is interfering with the normal biological functionality of a crocodilian, parasites are more likely to succeed as a result of host immunosuppression (Morley *et al*. 2006). With future data, we intend to provide more information on how heavy metal pollution affects the crocodilian-nematode dynamic in order to analyze crocodilian health and response to anthropogenic impacts.

Literature Cited

Crossgrove, J. and Zheng, W. (2004). Manganese toxicity upon overexposure. NMR Biomed. 17: 544-553.

Kannan, K., Agusa, T., Perrotta, E., Thomas, N.J. and Tanabe, S. (2006). Comparison of trace element concentrations in livers of diseased, emaciated and non-diseased southern sea otters from the California coast. Chemosphere 65: 2160-2167.

Morley, N.J., Lewis, J.W. and Hoole, D. (2006). Pollutant-induced effects on immunological and physiological interactions in aquatic host-trematode systems: implications for parasite transmission. Journal of Helminth 80: 137-149.

Rink, L. and Gabriel, P. (2000). Zinc and the immune system. Proceedings of the Nutrition Society 59: 541-552.

Effects of *In Vivo* Exposure to Roundup® on the Immune System of *Caiman latirostris*

Maria A. Latorre[1,4], Evelyn C. López González[1,4], Gisela L. Poletta[1,2] and Pablo A. Siroski[1,3]

[1] Proyecto Yacaré - Laboratorio de Zoología Aplicada: Anexo Vertebrados (Facultad de Humanidades y Ciencias, Universidad Nacional del Litoral/Ministerio de Aguas, Servicios Públicos y Medio Ambiente), Argentina
[2] Cátedra de Toxicología, Farmacología y Bioquímica Legal, Facultad de Bioquímica y Ciencias Biológicas, Universidad Nacional del Litoral/Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires-CONICET, Argentina
[3] Laboratorio de Biología Celular y Molecular, Facultad de Ciencias Veterinarias, Universidad Nacional del Litoral-CONICET, 4 CONICET, Argentina

Introduction

Caiman latirostris (Broad-snouted Caiman) is one of the two species of crocodilian in Argentina, distributed in the Provinces of Chaco, Corrientes, Formosa, Salta, Santa Fe, Entre Rios, Misiones, Santiago del Estero and Jujuy (Larriera *et al*. 2008). Since the introduction of transgenic soybean varieties resistant to glyphosate, this herbicide became the most widely used agrochemical in Argentina (Aizen *et al*. 2009). Among the possible effects that can result from *in vivo* exposure to glyphosate in *C. latirostris* are alterations on the immune system (IS), considering it is particularly vulnerable to xenobiotics.

Some of the alterations observed in the IS include variations in the number and type of leukocytes, resulting in reduced activity to trigger a defence against foreign organisms or removing damaged cells (Banerjee *et al*. 1996). Another possible disturbance is at the level of production of proteins that play an immune function, the most important fraction comprising antibodies (Song *et al*. 2000). The present study aimed to evaluate the effect of Roundup® (RU, glyphosate-based formulation) on some parameters of the IS and growth of *C. latirostris*.

Materials and Methods

Seventy-two 20-day-old caimans from three clutches collected by ProyectoYacaré (Gob. Santa Fe/MUPCN) during ranching activities were used. The animals of each clutch (N= 24) were randomly divided into three different groups: a control group (NC) and two treatments exposed to different concentrations of Roundup® (RU), each one with two replicates of 12 animals. Animals were measured (snout-vent length; SVL) and weighed at the beginning and end of the experiment to determine changes in size in each experimental group (final-initial values).

Exposure was performed during two months in plastic pens, tilted to offer a dry area and the other containing RU water solution. Water renewal was done every three days and RU concentration progressively reduced so that the concentration ranges were: treatment 1 (RU1): 11 mg/l (initial concentration) to 2.6 mg/l (final concentration) and treatment 2 (RU2): 21 mg/l (initial) to 5 mg/l (final), taking into account glyphosate metabolism in water, previously established by HPLC. At the end of the experiment, blood samples were taken from all specimens (Olson *et al*. 1977).

The total leukocyte count was performed in a Neubauer chamber. For the differential white blood cells (WBC) count, two smears were performed per animal, fixed with ethanol, and then stained with May Grunwald (50%) - Giemsa (10%) solutions. We determined the heterophil/lymphocyte index (H/L) as a marker of stress produced by exposure. From each treatment a subgroup of animals were used to determine plasma total protein (TP) and protein electrophoresis (Díaz Portillo *et al*. 1996).

Results

Results showed that total WBC count was lower in the groups of animals exposed to RU. Animals exposed to RU2 had the lowest leukocyte count (20282.61 ± 2302.65 WBC/mm^3), the difference being statistically significant with respect to the NC (29142.87 ± 1882.92 WBC/mm^3, p= 0.011) and to RU1 (28937.50 ± 1949.85 WBC/mm^3, p= 0.01; Fig. 1a). The results showed an increase in the population of heterophils in animals exposed to RU2 (28.24 ± 1.54%) compared with NC (19.46 ± 1.68%, p<0.01; Fig. 1b). In the case of lymphocytes, monocytes and eosinophils no significant differences were observed between experimental groups (p>0.016).

The H/L index showed a significant increase in RU1 (0.47 ± 0.05) and RU2 (0.45 ± 0.03) compared to the NC (0.30 ± 0.03, p<0.016), but no significant difference was observed between RU1 and RU2 (p>0.016; Fig. 1c). The total protein concentration was significantly higher in RU1 compared with NC (p<0.016), but there were no differences between the other groups (p>0.016). The analysis of protein fractions showed a significant difference between groups only in the case of F2 (p<0.05).

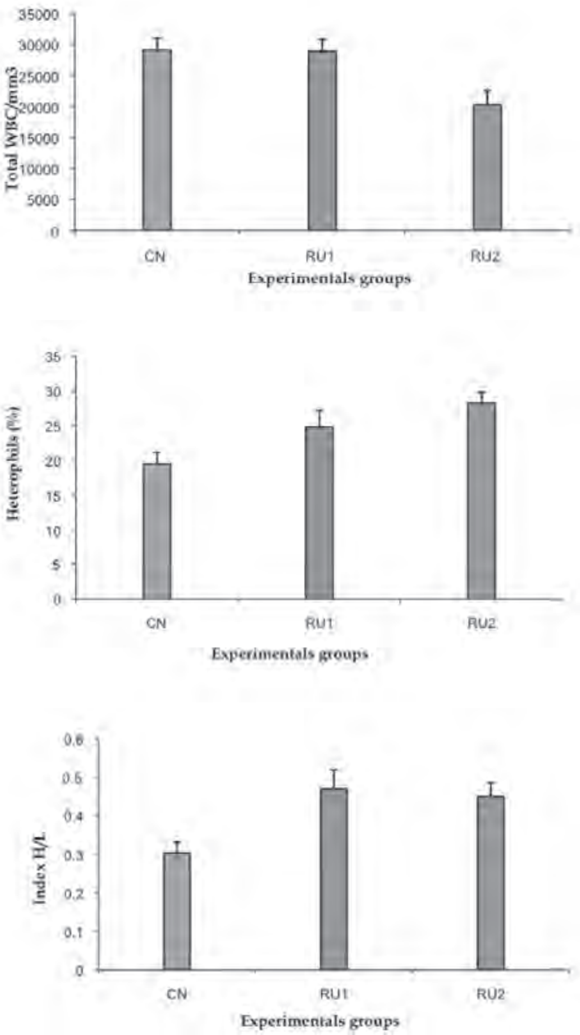


Figure 1. Mean (± standard error) for white blood cell count (top), Heterophile (middle) and heterophil/lymphocyte index (bottom). NC: negative control; RU1 and RU2: groups exposed to different concentrations of Roundup ®. *= statistically significant difference with respect to the NC (ANOVA-Tukey) for WBC and heterophil/lymphocyte index (Kruskal Wallis - Mann Whitney).

Besides, animals exposed to the highest concentration of RU (RU2) reported less growth in SVL and weight (2.80 ± 0.36 cm and 54.13 ± 6.80 g, respectively) than those of the NC (4.17 ± 0.29 cm and 69.44 ± 6.02 g, respectively) and RU1 (4.06 ± 0.19 cm and 82.16 ± 5.11 g, respectively); this difference was significant only in the case of SVL (Fig. 2).

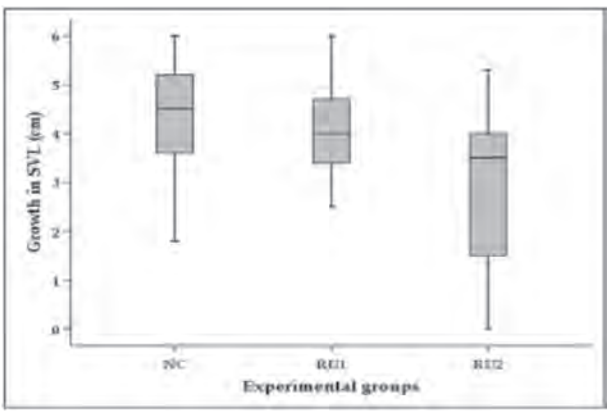


Figure 2. Increase in snout-vent length (SVL) in the different experimental groups.* = statistically significant difference with respect to the NC.

Discussion and Conclusions

Exposure to RU induced a decrease in the total WBC in caimans, with the lowest WBC count at the highest RU concentration (RU2). These values were higher than those found for captive sub-adult *C. latirostris* (Mussart *et al*. 2006; Barboza *et al*. 2008), which could be due to chronic stress state produced by captivity. The percentage of heterophils found in RU2 was higher than those reported by other authors for sub-adults of this species (Mussart *et al*. 2006; Barboza *et al*. 2008). The absolute values of total protein were similar to those reported by other studies (Coppo *et al*. 2006; Barboza *et al*. 2008). In our study, this value was higher in RU1 and analysis of protein fractions showed a significant difference between groups only in the case of F2, the fraction that includes $\alpha 1$ (Alfa-1-antitripsine), which is a component of IS and acts as an acute phase reactant, taking part in inflammatory processes or trauma, and stressful situations (Brandán *et al*. 2008). This means that pesticide exposure would generate a stressful situation, being also evident in the synthesis of proteins, especially those in the F2. The result of SVL and weight showed that exposure to RU has a negative effect on growth of animals, in agreement with previous studies made under in ovoexposure (Poletta *et al*. 2011).

This study indicate that exposure to Roundup® may cause alterations in the parameters of the IS and growth of caimans, so that the ability to respond to infectious agents could be diminished in caimans exposed in natural environments, especially hatchlings, where the IS is still immature. It is important to highlight that this is the first study reporting pesticides effects on the immune system of *C. latirostris*.

Acknowledgements

This study was supported by ProyectoYacaré and Yacarés Santafesinos (Gob. Sta. Fe/MUPCN), and was part of MAL's undergraduate thesis to obtain a Bachelor of Science degree. To Bioq. J.C. Collados, Laboratory of Central Analysis, Immunology Section, Hospital José Maria Cullen.

Literature Cited

Aizen, M., Garibaldi, L.A. and Dondo, M. (2009). Expansión de la soja y diversidad de la agricultura argentina. Ecol. Austral. 19: 45-54.

Banerjee, B.D., Koner, B.C. and Ray, A. (1996). Immunotoxicity of pesticides: perspectives and trends. Indian J. Exp. Biol. 34: 723-733.

Barboza, N.N., Mussart, N.B., Coppo, J.A., Fioranelli, S.A. and Koza, G.A. (2008). El medio interno de *Caiman latirostris* en cautiverio. Influencia del sexo, crecimiento y estación del año. Rev. Vet. 19(1): 33-41.

Brandán, N., Llanos, C., Barrios, M.B., Escalante Marassi, A.P. and Ruíz Díaz, D.A.N. (2008). Apunte de Cátedra de Bioquímica. Facultad de Medicina. Universidad Nacional del Nordeste, pp. 1-5.

Coppo, J.A., Mussart, N.B., Barboza, N.N., Zeinsteger, P.A. and Prado, W.S. (2006). Electrophoretic proteinogram reference intervalo from Argentina northeastern captive caimans (Crocodylia: Alligatoridae). In. Vet. 8: 129-137.

Díaz Portillo, J., Fernández del Barrio, M.T. and Parede Salido, F. (1996). Aspectos básicos de Bioquímica clínica. 1st Edition. Ediciones Díaz de Santos S.A.: Madrid.

Larriera, A., Imhof, A. and Siroski, P. (2008). Estado actual de los programas de conservación y manejo del género *Caiman* en Argentina. Pp. 139-179 *in* Contribución al conocimiento del Género Caiman de Sudamérica, ed. by J. Castroviejo, J. Ayarzaguena and A. Velasco. Public. Asoc. Amigos de Doña Ana 18: Seville, Spain.

Mussart, N.B., Barboza, N.N., Fioranelli, S.A., Koza, G.A., Prado, W.S. and Coppo, J.A. (2006). Age, sex, year season, and handling system modify the leukocytal parameters from captive *Caiman latirostris* and *Caiman yacare* (Crocodylia: Alligatoridae). Rev. Vet. 17(1): 3-10.

Olson, G., Hessler, J. and Faith R. (1977). Techniques for the blood collection and intravascular infusion of reptiles. Laboratory Animal Science 25: 783-786.

Poletta, G.L., Kleinsogre, E., Paonessa, A., Mudry, M.C., Larriera, A. and Siroski, P.A. (2011). Genetic, enzymatic and developmental alterations observed in *Caiman latirostris* exposed *in ovo* to pesticide formulation and mixtures in an experiment simultaing environmental exposure. Ecotoxicol. Environ. Saf. 74(4): 852-859.

Song, W.C., Sarrias, M.R. and Lambris, J.D. (2000). Complement and innate immunity. Immunopharmacol. 49: 187-198.

Philippine Crocodile Attacks on Livestock: Implications for Conservation

Femke Koopmans[1], Merlijn van Weerd[2,3], Dominic Rodriguez[3], Ignas Heitkönig[1], Willem van de Ven[2,3], Marites Gatan Balbas[3], Arnold Macadangdang[3] and Jan van der Ploeg[2,3]

[1] Wageningen University, Droevendaalsesteeg 3a, 6708 PB Wageningen, the Netherlands
[2] Leiden University, PO Box 9518, 2300 RA Leiden, the Netherlands
[3] Mabuwaya Foundation, ISU Garita, Cabagan, 3328 Isabela, Philippines (Mabuwaya@yahoo.com)

Abstract

Human-crocodile conflicts pose a serious threat to the conservation of crocodiles in the wild. This study examines conflicts between people and the critically endangered Philippine Crocodile (*Crocodylus mindorensis*). Interviews were conducted in 2010 to quantify the damage inflicted by Philippine crocodiles in the municipalities of San Mariano and Divilacan on the island of Luzon, Philippines. A total of 112 conflicts were recorded, mostly predation on livestock. These conflicts erode local support for the conservation of the species in the wild. Improving livestock husbandry, for example the construction of pig and chicken pens, offers the best prospects to prevent crocodile predation on livestock in the future.

Introduction

The Philippine Crocodile *Crocodylus mindorensis* is endemic to the Philippines. The species is listed as Critically Endangered on the IUCN Red list (IUCN 2012). The Mabuwaya Foundation aims to conserve the species in the wild with the consent and cooperation of rural communities and local governments in the northern Sierra Madre, northeast Luzon (van Weerd and van der Ploeg 2012). Most conservation efforts focus on the municipality of San Mariano where a remnant Philippine Crocodile population survives in the wild (van der Ploeg *et al*. 2008). In 2009, 50 captive-bred sub-adult Philippine Crocodiles were re-introduced in Dicatian Lake in the Northern Sierra Madre Natural Park (van Weerd *et al*. 2010). As a result of these conservation efforts, the Philippine Crocodile population is slowly recovering in the northern Sierra Madre. But predation on livestock increasingly causes frictions, and might erode local support for the conservation of the species in the wild.

Methods

Data collection

Between August and October 2010 we conducted 71 semi-structured interviews to record the damage inflicted by crocodiles in the Municipalities of San Mariano and Divilacan. Data were collected in all villages in the northern Sierra Madre where crocodiles are known to be present. Respondents were non-randomly selected by the head of the village (barangay captain). This resulted in a list of names of people who had negative experiences with crocodiles. Other respondents were identified using snowball sampling (in which respondents identify other people to be interviewed).

A structured questionnaire was used to gain information about household composition, livelihood strategies, and crocodile-livestock conflicts. In addition we had informal discussions with the respondents in which we focused on what happened, what the respondent did and felt at the time of the conflicting situation and what he/she thought would be an appropriate solution to the problem. Characteristics of the attack (distance to houses, distance to water, victim type, time of day and involved crocodile in terms of size and possible visible tags) were also recorded.

Thirty-five respondents were asked to rank pictures of 8 animal species (including the Philippine Crocodile) which could be potentially harmful to crops and livestock. By ranking pictures of these species, the relative damage caused by crocodiles was compared to other potentially pests.

Data analysis

The variables 'time of day', 'distance to water' and 'distance to house' were divided in classes (night/day, in water/<10 m from water/>10 m from water, <10 m from house/>10 m from house). These variables were tested for differences between observed and expected number of attacks per class using Chi-square tests where the expected number of attacks was equal for each of the classes.

In order to analyze the perceived relative threat of crocodiles compared to other potentially harmful species, each of the species was given a score according to the rank given by the respondents. The rank ranged from 'most harmful' (8 points) to 'least harmful' (1 point). All points were summed for the 35 respondents which resulted in one score for each species. These scores were analyzed using a Chi- square test to test for differences between the observed and expected rank, where the expected rank had equal scores for all species.

The costs associated to crocodile attacks were classified by the respondents: 'none', 'small' or 'big'. These classes were analyzed using a Chi- square test to test for differences between observed and expected classification, where the expected classification had equal scores for each level of financial loss.

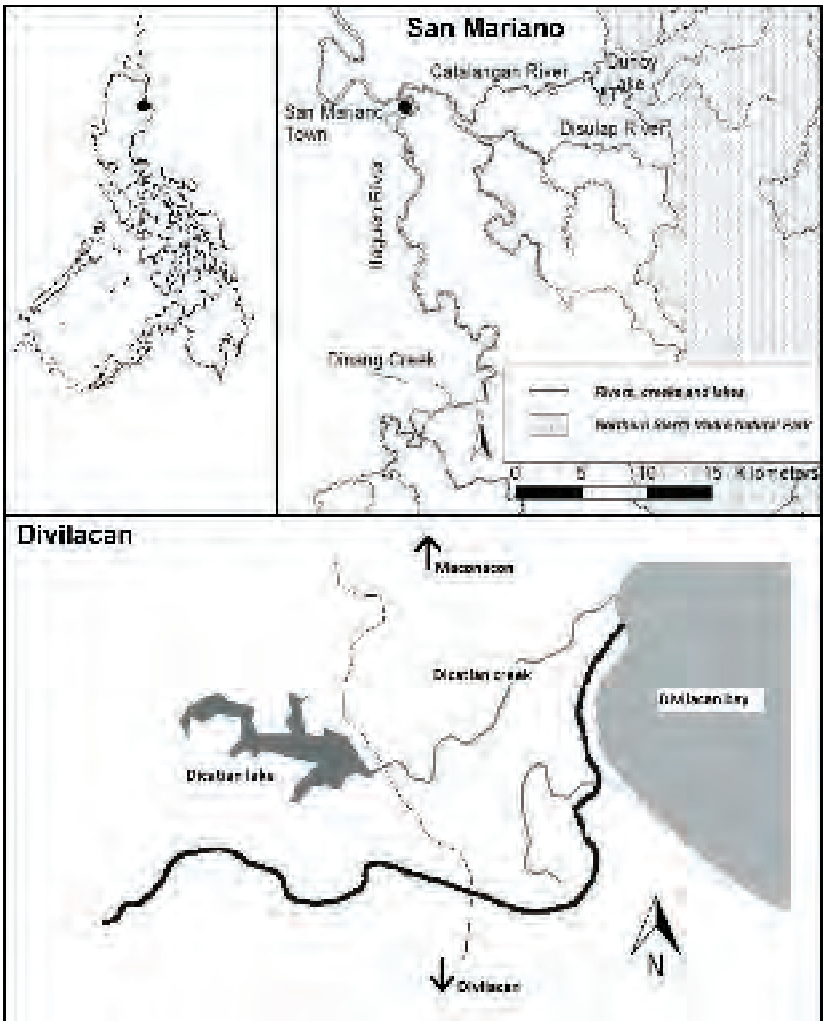


Figure 1. Location of the Municipalities San Mariano and Divilacan, Isabela Province, Luzon, Philippines.

Results

Conflicts

A total of 109 incidents involving predation on livestock or damage to fishnets by crocodiles were recorded, of which 106 took place between 2000 and 2010 (Table 1). The remaining three conflicts happened before that time. It is likely that there were more cases before 2000, but the respondents could no longer remember these. Most livestock predation cases involved chickens and ducks. Dogs and pigs were also attacked by crocodiles (Fig. 2). Fish was taken out of fishponds, and fishing gear (nets, fykes) was damaged (Fig. 3). In 13 incidents it was not clear whether the damage was caused by a crocodile, but respondents suspected that their animal was taken by a crocodile. In 7 cases animals had to be butchered after a crocodile attack. In these cases the owners could still eat or sell the meat and did not suffer direct financial loss (but could no longer generate income from these animals in the future).

Table 1. Philippine Crocodile attacks in San Mariano and Divilacan.

"Victim"	Killed/Destroyed	Injured/Damaged	Lost	Total
Pig	9	9		18
Carabao	1	2	1	4
Chicken	17	1		18
Dog	14	3	4	21
Fighting cock	1			1
Duck	24		4	28
Fishing net	10	3	4	17
Fish pond		2		2
Total	76	20	13	109

Locations and characteristics of crocodile attacks

Table 2 shows that there is a significant difference between the expected and observed number of attacks per class of the recorded characteristics of attacks. Most of the attacks took place at night, usually close to water and far from houses.

Table 2. Characteristics of Philippine Crocodile attacks.

Characteristic	Class	No. of Attacks	Chi-squared	df	P
Time of Day			14.7	1	<0.001
	Day	28			
	Night	65			
Distance to water			6.1	2	<0.05
	In water	47			
	<10 m from water	36			
	>10 m from water	25			
Distance to house			15.4	1	<0.001
	<10 m from house	32			
	>10 m from house	72			

Figure 2. (left) Piglet killed by a Philippine Crocodile in Dinang Creek, San Mariano (Telan 2011); (right) Dog killed by a Philippine Crocodile in San Mariano (Tinhout 2011).

Figure 3. (left) Fisherman shows his net damaged by a Philippine Crocodile (Telan 2011); (right) Fighting cock killed by a Philippine Crocodile in Dicatian (Rodriguez 2010).

Perceptions on possible causes

In the interviews the respondents explained what happened at the time of the attack, and what caused the incidents. Some people assume that crocodiles attack livestock because their natural prey is disappearing. The housing of livestock was often considered inappropriate: pigs often roam around at night and come in contact with crocodiles. According to some respondents in Divilacan, captive-bred crocodiles are less afraid of people and show more aggressive behavior. They suspect that these animals come closer to people and livestock since they are conditioned to be fed.

Costs suffered by people

Table 3 gives an indication of the prices of livestock animals and fishing gear, and the total financial costs of crocodile attacks.

Table 3. Financial costs of Philippine Crocodile attacks. Php= Philippines peso, EU= Euro.

"Victim"	No. Killed/ Destroyed	No. Injured/ Damaged	Price (Php)	Price (EU)	Total Damage (Php)	Total Damage (EU)
Pig	9	9	5000-7000	81-114	45,000-126,000	729-1026
Chicken	18	1	50-120	1-2	900-2280	18-36
Dog	18	3	1000	16	18,000	288
Duck	28	-	50-120	1-2	1400-3360	28-56
Fishing net	10	-	1000	16	18,000	160

The total costs associated to crocodile attacks are generally low, but the loss of livestock or fishing gear can have significant impact on the livelihood of individual households, especially in a remote and poor rural area such as the northern Sierra Madre. About 60 percent of the people in the study area live below the poverty line and have less than 40 pesos (0.73 Euro) to spend per person, per day (NSCB 2012).

For 94 out of the 109 attacks, a cost estimate was given by respondents in terms of big, small or no costs. The loss of ducks and chicken were usually categorized as small financial costs, with the notable exception of a fighting cock (Fig. 4). Loss of larger animals and fishing nets were generally considered big losses.

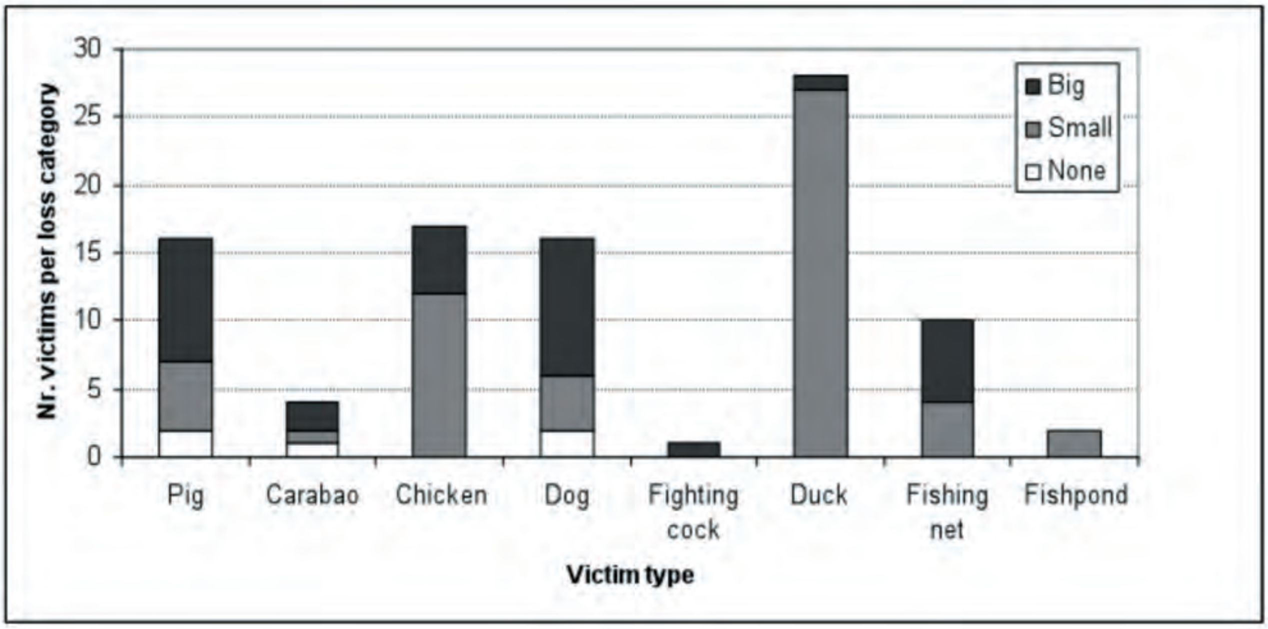


Figure 4. Perceived costs of crocodile attacks by respondents.

Remarkably, crocodiles are not perceived to be the most harmful species to people's income (Fig. 5). Damage to crops and livestock inflicted by brown rats (*Rattus norvegicus*), chestnut munias (*Lonchura malacca*) and Philippine wild pigs (*Sus philippensis*) was considered much worse than damage caused by crocodiles. The invasive cane toad (*Bufo marinus*) was ranked as least harmful to people's livelihood. The rank was significantly different from the expected rank (Chi square= 215.31, df= 7, p<0.001).

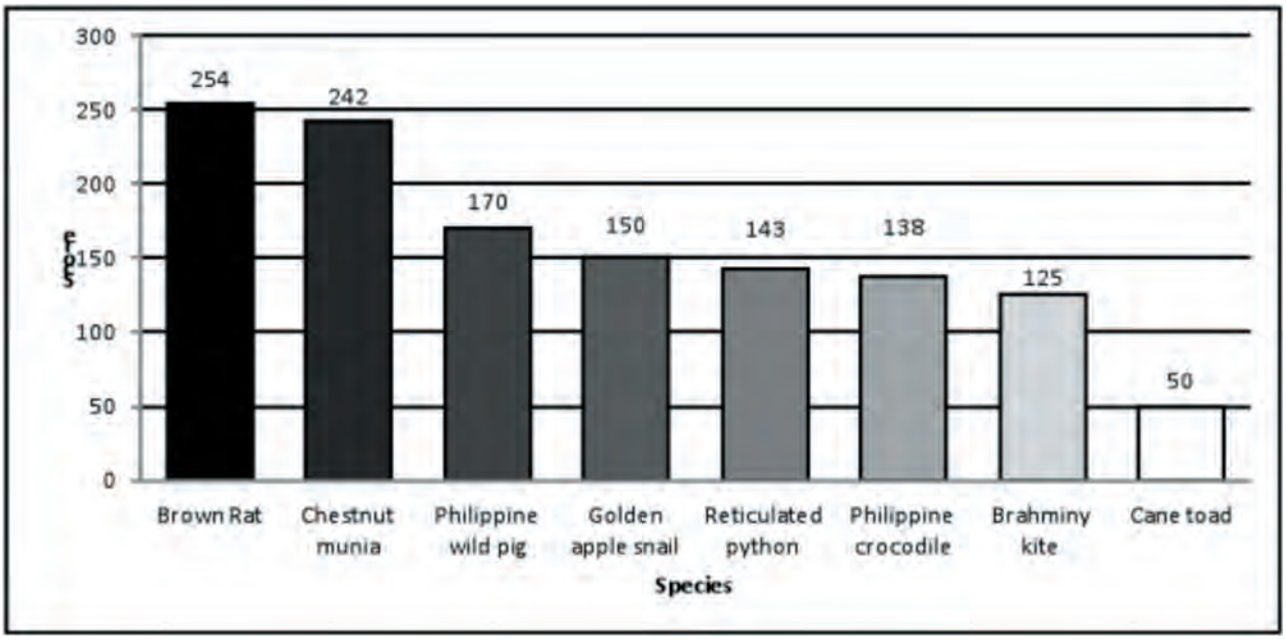


Figure 3. Ranking of harmful species to crops and livestock by respondents.

Solutions

All respondents gave suggestions how to solve livestock-crocodile conflicts. Multiple solutions were mentioned by most people. Placing fences around areas where crocodiles are known to be present was mentioned in 31 interviews, especially by people who live near Dicatian Lake and Dinang Creek where most attacks occured. Other solutions mentioned by the respondents were: financial and material compensation (mentioned 23 times), improvement of livestock housing (mentioned 21 times) and relocation or killing of crocodiles (mentioned 20 times). Financial compensation was mostly mentioned by people with big financial losses. Improved livestock housing was perceived to be a good solution by people who lost livestock to crocodiles.

The extension of buffer zones around rivers and lakes was generally regarded as ineffective. Respondents expressed that they would not like to move their houses or agricultural fields in order to increase space around river banks. Moreover, along Dinang Creek, where a reforestation project has already started, people say that it will take years before the planted trees mature and an actual buffer zone is formed. Some respondents liked the idea of an insurance program but others mentioned that this would be very difficult to accomplish and control.

Discussion

We recorded 112 human-Philippine Crocodile conflicts in the study area. But it can be expected that the actual total number of conflicts is higher. Most attacks on livestock took place at night, in close proximity to water and far from houses. This can be explained by the ecology of crocodiles and the behavior of livestock. Many crocodilian species feed mostly between dusk and dawn and mainly remain in the water during this time (Webb and Manolis 1989; Seebacher 1999). When not tied, pigs search for food and water in the early morning and late evening and ducks sleep in ponds or on river banks and thus become easy prey for crocodiles.

Crocodile abundance, density of natural prey species or vegetation cover might play a more prominent role in the explanation of attacks. Human population density and the associated level of disturbance in the area can be important factors related to vegetation density and thereby to the availability of habitat and natural prey species for crocodiles (Michalski *et al*. 2006). This can for example be the case in Dinang Creek, where the human population is rapidly growing.

Some respondents expressed fear of crocodiles living in their proximity. They are especially concerned about the safety of their children and said that they would kill the animals when their child would get attacked. They were aware of the fact that the killing of crocodiles is prohibited by law, but in such case they would ignore this. Although local people in the study area are afraid and suffered financial costs, only four Philippine Crocodiles have been deliberately killed in San Mariano since 2007. Traditional beliefs and practices determine to a large extend the relatively high level of tolerance towards crocodiles. Indigenous people in the research area revere crocodiles as the reincarnation of their ancestors, and refrain from killing the species (van der Ploeg *et al*. 2011a). Moreover, an intensive communication, education and public awareness campaign has been effective in mobilizing support for Philippine Crocodile conservation (van der Ploeg *et al*. 2011b).

Nonetheless, it is essential to reduce the number of conflicts and to alleviate the associated costs. As mentioned by respondents, the placement of fence lines along specific locations might reduce interaction between livestock and crocodiles. However, such crocodile-proof fences will be expensive and might easily wash away in rainy seasons. Another solution might be the use of compensation schemes. Although this seems an attractive concept, many programs where this was incorporated have difficulties related to claim assessments, long term viability and a lack of funding (Aust *et al*. 2009; Madhusudan 2003). Insurance programs can offer financial help for livestock mortalities to people who have taken the appropriate precautions to protect their livestock from predators (FAO 2009). It might however be difficult to proof attacks and validate claims, and the financial sustainability of such an approach seems problematic.

Improving livestock husbandry offers the best prospects to prevent crocodile predation on pigs, ducks and chicken (Odaga *et al*. 2003). Keeping livestock in proper enclosures has additional advantages, such as reducing crop raiding, preventing theft, providing manure and facilitating the control of diseases.

Conclusions

This study indicates that coexistence between people and the threatened Philippine Crocodile is challenging. Although the damage caused by the species is often much lower than the damage caused by other animals, crocodile predation on livestock needs to be effectively addressed as it erodes local support for the conservation of the species in the wild. Improving livestock husbandry, for example the construction of pig and chicken pens, offers the best prospects to prevent predation on livestock by crocodiles in the future. In areas where people and crocodiles live in close proximity, such as Dinang Creek and Dicatian Lake, additional measures such as fencing might be necessary.

Literature Cited

Aust, P.W. (2009). The Ecology, Conservation and Management of Nile Crocodiles *Crocodylus niloticus* in a Human Dominated Landscape. Ph.D. Thesis, Imperial College London.

Food and Agricultural Organization (FAO) (2009). Human-wildlife conflict in Africa, causes, consequences and management strategies. FAO Forestry Paper 157.

IUCN (2012). IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org.

Madhusudan, M.D. (2003). Living amidst large wildlife: livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. Environmental Management 31(4): 466-475

Meerburg, G.M., Singleton, G.R. and Kijlstra, A. (2009). Rodent-borne diseases and their risks for public health. Critical Reviews in Microbiology 35: 221-270.

Michalski, F., Boulhosa, R.L.P., Faria, A. and Peres, C.A. (2006). Human-wildlife conflicts in a fragmented Amazonian forest landscape: determinants of large felid depredation on livestock. Animal Conservation 9: 179-188.

Ogada, M., Woodroffe, R., Oguge, N. and Frank, G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology 17(6): 1521-1530.

National Statistical Coordination Board (2011). Available at: http://www.nscb.gov.ph/. Accessed May 2012.

Seebacher, F. (1999). Behavioural postures and the rate of body temperature change in wild freshwater crocodiles, *Crocodylus johnstoni*, Physiological and Biochemical Zoology 72(1): 57-63.

Singleton, G.R., Sudarmaji, Tuan, N.P., Sang, N.D., Huan, N.H., Brown, P.R., Jacob, J., Heong, K.L. and Escalada, M.M. (2003). Reduction in chemical use following integrated ecologically-based rodent management. International Rice Research Notes 28: 33-35.

van der Ploeg, J., Rodriquez, D., Tarun, B., Guerero, J., Balbas, M., Telan, S., Masipiqueña, A., Cauilan-Cureg, M. and van Weerd, M. (2008). Crocodile rehabilitation, observance and conservation (CROC) project: the conservation of the critically endangered Philippine crocodile (*Crocodylus mindorensis*) in Northeast Luzon, the Philippines. Final report of the BP Conservation Program Consolidation Award 2005. Mabuwaya Foundation: Cabagan.

van der Ploeg, J., van Weerd, M. and Persoon, G.A. (2011a). A cultural history of crocodiles in the Philippines; towards a new peace pact? Environment and History 17(2): 229-264.

van der Ploeg, J., Cauilan-Cureg, M., van Weerd, M. and de Groot, W.T. (2011b). Assessing the effectiveness of environmental education: mobilizing public support for Philippine crocodile conservation. Conservation Letters 4(4): 313-323.

van Weerd, M. and van der Ploeg J. (2012). The Philippine Crocodile: Ecology, Culture and Conservation. Mabuwaya Foundation: Cabagan.

van Weerd, M., Guerrero, J., Balbas, M.G., Telan, S., van de Ven, W., Rodriquez, D., Masipiqueña, A.B., van der Ploeg, J., Antolin, R., Rebong, G. and de Iongh, H.H. (2010). Reintroduction of captive-bred Philippine crocodiles. Oryx 44 (1): 13.

Webb, G.J.W. and Manolis, S.C. (1989). Australian Crocodiles: A Natural History. New Holland Publishers: Sydney.

Human-Wildlife Conflict: Increasing Understanding Through Satellite Tracking, Education, and Resource Management

Luke Evans[1,2], Mark Rampangajouw[1], Jibius Dausip[3], Silvester Saimin[3] and Benoit Goossens[1,2,3]

[1] Danau Girang Field Centre, c/o Sabah Wildlife Dept., Wisma Muis, 88100, Kota Kinabalu, Sabah, Malaysia
[2] Organisms and Environment Division, School of Biosciences, Cardiff University, Cardiff CF10 3AX, UK
[3] Sabah Wildlife Department, Wisma Muis, 88100 Kota Kinabalu, Sabah, Malaysia

Abstract

Sabah's Saltwater Crocodile (*Crocodylus porosus*) population has begun to recover after hunting was banned in the late 1980s. Consequently, the number of crocodile attacks has increased, especially in areas where the landscape is dominated by palm oil plantations. The primary focus of the project is to assess the medium to long-term movements of large crocodiles in 10 main rivers in Sabah and understand how the introduction of oil palm monoculture could have affected these movements. To date two male crocodiles have been tagged with satellite units. Early results show that, collared in well-forested areas, both individuals have relatively small home ranges and spend large amounts of time in flooded forest. We plan to collar up to 20 crocodiles in both forested and plantation areas. We will also carry out crocodile sampling in the 10 rivers, collecting tissue samples for DNA analysis, in order to ascertain population genetic health and inter-river migration. Finally, we will carry out nesting surveys in two rivers, Kinabatangan and Paitan, to assess how females select their nesting sites in a man-shaped landscape.

Caiman Surveys in Corrientes Province, Argentina

Carlos I. Piña[1,2,3,4], Melina S. Simoncini[1,2], M. Virginia Parachú Marcó[1,2], Thiago C. Portelinha[1,2,3], M. Carla Cundé[1], Rosina Hernández[5], Cesar Leal[6] and Cristina Mora[7]

[1] CIC y TTP-CONICET. Dr. Materi y España, (3105) Diamante, Entre Ríos, Argentina (cidcarlos@infoaire.com.ar)
[2] Proyecto Yacaré - Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC - UNL / MASPyMA) - A. del Valle 8700, Santa Fe, Argentina
[3] Facultad de Ciencias y Tecnología. Universidad Autónoma de Entre Ríos, Argentina
[4] Facultad de Ciencias de la Alimentación, Universidad Nacional de Entre Ríos, Argentina
[5] Maestría en Manejo de Ecosistemas Marinos y Costeros, Universidad Veracruzana, Carretera Tuxpan-Tampico Km. 7.5, Col. Universitaria, C.P. 92860, Tuxpan, Veracruz, México
[6] Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas, Centro Universitario Adolfo López Mateos, Ciudad Victoria, Tamaulipas, México
[7] Cra. 4D # 39-79 Barrio Macarena Alta (Ibagué-Tolima), Colombia

Abstract

In this work we report relative densities (ind./km) of *Caiman latirostris* and *Caiman yacare* in Corrientes Province, Argentina, which is one of the Provinces where there is a ranching program going on. We studied 11 different sites. Four sites where nest harvesting occurs, three sites within Iberá Reserve where management is not allowed, and four places outside the reserve where populations are not yet managed. Since 2008 relative densities were highly variables, except in Yaguareté Corá, Galbán (harvesting), and Empedrado (not managed). The most variable number of caiman observed over time was in La Salada (not managed), Tabé, San Juan Poriahú (Iberá Reserve), and San Martín (managed). In 2009 and 2012 Corrientes had a drought period that increased relative densities. Present results do not indicate any tendency in population due to management, but in those sites where harvesting occurs Class IV (22.3 ± 6.8%), and Class III + IV (63.3 ± 17.6%), represent a higher percentage of animals (excluding Class I) than places where there is not management (Class IV= 2.8 ± 3.3%; Classes III+IV= 44.8 ± 23.9%), actually managed sites and Iberá Reserve sites presented similar values (Class IV= 15.2 ± 11.7%; Class III+IV= 62.3 ± 11.7%). In the managed sites we have found hatchlings indicating that harvesting does not include 100% of the nests.

Soft and Hard-Shelled Eggs of *Caiman latirostris*

Mariela S. Fernández[1], Alejandro Larriera[2,3,4] and Melina S. Simoncini[2,4,*]

[1] INIBIOMA-CONICET, Centro Regional Universitario Bariloche, Quintral 1250, 8400 San Carlos de Bariloche, Río Negro, Argentina
[2] Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUCUNL/MASPyMA), A. del Valle 8700, 3000 Santa Fe, Argentina
[3] Facultad de Humanidades y Ciencias, UNL, Santa Fe, Argentina
[4] CIC y TTP, CONICET, Dr. Materi y España, 3105 Diamante, Entre Ríos, Argentina
[*] Corresponding author: melinasimoncini22@yahoo.com.ar

Abstract

We report the first record of abnormal eggshells (soft-shelled and hard-shelled eggs) in nests of the Broad-snouted caiman (*Caiman latirostris*). These eggs were collected in Santa Fe Province, Argentina, from wild and captive nests. Two types of abnormalities were identified: 1. hard-shelled eggs, among which can be distinguished (1a) eggs exhibiting a wrinkled texture that occurs in circles around one pole and (1b) aggregates of calcitic grains on the eggshell surface; and, 2. soft-shelled eggs. The inner portion of the shell units that comprise the eggshell is interrupted (2), producing gaps that weaken the shell. These soft-shelled eggs lack the hard and continuous shell wall present in normal eggs. Some nests containing recently laid clutches included eggs with most of the eggshell broken and detached from the flexible membrane. In *C. latirostris*, most hard-shelled eggs, those with the granular texture (1b) could be lost during incubation, even dissapear on the end of that process. Therefore, the granular texture presence in earlier stages of development does not directly affect the embryos survival. Soft *C. latirostris* eggs studied here (2), have mean hatching success of 8.9% (range 0% to 38%). Most of the loss of eggs is probably due to infection (fungi and bacteria).

Detectability of *Caiman latirostris* (Crocodylia, Alligatoridae) during Night Count Surveys in Argentina

Thialgo C.G. Portelinha[1,2,3], Luciano M. Verdade[4] and Carlos I. Piña[1,2,3,5]

[1] Centro de Investigaciones Científicas y Transferencia de Tecnología a la Producción (CICyTTP-CONICET), Diamante, Entre Ríos, Argentina
[2] Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASP y MA), Santa Fe, Argentina
[3] Facultad de Ciencias y Tecnología, Universidad Autónoma de Entre Ríos (thiagoportelinha@yahoo.com.br)
[4] Laboratório de Ecologia Isotópica/CENA/Universidade de São Paulo, Piracicaba, Brazil (thiagomq@yahoo.com.br; lmverdade@usp.br)
[5] Facultad de Ciencias de la Alimentación, Universidad Nacional de Entre Ríos, Argentina (cidcarlos@infoaire.com.ar)

Abstract

Night count surveys are one of the most used methods to study distribution and determine some population parameters in crocodilians. However, there are some difficulties and biases during the sampling preventing the sighting of animals submerged or hidden among vegetation. We investigated the proportion of caiman available to be observed during a night count survey based on the positions of 8 adult female *Caiman latirostris* on which we had placed radio-transmitters (VHF, GPS and UHF). Fieldwork was carried out in a protected area with a natural stream and lagoon (30°11'26"S, 61°0'27"W) between January and March 2011. We only considered for analysis locations acquired at night (1800 to 0500 h) and those acquired inside vegetation were considered undetectable. Lagoons with greater availability of vegetation (cattail) can offer refuges and therefore more than 80% (60-100%) of the animals were hidden and not able to be sighted during surveys, on the other hand in the stream 100% of the caiman were located in an area where they could be observed. We did not observe a relationship between female body size and the probability of being sighted. The best time to do a survey appears to be between 2200 h and 0300 h.

Distribution of Tissue Enzymes in *Crocodylus porosus*

Paolo Martelli and Mickey Cheung

Veterinary Department, Ocean Park Hong Kong, Hong Kong

Abstract

In domestic animals changes in serum enzymes are used to diagnose morbid organ changes, including liver, kidneys, muscle, heart. In crocodile medicine there are no studies correlating known diseases or lesions with changes in blood chemistry. For the most part, extrapolation and assumptions replace veracity and certainty. We have measured the concentration of the enzymes AST, ALT, LDH, ALP, CK, GGT and SDH from the fat, muscle, liver, lung, kidney and spleen of 10 apparently healthy, slaughter-size *C. prorosus*, as well as brains from 5 of these. Tissues were homogenized according to the techniques from Deborah *et al*. (2008). This is a starting point for studies wanting to relate blood pictures to actual morbid processes. Two animals in this study (BY27 and S5) were retrospectively found to have unusual distribution of enzyme activity, suggesting morbid process of the lung and liver respectively.

Literature Cited

Deborah, A.F., Mazet, J.A.K., Gulland, F.M.D., Spraker, T.R. and Christopher, M.M. (2008). Distribution of tissue enzymes in three species of pinnipeds. Journal of Zoo and Wildlife Medicine 39(1): 1-5.

Effect of Venipuncture Site on Hematologic and Serum Biochemical Parameters in the Chinese Alligator (*Alligator sinensis*)

Paolo Martelli, Lily Tse and Mickie Cheung

Veterinary Department, Ocean Park Hong Kong, Kong Kong

Abstract

Complete blood count and serum chemistry are commonly used to assess health status and clinical response. References values and validity, sensitivity or specificity of the various blood parameters have not been established in crocodilians. Blood values are affected by a number of extrinsic factors such as temperature, season, husbandry and, relevant to this study, venipuncture site. Understanding the effect of venipuncture site allows better interpretations of blood results. Blood is typically obtained from the tail (ventral coccygean vein) and the neck (supravertebral vein). In this study we also included a third site discovered by the author, and as yet unpublished, the mandibular shelf.

Delayed Hatching Moment on *Caiman latirostris* Under Experimental Conditions

Hernán Ciocan, Alba Imhof and Alejandro Larriera

Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUCUNL/MASPyMA), A. del Valle 8700, Santa Fe, Argentina (hernanciocan@hotmail.com)

Abstract

The incubation period and its conditions are relevant issues to consider on the planning of the sustainable use programs based on the ranching technique, so to be able to manage the hatch moment of the hatchlings could be a valuable tool. The aim of this study was to evaluate the effect of low temperature during a part of the incubation period as a hatching delay factor. We utilized three nests of *Caiman latirostris* with known date of lay (102 eggs in total). Eggs were randomly distributed in two treatments: A) full incubation at standard conditions (30°C ± 1°C.); and, B) after a period of 8 weeks at standard incubation conditions, eggs were placed at 20°C (± 0.5°C) for a period of 15 to 20 days, and after this they were placed back to the standard incubator to complete development. The delay in incubation period was on average 22.5 days. Significant differences were found with respect to size of hatchlings from the two treatments. Despite the fact that hatchlings from both treatments showed excellent body conditions, the hatching success for treatment A was 54.1% (± 15.7%) and for treatment B it was 89.2% (± 4.15%).

Usefulness of Homemade Camera Traps for Recording Activity Patterns in *Caiman latirostris* Nesting Areas

Leonardo Adrián Leiva, Patricia Leonor Bierig, Alba Imhof and Alejandro Larriera

Proyecto Yacaré, Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUCUNL/MASPyMA), A. del Valle 8700, Santa Fe, Argentina (leoleiva1811@hotmail.com)

Abstract

Camera traps are a useful tool for a variety of natural history and biology research lines, and one of the very few techniques that allow recording an activity pattern on many species. The aim of this study was to evaluate the effectiveness of homemade camera traps model, weight-activated on the surroundings of *Caiman latirostris* nests. The equipment is based on an electro mechanic activation system consistent in two sets, one of a camera and shooter, and the other one of an interrupter together with a retarder (0 to 4 minutes), with a sensitivity of about 300 g. Two traps were located on the nesting area at the Experimental Breeding Station "Granja La Esmeralda" in Santa Fe, Argentina, and were leaved activated during 10 days in December, 24 hours per day. We obtained 83 *C. latirostris* photos in that period. The breeders showed an intense activity around the nesting areas between 1100 and 0500 h, with two peaks, one at 1500-1600 h and the other at 2000-2100 h. No activity was registered between 0500 and 1100 h.

Status and Conservation of the American Crocodile in Jamaica

Frank J. Mazzotti[1], Byron Wilson[2], Michael S. Cherkiss[3], Jeff Beauchamp[1,3], Joseph Wasilewski[4] and Brian M. Jeffery[1]

[1] University of Florida, 3205 College Ave., Davie, FL 33314, USA (fjma@ufl.edu)
[2] University of West Indies, Mona, Kingston 7, Jamaica (byron.wilson@uwimona.edu.jm)
[3] United States Geological Survey, 3205 College Ave., Davie, FL 33314, USA (mcherkiss@usgs.gov)
[4] Jadora, Natural Selections of South FL, 24305 SW 142nd Ave., Princeton, FL 33023, USA (jawnatsel@bellsouth.net)

Abstract

American Crocodiles are concentrated on the southern coast of Jamaica and present on the northern coast as individual sightings and at least one small breeding population. Presence of crocodiles on the northern coast has been facilitated by translocation of crocodiles to provide viewing opportunities for tourists. The American Crocodile in Jamaica inhabits a wide variety of natural and man-made wetland habitats, but is particularly fond of brackish water coastal wetlands including estuarine sections of rivers, coastal lagoons, ponds, and mangrove swamps. Man-made habitats include aquaculture ponds, water and sewage treatment ponds, and canals. Threats to the American Crocodile include habitat loss and increased persecution by humans and the situation appears dire. The solution to the conservation of crocodiles in Jamaica is the initiation of a systematic countrywide survey of crocodiles and their habitat, protection of existing habitat, development of a public education program and enforcement of the Wild Life Protection Act to protect against increasing human hunting pressure.

History

The Jamaican Coat of Arms was granted to Jamaica in 1661 under Royal Warrant. Designed by William Sancroft, then Archbishop of Canterbury, the Coat of Arms shows a male and female member of the Taino tribe standing on either side of a shield which bears a red cross with five golden pineapples. The Crest of the Coat of Arms is a Jamaican crocodile above a royal helmet. Taino Indians represented the original inhabitants of Jamaica, the pineapples and crocodile symbolized indigenous flora and fauna. The reverence for crocodiles expressed by placing them atop the Crest of the Coat of Arms did not appear in early writings about crocodiles in Jamaica.

Early accounts of the American Crocodile (*Crocodylus acutus*) provide little detailed information on their status or ecology but consistently indicated that crocodiles were abundant, if not too abundant. Hickeringhill (1661) described crocodiles as being "in Jamaica too great aplenty" and in 1740 Charles Leslie in his "New History of Jamaica" described crocodiles as being "terrible creatures" common in rivers and ponds where they "breed like toads" (Leslie 1740). Phillippo (1843) also observed that crocodiles were numerous and he mentions that they were found on the southern coast, an observation repeated by Caine (1908). Phillippo (1943) also provides the only mention of crocodile nesting by describing clutch sizes of 30-40 eggs. Additionally, Barbour (1910) notes that crocodile specimens "hideously stuffed" could be found in the tourist shops in Kingston and according to the local people crocodiles were abundant in some rivers flowing to the South and East.

Until the early 1960s crocodiles were considered plentiful in Jamaica (Garrick 1982). During the 1950s and 1960s there was considerable hunting for recreation and perhaps more importantly, for hides (C. Moody, pers. comm.). In addition, hundreds of crocodiles were removed from Jamaica during the 1960s, destined for commercial exhibits, primarily in the United States (Garrick 1982). By 1970 the number of crocodiles in Jamaica had dwindled to a level considered to threaten survival of the species, and by 1971, the species was added to the Third Schedule of the *Wild Life Protection Act of Jamaica*. The Third Schedule lists animals that are endangered and need protection for continued survival. Under Section 6 of the *Wild Life Protection Act*, it is an offence for anyone to kill or have in their possession the whole or any part of a crocodile, living or dead. The *Wild Life Protection Act* does not protect habitat and did not have any enforcement provisions. Removal of crocodiles continued, then in 1975 the American Crocodile was listed under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and in the Protocol on Specially Protected Areas and Wildlife (SPAW). Species listed under Appendix I of CITES are subject to restrictions on international trade. Also in 1975 the United States declared the American Crocodile an endangered species throughout its range (USFWS 1975). By the end of the 1970s, public attention and a lack of an international market effectively brought an end to exploitation and export of crocodiles from Jamaica; but not an end to problems for crocodiles in Jamaica.

Status and Ecology

In "The Herpetology of Jamaica" Lynn and Grant (1940) noted that distribution of American Crocodiles in Jamaica was limited to the southern coast and emphasized their absence from the northern coast. Today, crocodiles are concentrated on the southern coast of Jamaica and present on the northern coast as individual sightings and at least one small breeding population. Presence of crocodiles on the northern coast has been facilitated by translocation of crocodiles to provide viewing opportunities for tourists. For example, a small breeding population near Falmouth, Trelawny Parish, escaped from an adjacent commercial exhibit.

Jamaica is a small island, about the same size as the historical Everglades (11,000 km^2). Only a small portion of the island provides habitat for crocodiles. The American Crocodile in Jamaica inhabits a wide variety of natural and manmade wetland habitats, but is particularly fond of brackish water coastal wetlands, including estuarine sections of rivers, coastal lagoons, ponds, and mangrove swamps. Although it is principally a coastal species, the American Crocodile is ecologically adaptable and is known to extend its distribution inland, especially along rivers and their associated wetlands habitat such as those found in the Black River Morass. Man-made habitats include aquaculture ponds, water and sewage treatment ponds, and canals and ponds in residential areas. American Crocodiles are proof of the concept that if you create their habitat, they will occupy it (Mazzotti *et al*. 2007).

Most of Jamaica's principal wetlands are distributed in patches along the coast (Table 1, Fig. 1) and offer potential crocodile habitat ranging from mangroves to brackish water lagoons and estuarine sections of rivers. Crocodiles are also known to inhabit three freshwater marsh ("morass") habitats. However, these areas are relatively small; the largest, Black River Lower Morass, is approximately 6000 ha and is the one best known for containing crocodiles (Garrick 1982, 1986).

Figure 1. Map of Jamaica showing locations important to crocodiles.

Table 1. Major wetlands of Jamaica (source: Natural Resources Conservation Authority).

Location	Parish	Size (ha)	Description
Black River Lower Morass	St. Elizabeth	6000	Riverine/Estuarine; Marsh with Swamp, Forest & Mangrove
Negril Geat Morass	Hanover	2400	Estuarine; Marsh and Swamp Forest
Cabarita Swamp	St. Catherine	1600	Marine/Estuarine; Mangrove
The Great Morass	St. Thomas	1600	Marine; Mangrove
West Harbour	Clarendon	1600	Marine; Mangrove
Canoe Valley	Manchester	1200	Riverine/Estuarine; Marsh with Swamp, Forest & Mangrove
Falmouth and Saltmarsh	Trelawny	1070	Marine/Estuarine; Mangrove & Marsh
Amity Hall	St. Catherine	480	Marine; Mangrove
Great Salt Pond	St. Catherine	448	Marine/Estuarine; Mangrove
Manatee Bay	St. Catherine	370	Marine; Mangrove and Marsh
Luana Point, Fonthill	St. Elizabeth	400	Marine; Mangrove; Ponds
Carita	Westmoreland	240	Estuarine; Mangrove and Marsh
Kingston Harbor	Kingston & St. Andrew	200	Marine/Estuarine; Mangrove
Cockpit-Salt River	Clarendon	160	Riverine/Marine; Marsh and Mangrove
Cow Bay	St. Thomas	146	Estuarine; Marsh
Mason River	Clarendon	80	Palustrine; Marsh
Peartree Bottom	St. Ann	80	Riverine; Marsh

Supported by the Wildlife Conservation Society (WCS), Les Garrick conducted the most systematic study of crocodiles in Jamaica between 1975 and 1983. He was guided on many of his crocodile surveys by Mr. J. Charles Swaby, who has long been recognized as an expert on crocodiles in Jamaica. Other investigators visited Jamaica in the 1980s. However, other than brief observations of crocodile behavior and population structure, a general description of distribution of crocodiles (and nests), and importance of specific habitats for their conservation in Jamaica (Garrick 1982, 1986), little information is available on ecology of crocodiles in Jamaica.

By the end of the 1990s increased interactions between crocodiles and humans prompted the Natural Resources Conservation Authority (NRCA; now the National Environmental and Planning Agency, NEPA) to request assistance from the Crocodile Specialist Group (CSG). In 1995, 1997 and 2001, charrettes, field trips and training workshop sponsored by the NRCA

(NEPA), WCS, National Geographic, University of Florida and CSG, were conducted in Jamaica with diverse stakeholders to identify potential habitats for crocodiles, to summarize knowledge of occurrence of crocodiles and to provide training to government biologists in proper survey and capture techniques. WCS returned to Jamaica in 2001 when Dr. John Thorbjarnarson traveled to Jamaica at the invitation of Mr. Swaby. Mr. Swaby provided updated information on locations of crocodiles in Jamaica and guided Dr. Thorbjarnarson on field trips around St. Elizabeth Parish (Thorbjarnarson 2001). Results of these field trips and charrettes have never been published, but are summarized here and synthesized with observations of Les Garrick.

An immediate caveat is that these are impressions about distribution and abundance of crocodiles in Jamaica and are not based upon systematic surveys. However individuals involved in charrettes were recognized as experts on crocodiles in Jamaica. There was a strong consensus among experts at a charrette and a remarkable consistency in descriptions of distribution and abundance among different sources and over time.

A clear finding of all observations, charrettes, and field trips was that coastal wetland habitats along the southern coast are still the main locations for crocodiles in Jamaica. This supports Lynn and Grant's (1940) observation that American Crocodiles in Jamaica were distributed along the southern coast and absent from the northern coast. Today, exceptions include a mangrove wetland in Falmouth, Trelawny Parish (Fig. 1, Table 1), where a small population of crocodiles has become established adjacent to a commercial exhibit. Escaped crocodiles took up residence in the adjacent mangrove swamp and eventually began nesting on berms of a canal along the small swamp. The combination of human-aided movement to the north coast for a tourist attraction and creation of nesting habitat provided this new location for crocodiles in Jamaica.

Crocodiles are also occasionally observed on either end of the north coast near Port Antonio, Portland Parish; and Lucea, Hanover Parish (Fig. 1, Table 1). Whether those crocodiles were displaced by humans or dispersed naturally from source populations is not known. Permanent populations of crocodiles are found in the morasses on the east coast (Point Morant, Holland Bay, The Great Morass) and west coast (Negril Point, Negril Great Morass, Negril River). The impression from charrettes and field trips is that crocodiles are not uncommon in these areas but are in low density. The same description, that crocodiles are sighted frequently but not abundantly, characterizes most wetlands along the southern coast of Jamaica in St. Thomas, St. Andrew, and Westmoreland parishes. The main concentration of crocodiles in Jamaica is in the coastal wetlands in St. Catherine, Clarendon, Manchester, and St. Elizabeth Parishes. This core crocodile area extends from the Greater Portmore region near Kingston (Fig. 1) west to Luana Point/Fonthill, just west of Black River and includes Portland Bight, Canoe Valley, Black River and associated rivers and wetlands (Table 1). Locations within this area were described as containing a range of crocodile abundances, from small groups, to high density, to "crocodile country." One set of spotlight surveys in the Greater Portmore area in 2002 conducted by NRCA and University of Florida biologists resulted in sightings of 42 crocodiles (22 adults, 12 juvenile/sub-adults, 1 hatchling, and 7 unknown sizes) in 3 nights of surveys. This supports the impression that there were areas along the southern coast where crocodiles were common 10 years ago, although there is substantial evidence that the recent increase in crocodile consumption is potentially having catastrophic effects on population numbers.

Table 2. Location of known nesting areas of American Crocodiles in Jamaica. UWI= University of West Indies; SCS= South Coast Safaris; SCCF= South Coast Conservation Foundation.

Location	Parish	Notes (Sources)
Hellshire Hills	St. Catherine	3-4 nests were successful in 2008; Byron Wilson, UWI
Cockpit River	Clarendon	Nest adjacent to road; Charles Swaby, SCS
Portland Bight	Clarendon	2 nests with hatched shells were found in 1997; Brandon Hay, SCCF
Portland Point	Clarendon	Nesting Beach; Charles Swaby, SCS
Milk River	Clarendon	Nest on riverbank; Charles Swaby, SCS Les Garrick
Canoe Valley	Manchester	No specific Location; Les Garrick
Swift River/Three Rivers	Manchester	Possible nest in marsh; Charles Swaby, SCS
Calabash Bay	St. Elizabeth	Nesting Beach; Charles Swaby, SCS
Parotee Ponds	St. Elizabeth	Nesting Beach; Charles Swaby, SCS Les Garrick
Font Hill/Luana Point	St. Elizabeth	Nesting Beauch, "best nesting population"; Charles Swaby, SCS, Les Garrick

The south coast core crocodile area is also where nesting of crocodiles has been reported (Table 2). In addition to these confirmed records, there are anecdotal reports of crocodile nests in artificial habitats along the southern coast such as water and sewage treatment ponds, fish ponds, and canals. However, other than the fact that some nests occur in these manmade habitats, nothing is known about their location, number, or fate. In other locations such as southern Florida, nests on artificial substrates have to some extent compensated for nests lost to development of coastal habitat (Mazzotti *et al*. 2007).

Garrick (1982) described natural nest sites as either mounds on beaches or holes along elevated portions of riverbanks, similar to descriptions of nests in Florida (Mazzotti 1989). He commented that the maximum hatched clutch size (number of hatchlings caught adjacent to a hatched nest) was 30 but did not provide a sample size. He estimated size at first reproduction to be 2.2 m (7.3'), at 9 years of age.

Garrick (1982) also observed size-specific habitat use by crocodiles. Hatchling crocodiles near nest sites were found in shallow brackish ponds, or narrow creeks, similar to crocodiles in Florida (Mazzotti 1983). However, Garrick (1982) reported that, unlike in Florida, adult female crocodiles remained in the same ponds with hatchlings up to one month after hatching. After two months hatchling crocodiles dispersed to more open-water areas, remaining in the same general area for up to one year. Garrick described 2- and 3-year-old animals as dispersing farther away but also mentions that they are underrepresented in his samples, indicating that juveniles were in inaccessible habitats, had dispersed, or died. Of hatchling crocodiles tagged in Milk River in 1981-1982 Garrick found 46% alive after 2 months, 24% after 10 months, and 8.9% after 14 months. No sample sizes were given. He recognized that this was an underestimate of actual survival. This falls within the range of 12-month hatchling survival found in Florida (Mazzotti *et al*. 2007).

Garrick (1982, 1986) found that habitat loss (as a result of agriculture, aquaculture, peat mining, and pollution) and killing of crocodiles (mainly a result of uncontrolled fishing practices) were major threats to their conservation in Jamaica. More recently, habitat loss (exacerbated by development of nesting beaches and nursery habitat for touristic and residential projects) continues to diminish and fragment habitat, while killing of crocodiles as a result of persecution, and illegal harvesting for meat, both appear to be on the increase (Harrison 2010; Kelly 2006; Ritch 2006).

Conservation

Issues

Based on the above synthesis, it appears that in spite of decades of habitat loss and illegal removal and killing, crocodiles remain relatively widespread in Jamaica. However, while they are found in a variety of coastal habitats, populations appear small and there is little information on current status of crocodile populations.

Worldwide, the greatest problem facing crocodiles, and all wetland fauna, is loss of habitat, and Jamaica is no exception. Loss and fragmentation of coastal wetlands have been extensive in Jamaica, and are increasing as the country's population grows and people move farther into coastal areas. Major threats to these ecosystems identified by the NEPA include cutting, dredging and filling of mangrove habitats and other coastal wetlands as a result of urbanization and tourism-related development, agriculture, and fish farming. Other threats include pollution, and altered hydrology or soil salinity as a result of stream diversion or irrigation. Development of coastal beaches for resorts threatens critical nesting sites used by crocodiles (Ritch 2007). In many areas, natural habitat is being replaced by artificial wetlands such as canals or fish ponds, which when used by crocodiles can lead to conflicts with local people. This problem is compounded in Jamaica by the tendency of people to unwittingly provide food for crocodiles by throwing small fish or entrails into the water, by dumping dead dogs into mangrove ponds, or simply by creating garbage dumps along coastal wetlands. Under these conditions, adaptable crocodiles find food readily available in areas close to human habitation.

Conflicts between people and crocodiles in Jamaica arise as a result of destruction of the crocodile's natural habitat and the ability of American crocodiles to thrive in disturbed habitats close to people. American crocodiles are not considered to be a very aggressive species. Unlike Nile Crocodiles (*C. niloticus*) in Africa or Saltwater Crocodiles (*C. porosus*) in Asia and Australia, American Crocodiles do not regularly consider humans as food. They are potentially dangerous principally by virtue of their size in areas where people and crocodiles are not suitably buffered from one another. Over the last few decades, attacks on people have been rare but have occurred in Jamaica (eg Williams 2010).

Recently, a new threat to *C. acutus* in Jamaica has emerged - the increased killing of crocodiles for meat and the growing belief amongst Jamaicans that consuming crocodiles will lead to enhanced male sexual performance ('strong back'). This myth, perhaps precipitated by the influence of recent Asian immigrants (primarily Chinese), is creating a new market demand and by some accounts is driving up the price of crocodile meat (Harrison 2010; Wilson 2011). Unfortunately, this latest threat has not been effectively managed, and the illegal harvesting of crocodile meat continues to increase.

Recommendations

Efforts to protect the American Crocodile and other coastal wildlife in Jamaica would be most effective if done within the context of an overall coastal management plan that includes setting aside critical habitats as protected areas. Nevertheless, specific measures should be taken to address issues unique to crocodiles.

Management objectives for American Crocodiles in Jamaica should include ensuring survival of viable populations, reducing potential for conflict between crocodiles and people, public education, and developing programs whereby local communities can benefit from the presence of crocodiles. There are a number of actions that could be taken to attain these objectives; several are briefly discussed below.

Crocodile Surveys

The development of a crocodile management program in Jamaica requires an understanding of several key factors, including the present status and distribution of crocodiles, crocodile habitat, and the nature of crocodile-human conflicts. A survey of human-crocodile conflicts and attitudes of humans towards crocodiles would be helpful in developing educational campaigns and problem crocodile programs. A prerequisite for preparation of any management plan should be crocodile surveys to collect baseline data.

Crocodile surveys are typically based on indices of population size such as spotlight counts or nest counts. Both of these methods could be effectively employed in Jamaica as part of an initial effort to assess current status of crocodile populations. These surveys would provide a basis for long-term monitoring and could aid in obtaining future CITES approval to export crocodile products as part of an overall management plan. In addition to information on status and distribution of crocodile populations, it will be important to collect habitat data. Some of the most important factors that should be considered are the size and quality of habitat, land tenure and land use, and presence of other wildlife. An efficient way to merge all this information and make proper use of it for crocodile management purposes would be through the development of a geographic information system (GIS).

Provide Secure Habitat

Providing secure habitat for crocodiles would help meet two management objectives: securing crocodile populations and reducing conflicts with humans. Habitat loss and the resulting movement of crocodiles into areas of human occupation is one of the factors contributing to conflicts (Jamaica Information Service 2004). The long-term survival of crocodiles will require protection of critical habitats such as mangroves, freshwater wetlands, and nesting beaches. Many other species of wildlife, and many human activities, depend on the existence of healthy coastal wetlands. In this regard the crocodile could be used as a "flagship" species for the identification and protection of the most important of these natural wetland systems.

Public Education

Conflicts between people and crocodiles arise in part because of widespread misunderstandings about these large reptiles and the failure of people to take common-sense measures to reduce the potential for attacks. A public education campaign is needed to highlight the usually non-aggressive nature of the crocodile, and ways to avoid risky activity and inadvertent feeding of crocodiles (ie proper disposal of dead animals and fish). Similar efforts have had remarkable success in countries like Australia where crocodile attacks are a significant issue. Additionally, given the recent dramatic increase in consumption of crocodile meat, any public education campaign should expose the fallacy of the 'strong back' myth.

Problem Crocodile Program

No measures will completely eliminate conflicts between people and crocodiles. A transparent, government-managed (operated or regulated) program will need to be defined to deal with crocodiles that show up in inappropriate areas. A number of models for dealing with problem crocodiles could be used including examples from Australia, Florida (USA) and Mexico.

Crocodile Use Programs

Crocodiles can provide benefits for neighboring human communities. Worldwide, consumptive "ranching" programs based on the collection of eggs or hatchlings provide economic rewards through the sale of skins or meat. These types of programs must ensure that the harvest is sustainable and follow management guidelines that are enforceable. The non-consumptive use of crocodiles through ecotourism is also becoming a popular way for crocodiles to "pay their way" and benefit local communities. In fact, a booming business has developed in the Black River area of Jamaica based on river tours where crocodiles are the principal attraction.

Prognosis

Crocodiles occur in most locations in Jamaica where there is habitat to support them. Crocodiles are common enough to cause concern over an apparent increase in human-crocodile conflicts (Jamaica Information Service 2004) and support an ecotourism operation in the Black River Lower Morass. That crocodiles remain widespread in Jamaica, even with continued habitat loss and killing, is remarkable and evidence of their ability to survive in a human-dominated landscape in a mosaic of natural and artificial habitats. This is a demonstration of their basically secretive, non-aggressive, adaptable nature.

There is a new aspect to loss of crocodile habitat that may accelerate problems for crocodiles. Compared to the northern coast of Jamaica, the southern coast has remained relatively undeveloped in terms of resorts and residential development. However, the past decade has seen more rapid growth in both resorts and residential communities. Resorts tend to be built on nesting beaches and in adjacent nursery habitat. Development of residential communities and roads on beaches (eg Parotee Beach near Black River) can destroy nesting habitat and sever connections to interior nursery habitats (Fig. 2). Development of crocodile nesting beaches displaces crocodiles, causing an increase in interactions with humans in adjacent areas (Ritch 2007). Crocodile-human interactions further increase as a result of residential development in and adjacent to coastal wetlands that creates new crocodile habitats such as canals and ponds (Fig. 3). Such is the case in Greater Portmore, St. Catherine Parish, where crocodiles are now nesting near sewage ponds and causing concern in nearby neighborhoods (Mundle 2009).

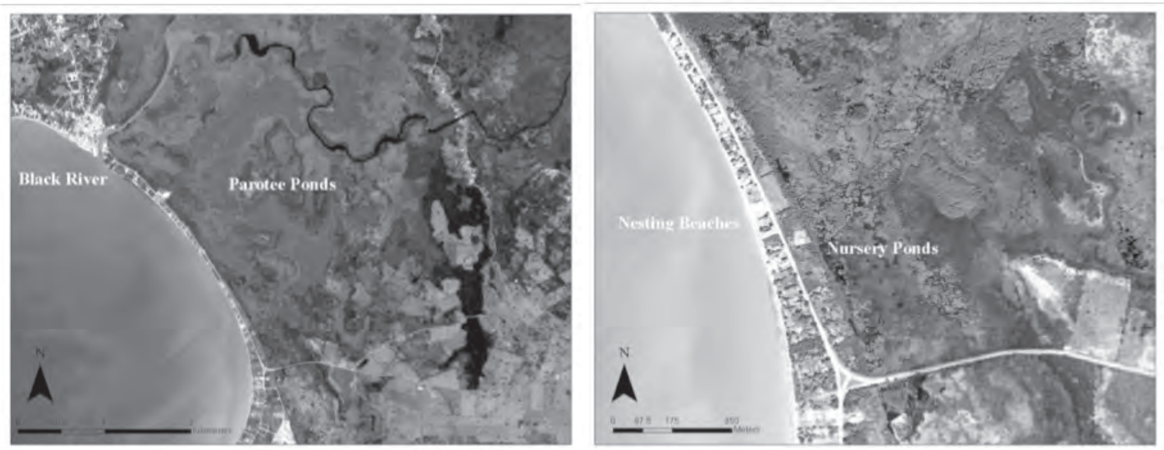


Figure 2. Development of crocodile nesting beach near the Parotee Ponds. Wider view (left) shows relation of nesting beach to ponds and Black River. Close up view (right) shows separation of nesting beach and nursery ponds by the road to Treasure Beach.

The solution for conservation of crocodiles in Jamaica, which will maximize options for dealing with problem crocodiles, earning foreign exchange, and increasing community participation in crocodile conservation, is the same as that recommended by Garrick (1982): protect core areas for crocodiles from further loss and degradation, and protect crocodiles from hunting by enforcing the *Wild Life Protection Act*. A very high priority should be placed on a countrywide survey of crocodiles and their habitat. A combination of habitat protection and increased knowledge of crocodiles could provide the basis for economically sustainable conservation of crocodiles in Jamaica.

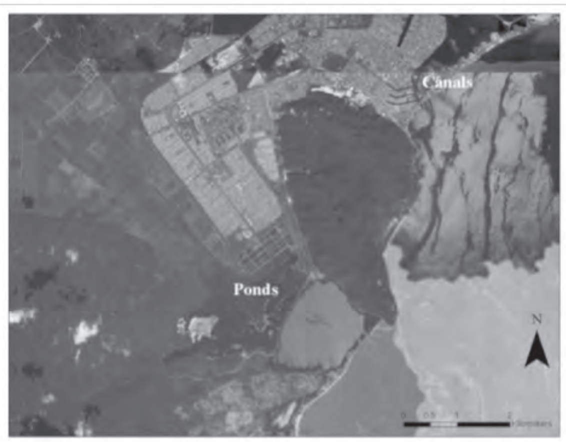


Figure 3. Greater Portmore area showing juxtaposition of residential development and coastal wetlands southwest of Kingston, Jamaica. Canals and ponds create habitat for crocodiles in proximity to people.

Literature Cited

Barbour, T. (1910). *Crocodilus americanus* Laur. Notes on the Herpetology of Jamaica. Bull. Mus. Comp. Anat. 52: 301.

Caine, W.R.H. (1908). The Cruise of the Port Kingston. Collier & Co.: London.

Garrick, L.D. (1983). Ecology of the American Crocodile in Jamaica. A research report submitted to Conservation Committee, The New York Zoological Society.

Garrick, L.D. (1986). The Black River Lower Morass: a threatened wetland in Jamaica. Oryx 20: 155-160.

Harrison, C. (2010). Jamaicans chew into croc tail: curried, jerked, or barbecued reptile meat is popular. The Jamaica Online Star, 23 September 2010 (http://jamaica-star.com/thestar/20100923/news/news1.html).

Hickeringill, E. (1661). Jamaica viewed: with all the ports, harbours, and their several soundings, towns, and settlements thereunto belonging together, with the nature of it's climate, fruitfulnesse of the soile, and its suitableness to English complexions. With several other collateral observations and reflexions upon the island. The second edition. London: Printed for Iohn Williams, at the Crown in St. Paul's Church-yard.

Jamaica Information Service (2004). Crocodile survey currently underway. www.jis.gov.jm/news/103-agriculture-fisheries/2492-land_environment-crocodile-survey-currently-underway.

Kelly, D. (2006). The American crocodile, *Crocodylus acutus*, in Jamaica. Jamaica Clearing-House Mechanism, The Institute of Jamaica.

Leslie, C. (1740). A new History of Jamaica: from the earliest accounts to the taking of Porto Bello by Vice Admiral Vernon. In Thirteen letters from a gentleman to his friend... In which are briefly interspersed the characters of its Governors and Lieutenant-Governors..with tow maps, one of that island and the other of the circumjacent islands, and territories belonging to France, Spain, &c. 2nd Edition. J. Hodges: London.

Lynn, W.G. and Grant, C. (1940). The herpetology of Jamaica. Bulletin of the Institute of Jamaica. Science Series, No 1.

Mazzotti, F.J. (1983). The Ecology of the American Crocodile in Florida. PhD thesis, Pennsylvania State University, University Park, Pennsylvania, USA.

Mazzotti, F.J. (1989). Factors affecting the nesting success of the American crocodile, *Crocodylus acutus*, in Florida Bay. Bull. Mar. Sci. 44: 220-228.

Mazzotti, F.J., Brandt, L.A., Moler, P.E. and Cherkiss, M.S. (2007). American crocodile (*Crocodylus acutus*) in Florida: recommendations for endangered species recovery and ecosystem restoration. J. Herpetol. 41: 122-132.

Mundle, T. (2009). Crocodile scare in Greater Portmore. The Jamaica Observer, 9 July 2009 (http://www.jamaicaobserver.com/news/html/20090709T010000-0500_155015_OBS_CROCODILE_SCARE_IN_GREATER_PORTMORE__.asp?FORM=ZZNR).

Phillippo, J.M. (1843). Jamaica: It's Past and Present State. John Snow: Paternoster Row, London.

Ritch, D. (2006). Whitehouse development: a bad idea. Jamaica Gleaner, 30 July 2006 (http://jamaica-gleaner.com/gleaner/20060730/cleisure/cleisure3.html).

Ritch, D. (2007). A pattern of bad government. Jamaica Gleaner, 24 June 2007 (http://jamaica-gleaner.com/gleaner/20070624/cleisure/cleisure3.html).

Thorbjarnarson, J.B. (2001). Crocodiles in Jamaica: Overview of March 2001 Visit with Comments on Management and Conservation. Herpetology Program Trip Report, May 2001. Wildlife Conservation Society: New York.

USFWS (1975). United States Fish and Wildlife Service. Federal Register 40: 44149.

Williams, S. (2010). Man fights crocodile - survives attack by poking reptile's eye. The Jamaica Online Star, 15 September 2010) http://jamaica-tar.com/thestar/20100915/news/news1.html

Wilson, B. (2011). Sea turtles, "strong back" and extinction. Jamaica Observer (http://www.jamaicaobserver.com/environment/Sea-turtles---strong-back--and-extinction_8286249).

Spatial Ecology of the American Alligator (*Alligator mississippiensis*) and American Crocodile (*Crocodylus acutus*) in Estuarine Areas of Everglades National Park

Michael S. Cherkiss[1], Frank J. Mazzotti[2], Brian M. Jeffery[2], Jeffrey Beauchamp[2], Kristen M. Hart[1] and Edward J. Larrivee[2]

[1]U.S. Geological Survey, Southeast Ecological Science Center, 3205 College Ave., Davie, FL 33314, USA
[2]University of Florida, 3205 College Ave., Davie, FL 33314, USA

Abstract

Efforts are underway to improve Florida Bay and adjacent estuaries by improving water delivery. This may change salinities, water levels, and availability of nesting habitat. Alligators and crocodiles are among top predators within the Greater Everglades ecosystem; these species integrate biological impacts of hydrological operations, which affect them at all life stages through food webs, diversity and productivity, and freshwater flow. The purpose of our study was to determine home range and core-use areas for crocodilians in Everglades National Park. Kernel density estimation with site fidelity tests were used to quantify spatial habitat-use patterns over time. Through our analysis, we found habitat-use patterns of several individuals. Individuals traveled relatively low distances from capture sites, with 5.3 km mean displacement values. Core-use areas for 6 crocodiles with long-term data ranged from 51.6 to 155.2 km² (mean 86.8 ± 40.0 km² SD).

Development of a Conceptual Model Based on the Soft Systems Methodology for Evaluating Sustainability of *Caiman latirostris* and *Caiman yacare* Production in Argentina

Cecilia Gelabert[1], Pablo Siroski[2,3], María Virginia Parachu Marcó[2,4] and Olga González[1]

[1] Department of Alternative Animal Production, College of Agriculture, University of Buenos Aires, Av. San Martín 4453 - C1417DSE - Bs. As., Argentina (gelabert@agro.uba.ar)
[2] Jacare Project - Laboratory of Applied Zoology: Vertebrates Annex (FHUC-UNL/MASPyMA) - A. Valley 8700, Santa Fe, Argentina
[3] Laboratory of Cellular and Molecular Biology (FCV-UNL). CONICET, Argentina
[4] CIC and TTP-CONICET, Dr. Materi and Spain (3105) Diamante, Entre Rios, Argentina (virginiapara2@yahoo.com.ar)

Abstract

Since the 1990s, five management programs on caimans (*Caiman latirostris* and *C. yacare*) have been developed in Argentina, all of them based on ranching. The aim of this work was to develop a conceptual model including economic, social and environmental variables, on caiman production in Argentina between 1997 and 2011. Four programs were evaluated (Formosa, Chaco, Santa Fe, Corrientes Provinces). The model was developed using the "Soft Systems Methodology" and data obtained through ethnographic techniques. We found cause-effect relationships between those variables that determined the activity: international demand for skins is influenced by the international regulatory framework, the global supply of crocodilian skins, the conservation status of the species under management, and customer's valorization of the product. These variables at a global scale impact on the amount of skins produced locally, and thus on the profit of ranches which could discourage business continuity, affecting its effectiveness as a strategy for conservation of species and their habitats.

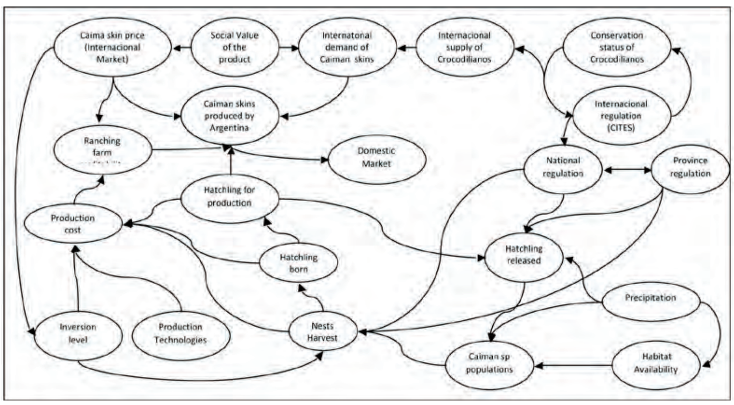


Figure 1. Argentine system of caiman skin production - conceptual model of cause-effect relationships.

Oxidative Stress and Antioxidant Defense Capacity Markers to be Applied in *Caiman latirostris* Blood

Gisela L. Poletta[1,2,3], Elisa C. Kleinsorge[2], Pablo A. Siroski[1,4] and Marta D. Mudry[3]

[1] Proyecto Yacaré - Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASPyMA), A. del Valle 8700, Santa Fe, Argentina
[2] Cat. Toxicología, Farmacología y Bioquímica Legal, FBCB, UNL, Santa Fe, Argentina
[3] Grupo Investigación Biología Evolutiva, IEGEBA (CONICET-UBA), Buenos Aires, Argentina
[4] Laboratorio de Biología Celular y Molecular (FCV-UNL), CONICET, Santa Fe, Argentina

Introduction

It has been indicated that one of the main mechanisms of pesticide toxicity is the production of reactive oxygen species (ROS).ROS include free radicals and other highlyreactive forms of oxygen (eg hydrogen peroxide, superoxide anionradical, hydroxyl radical). In excess, ROS can overwhelm the normal antioxidant buffering capacity of the cell, leading to significant damage to cellular components, including proteins, lipids and DNA.Cell damage caused by an excess of ROS,has been defined as oxidative stress (Azqueta *et al*. 2009). Organisms protect themselves from such damage with both enzymatic and non-enzymatic antioxidantdefenses. Three levels of protection have been considered: 1) prevention of ROS formation; 2) termination of the ROS using free radical scavengers or antioxidant enzymes; and, 3) repair of damaged cellular components (Storey 1996).

Measurements of lipid peroxidation products, such as malondialdehyde (MDA), as well as modifications in endogenous oxygen free radical (OFR) scavengers, including superoxide dismutase (SOD) and catalase (CAT), are used as effective biomarkers to study pollutant-mediated oxidative stress (Limón-Pacheco and Gonsebatt 2009). DNA damage induced by oxygen radicals occurs by oxidative modification of the bases in nucleicacids. Regarding this, the Comet assay modified by using repair endonucleases, such as formamidopyrimidine-DNA glycosylase (FPG), has demonstrated to be the most sensitive technique for measurement of oxidized bases (Collins 2009).

There was no previous data on the application of any oxidative stress technique in *C. latirostris* and only a few reports were found in crocodilians, including *C. yacare* (Furtado Filho *et al*. 2007) and *Alligator mississipiensis* (Gunderson *et al*. 2004; Lance *et al*. 2006). The aim of this study was to adapt oxidative stress biomarker techniques: 1) damage to lipids by Thiobarbituric Acid Reactive Substances (TBARS); 2) to DNA by Comet assay modified with the enzyme Formamidopyrimidine DNA glycosylase (FPG); and, 3) antioxidant defense: catalase and oxidized-reduced glutathione (GSH), for their application in blood of *C. latirostris* as early markers of pesticide effects in wild populations.

Materials and Methods

<u>Blood samples</u>: Blood samples were obtained from the spinal vein of 5 juvenile caimans from Proyecto Yacaré (Gob. Santa Fe/MUPCN), with heparinised syringes. Peripheral blood was used immediately for the modified comet assay. For the other techniques, blood was centrifuged,erythrocytes washed with saline solution and stored at -20^oC until analysis. Then erythrocytes were lysed with ice-cold distilled water and different dilutions were tested in order to determine the proper one for this species: 1:10, 1:20 and 1:40.

<u>FPG-Modified Comet Assay</u>: The alkaline Comet assay was performed with modifications required by *C. latirostris* erythrocytes, as described by Poletta *et al*. (2008). After lysis, slides were incubated with FPG or with enzyme buffer alone for 30 min at 37^oC, submerged in alkaline buffer for 10 min and then electrophoresed at 0.90 V/cm for 10 min. One hundred randomly selected comet images were analyzed, classified into 5 arbitrary classes, and a single DNA damage index (DI= n1+2 n2+3 n3+4 n4) calculated for each animal (Poletta *et al*. 2008). DNA breaks induced by oxidative damage are calculated by subtracting breaks with buffer from breaks with FPG as follows: FPG sites= Damage Index CA with FPG - Damage Index CA without FPG (Collins *et al*. 2008).

<u>Catalase(CAT) activity in erythrocytes</u>: CAT activity in hemolyzed erythrocytes was measured spectrophotometrically by monitoring the decrease in H_2O_2 concentration over time (Aebi 1984). The specific activity of each sample was calculated on the basis that one unit of enzyme activity was defined as the activity required to degrade 1 mole hydrogen peroxide during 60 s/g Hb.

<u>Lipid peroxidation in erythrocytes (TBARS)</u>: Malondialdehyde (MDA) as a marker of lipid peroxidation in red blood cells was determined by measuring the formation of the color produced during the reaction of thiobarbituric acid (TBA) with MDA (TBARS Assay) according to a modification of the method of Beuge and Aust (1978). The sample absorbance was determined at 535 nm and TBARS concentration was calculated using the extinction coefficient 1.56 x 105 M^{-1} cm^{-1}.

MDA concentration in erythrocytes was expressed as nmol/g Hb.

Reduced and oxidazed glutathione relation (GSH/GSSG): Lizederythrocytes were mixed with trichloroacetic acid. GSH was determined in the supernatant following the procedure described by Ellman (1961). For the determination of total glutathione (GSH + GSSG), GSSG was reduced to GSH with glutathione reductase and NADPH during appropriate time at room temperature. Reaction was stopped by acid precipitation with trichloroacetic acid. Dithionitrobenzoic acid (DTNB) was added to the supernatant and absorbance read at 412 nm. Total glutathione is expressed as μM of glutathione mg^{-1} Hb and then the relation GSH/GSSG is calculated.

Results and Discussion

Different modificationstested on the techniques protocols allowed the determination of suitable parameters for each biomarker to be applied in *C. latirostris* blood. We observed that the proper dilution for the determination of TBARS is 1:20, while for CAT and GSH it is 1:10.

All the studies previously made in crocodilians were applied in tissues from kidney, muscles, gonads or liver, so that animals have to be sacrificed or samples obtained from animals recently dead (Furtado Filho *et al*. 2007; Gunderson *et al*. 2004; Lance *et al*. 2006). In our study, different modifications were done to standard procedures in order to applythe techniques in *C. latirostris* blood.

There are still only a limited number of reports of the use of the CA in an ecotoxicological context, and very few of theseuse lesion-specific enzymes to detect specifically oxidised bases (Azqueta *et al*. 2009). Up to our knowledge no studies had been made evaluating DNA oxidative damage through the modified comet assay on reptile species, so that this is the first report on it. Considering our previous studies on the genotoxic effects of pesticides and pesticides mixtures on *C. latirostris* (Poletta *et al*. 2009, 2011), the possibility to add oxidative stress biomarkers represents an important advance for the evaluation of wild caiman populations, as we can obtain samples without causing any damage to the animals.

Acknowledgements

This work was supported by CONICET (PIP 112 to MDM), ProyectoYacaré and YacarésSantafesinos (Gob. Sta. Fe/MUPCN), and Universidad de Buenos Aires (UBACyT X154 to MDM).

Literature Cited

Aebi, H. (1984). Method. Enzymol. 105: 121-126.

Azqueta, A., Shaposhnikov, S. and Collins, A.R. (2009). Mutat. Res. 674: 101-108.

Beuge, J.A. and Aust, S.D. (1978). Method. Enzymol. 52: 302-310.

Collins, A.R. (2009). Mutat. Res. 681: 24-32.

Ellman, G.L., Curtney, K.D., Andrews, V. and Featherstone, R.M. (1961). Biochem. Pharmacol. 7: 88-95.

Furtado-Filho, O.V., Polcheira, C., Machado, D.P., Mourão, G. and Hermes-Lima, M. (2007). Comp. Biochem. Physiol. C 146(1-2): 241-254.

Gunderson, E., Oberdörster, A. and Guillette, L.J. Jr. (2004). Comp. Biochem. Physiol. C 139(1-3): 39-46.

Lance, V.A., Horn, T.R., Elsey, R.M. and de Peyster, A. (2006). Comp. Biochem. Physiol. C 142: 30-35.

Limón-Pacheco, J. and Gonsebatt, M.E. (2009). Mutat. Res. 674: 137-147.

Poletta, G.L., Larriera, A., Kleinsorge, E. and Mudry, M.D. (2008). Mutat. Res. 650: 202-209.

Poletta, G.L., Larriera, A., Kleinsorge, E. and Mudry, M.D. (2009). Mutat. Res. 672: 95-102.

Poletta, G.L,; Kleinsorge, E., Paonessa, A., Mudry, M.D., Larriera, A. and Siroski, P.A. (2011). Ecotoxicol. Environm. Saf. 74: 852-859.

Storey, K.B. (1996). Braz. J. Med. Biol. Res. 29: 1715-1733.

Red Fire Ant (*Solenopsis invicta*) Venom Effects on Physiological Responses and Survivorship in *Alligator mississippiensis* Hatchlings

María V. Parachú Marcó[1,2], Mark E. Merchant[3], Pablo A. Siroski[1,4] and Carlos I. Piña[1,2,5]

[1] Proyecto Yacaré - Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASPyMA) - A. del Valle 8700, Santa Fe, Argentina
[2] CIC y TTP-CONICET, Dr. Materi y España, (3105) Diamante, Entre Ríos, Argentina (virginiapara2@yahoo.com.ar)
[3] Department of Chemistry, McNeese State University, P.O. Box 90455, Lake Charles, LA 70609, USA
[4] Laboratorio de Biología Celular y Molecular (FCV-UNL), CONICET, Argentina
[5] Facultad de Ciencias y Tecnología (Subsede Diamante), Universidad Autónoma de Entre Ríos, Facultad de Ciencias de la Alimentación, Universidad Nacional de Entre Ríos, Argentina

Abstract

In the United States, approximately of 20% of American Alligator (*Alligator mississippiensis*) nests contain *Solenopsis invicta* colonies, and at least 50% of surviving hatchlings shows signs of attacks, such as swelling of toes and eyes, as well as pustules. Studies have demonstrated that the venom delivered by bites of *S. invicta* affect bodyweight increases and survival of *A. mississippiensis* hatchlings. However, the physiological mechanisms and the implications for the immune system after *S. invicta* attacks are unknown. The aims of this study were to measure plasma corticosterone concentration, white blood cell counts and survivorship of *A. mississippiensis* hatchlings after exposure to a *S. invicta* colony. Exposure of hatchling alligators to *S. invicta* induced an increase in plasma corticosterone over time, a decrease in the total white blood cell counts, and survivorship that could be associated with physiological stress.

Introduction

The first experimental evidence of indirect effects of *Solenopsis invicta* (Hymenoptera: Formicidae) in herpetofauna was performed in *Alligator mississippiensis* (Crocodilia: Alligatoridae), demonstrating that the venom of bites reduced weight and survival (Allen *et al*. 1997). In the USA, 20% of alligator nests contain *S. invicta* colonies, and at least 50% of those hatchlings that survive show attacks evidence, such as swelling of the fingers and eyes, as well as visible pustules (Moloney and Vanderwoude 2002). However, physiological response mechanisms regulating these changes are still unknown, as well as the implications on the immune system that affect their survival. As in other vertebrates, reptiles have a well developed response to stress, which could affect the behavior, reproductive activity and intermediary metabolism (Guillette *et al*. 1995; Tyrrell and Cree 1998). Many of these changes are correlated with plasma concentrations of corticosterone, the major glucocorticoid produced by the adrenal gland in reptiles (Callard 1975). This work evaluated corticosterone production in *A. mississippiensis* hatchlings in response to *S. invicta* venom. Moreover, stress conditions and increased plasma concentrations of corticosterone have been repeatedly associated with immunosuppression in several species of crocodiles (Lance 1994; Morici *et al*. 1997; Rooney and Guillette 2001), so we analyzed if there are any alterations in white blood cells after contact with ants.

Methods

Solenopsis invicta colonies were collected in the wild and reared in plastic trays at the Louisiana Environmental Research Center (LERC), McNeese University, according to the technique described in Parachú Marcó (2011). For all experiments *A. mississippiensis* hatchlings from different nests were collected in the J.D. Murphree Wildlife Management Area, in Port Arthur, Texas, USA. Animals were kept isolated in plastic trays preventing any external factors that could generate them stress. During the preliminary test 12 hatchlings from different nests were used, being individualized through a non-invasive marking system that avoids excessive handling.

Animals from each clutch were divided into 4 treatments of 3 hatchlings each to be subjected to different blood sampling times after exposure to *S. invicta* bites. One group was used as control without exposure. All individuals were exposed at the same colony of *S. invicta*. The procedure consisted of placing all individuals in a tray with the same ant colony for 2 minutes, then washing them in water to remove ants from their bodies, and then placing each group in a different tray, and then bleeding a single time. Bleeding occurred at 0, 15, 30 and 60 minutes. Blood samplings were performed by extraction in the area of the vein cord at the cervical vertebrae (Zippel *et al*. 2003). After bleeding, animals were placed in trays, and raised and fed under routine techniques. An aliquot of whole blood was removed for white blood cell (WBC) determinations. The remain sample was centrifuged, and plasma stored at -20°C for determination of corticosterone with enzyme immunoassay (ARBOR ASSAY ®, Catalog N K014-H1). Total leukocytes were counted in Neubauer chamber. Leukocytes quantification was done by microscopic observation of whole blood smears stained with May Grunwald-Giemsa.

To assess whether the exposure to bites of *S. invicta* affects *A. mississippiensis* hatchling survival, in the second part of this study, 40 individuals from 4 nests were split into 5 different groups and exposed for different times to *S. invicta* bites (0, 0.5, 1, 2 and 4 minutes).

Results and Discussion

Preliminary results showed a gradual increase in blood corticosterone concentration in *A. mississippiensis* hatchlings after *S. invicta* attack (Fig. 1). Differences were found at 30 and 60 minutes compared to control (Tukey Test: $P \leq 0.05$). This suggests that red fire ants bites stress *A. mississippiensis* hatchlings. However, corticosterone concentration at 15 minutes after stings revealed no differences with control (Tukey test: $P \geq 0.05$).

Increase in glucocorticoid hormones cause characteristic changes in the leukocyte numbers that can be quantified and related to hormone levels (Barreno 2008). Leukocyte profiles are particularly useful in the field of conservation physiology because they are altered by stress and can be directly related to stress hormone levels (Davis *et al*. 2008). Indeed, we observed a decrease in total white blood cells (WBC) count in increased time blood samples from *A. mississippiensis* hatchlings. We found differences between 15, 30 and 60 minutes regarding control group (P= 0.0154, Fig. 2). As previously shown in response to glucocorticoids increase, circulating lymphocytes migrate to other tissues (lymph nodes, spleen, bone marrow or skin) where they are requested (Davis *et al*. 2008). On the other hand, neutrophils/heterophils are the primary phagocytic leukocyte, and proliferate in circulation in response to infections, inflammation and stress (Jain 1993; Campbell 1995; Thrall 2004). However, the heterophil-lymphocyte ratio in WBC differential count, showed no differences between treatments (P= 0.4579, Fig. 3).

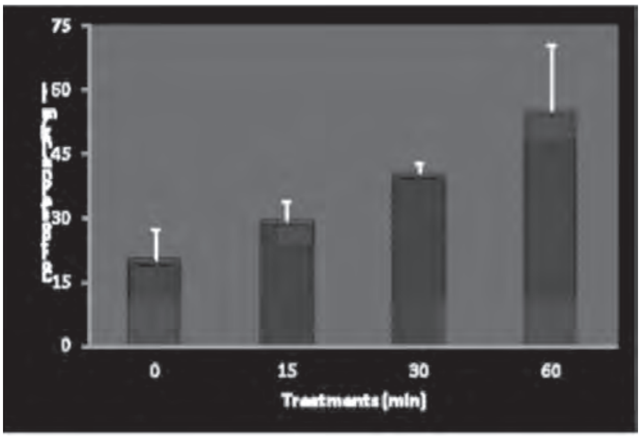


Figure 1. Mean plasma corticosterone (± SD) in *A. mississippiensis* hatchlings after exposure to *S. invicta*.

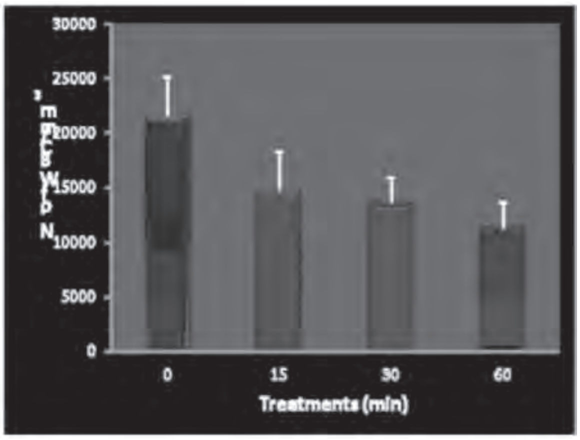


Figure 2. Mean total white blood cell (WBC) counts (± SD) in *A. mississippiensis* hatchlings after exposure to *S. invicta*. *= statistically significant differences with respect to the control group (ANOVA - Tukey).

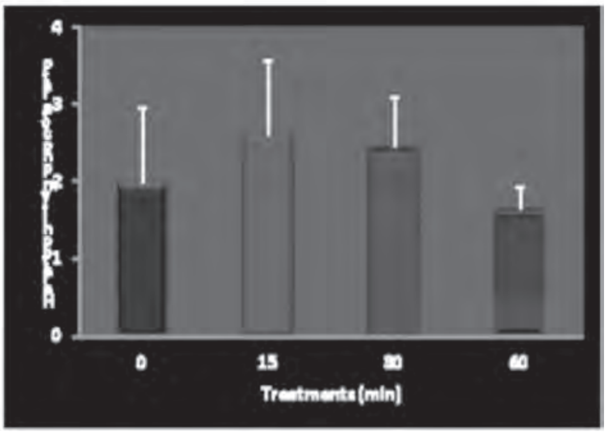


Figure 3. Mean heterophil-lymphocyte ratio (± SD) in *A. mississippiensis* hatchlings after exposure to *S. invicta*.

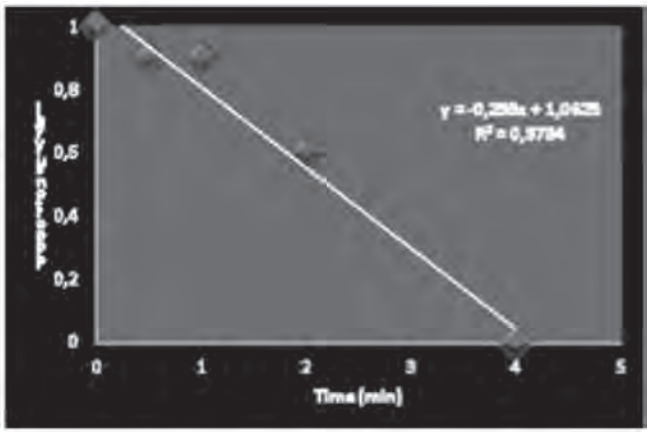


Figure 4. Survival of *A. mississippiensis* hatchlings after different times of exposure to *S. invicta* bites.

We found that survival of *A. mississippiensis* hatchlings decreased while time of exposure to *S. invicta* increased (Fig. 4). This relationship was reported in *Caiman latirostris* (Parachú Marcó 2011), although the survival of animals exposed to 4 minutes reached approximately 40%, while in *A. mississippiensis* there were no survivors after 4 minutes. This demonstrates that *S. invicta* bites have a greater effect on alligators than caimans.

Literature Cited

Allen, C.R., Rice, K.G., Wojcik, D. and Percival, H.F. (1997). Effect of red imported fire ant envenomization on neonatal American alligators. Journal of Herpetology 31: 318-321.

Callard, G.V. (1975). Control of the interrenal gland of the freshwater turtle *Chrysemys picta in vivo* and *in vitro*. General and Comparative Endocrinology 25: 323-331.

Campbell, T.W. (1995). Avian Hematology and Cytology. Iowa State University Press: Ames, Iowa.

Davis A.K., Maney, D.L. and Maerz, J.C. (2008). The use of leukocyte profiles to measure stress in vertebrates: a review for ecologists. Functional Ecology 22: 760-772.

García Barreno, P. (2008). Inflamación. Revista de la Real Academia de Ciencias Exactas Físicas y Naturales 102: 91-159.

Guillette, L.J. Jr., Cree, A. and Rooney, A.A. (1995). Biology of stress: Interactions with reproduction, immunology and intermediary metabolism. *In* Health and Welfare of Captive Reptiles, ed. by C. Warwick, F.L. Frye and J.B. Murphy. Chapman and Hall: London.

Jain, N.C. (1993). Essentials of Veterinary Hematology. Blackwell Publishing: Philadelphia.

Lance, V.A. (1994). Life in the slow lane: hormones, stress, and the immune system in reptiles. Pp. 529-534 *in* Perspectives in Comparative Endocrinology, ed. by K.G. Davey, R.E. Peter and S.S. Tobe. National Research Council of Canada: Ottawa.

Moloney, S. and Vanderwoude, C. (2002). Red imported fire ants: A threat to eastern Australia's wildlife? Ecology Man. Rest. 3: 167-175.

Morici, L.A., Elsey, R.M. and Lance, V.A. (1997). Effect of long-term corticosterone implants on growth and immune function in juvenile Alligators, *Alligator mississippiensis*. Journal of Experimental Zoology 279: 156-162.

Parachú Marcó, M.V. (2011). Efecto de las hormigas coloradas (*Solenopsis invicta*) en nidos y el crecimiento post-natal del yacaré overo (*Caiman latirostris*; Reptilia, Alligatoridae). Ph.D. Thesis, Universidad Nacional de Córdoba, Argentina.

Rooney, A.A. and Guillette, L.J. (2001). Biotic and abiotic factors in crocodilian stress: The challenge of a modern environment. Pp. 214-228 *in* Crocodilian Biology and Evolution, ed. by G. Grigg, C. Franklin and F. Seebacher. Surrey Beatty and Sons: Chipping Norton, Australia.

Thrall, M.A. (2004). Hematology of Amphibians, Veterinary Hematology and Clinical Chemistry: Text and Clinical Case Presentations. Lippincott Williams & Wilkins: Philadelphia.

Tyrrell, C.L. and Cree, A. (1998). Relationships between corticosterone concentration and season, time of day and confinement in a wild reptile (tuatara, *Sphenodon punctatus*). General and Comparative Endocrinology 110: 97-108.

Zippel, K.C., Lillywhite, H.B. and Mladnich, C.R. (2003). Anatomy of the crocodilian spinal vein. Journal of Morphology 258: 327-335.

Detection and Characterization of Chitotriosidase Enzyme in *Caiman latirostris* Plasma

Pablo A. Siroski[1,2], Gisela L. Poletta[1,3], Maria V. Parachú Marcó[1,4], Hugo H. Ortega[2] and Mark E. Merchant[5]

[1]Proyecto Yacaré - Laboratorio de Zoología Aplicada: Anexo Vertebrados (FHUC-UNL/MASPyMA) - A. del Valle 8700, Santa Fe, Argentina
[2]Laboratorio de Biología Celular y Molecular (FCV-UNL), CONICET, Argentina
[3]Cat. Toxicología, Farmacología y Bioquímica Legal, FBCB, UNL, Santa Fe, Argentina; IEGEBA, FCEyN (CONICET-UBA), Buenos Aires, Argentina
[4]CIC y TTP-CONICET, Dr. Materi y España, (3105) Diamante, Entre Ríos, Argentina
[5]Department of Chemistry, McNeese State University, P.O. Box 90455, Lake Charles, LA 70609, USA

Introduction

Crocodilians have demonstrated to have some immune components with an apparently higher activity than others animals, even humans. The ability to resist, with serious injuries in places with high concentrations of pathogen microorganisms without signs of illness, makes them interesting models to elucidate those mechanisms and components involved in the defense system. Among these components is chitotriosidase (CHT) enzyme, one of the main proteins secreted by activated macrophages. Chitotriosidase, also known as chitinase, is a glycosyl hydrolase secreted by activated macrophages (Hollack *et al*. 1994). For its specific expression, it is believed that CHT plays a role in mechanisms of immunity which hydrolyzes chitin and protection against chitin-containing pathogens (fungi, parasites, arthropods, etc.).There are two distinct isoforms of CT in humans, one that is 50 kDa and the other is 39 kDa (Renkema *et al*. 1997). The enzyme is located in specific granules of polimorphonuclears and secreted following stimulation with granulocyte macrophage colony-stimulating factor (GM-CSF). In addition, GM-CSF induces expression of CHT in macrophages that constitutively secrete the enzyme and partly accumulate it in their lysosomes. Our study was the first that revealed the presence of this enzyme in Caiman latirostris plasma, and based in its properties and functions, CHT activity was characterized under different laboratory conditions (pH, temperature, time, plasma concentration and salinity).

Material and Methods

Samples were collected from wild adult *C. latirostris* (7F, 6M; 1.51-2.31 m TL) in different areas of Santa Fe Province, Argentina. It is worth mentioning that, due to the influence of temperature on the physiology of these animals, the samples were collected during the summer. Animals were measured and returned to their environment within an hour of capture. The blood samples were collected relatively quickly after capture to avoid an increase in corticosterone concentration.

Blood samples were obtained from the spinal vein (Zippel *et al*. 2003) using heparin as an anticoagulant. Whole blood was centrifuged immediately at 4500 g for 20 min, at room temperature (approximately 24°C). The plasma was frozen at -20°C and CHT enzyme assays were conducted within 7 days of capture.

CHT plasma enzyme activity was determined as described by Hollack *et al*. (1994) using the artificial substrate 4-methylumbelliferyl-β-D-N,N´,N´´-triacetylchitotrioside (4 MU-chitotrioside; Sigma Chemical Co., St. Louis, MO). The enzymeassay mixture contained 15 µL of plasma and 100 µL (0.022 mM) of the substrate dissolved in citrate-phosphate buffer, pH 5.2, in a total volume of 115 µL. The reaction was stopped with 1 mL of glycine-sodium hydroxide buffer, pH 10.6. This mixture was incubated depending on determination dependence and fluorescence was read with spectrofluorometer (excitation and emission wavelength of 365 and 450 nm, respectively).

<u>Caiman CHT activity temperature dependence</u>: To evaluate the effect of temperature on enzyme activity, CHT assays were performed at different temperatures (from 5 to 40°C, at intervals of 5°C).

<u>Caiman CHT activity plasma concentration dependence</u>: To determine the effect of plasma concentration on CHT activity, different amounts of caiman plasma (0, 1, 2, 5, 10, 20, 50 and 100 µl) were added.

<u>Caiman CHT activity time dependence</u>: CHT assays were performed at different time intervals (0, 5, 10, 15, 20, 30, 60 and 90 min).

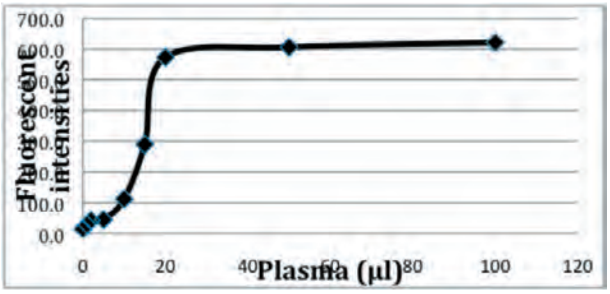
<u>Caiman CHT activity pH and salinitydependence</u>: To evaluate these activities, pH was changed by adding buffers ranging from pH 4 to 10, and salinity with different volumes of 1 M NaCl solution.

All assays were performed in quadruplicate and the results are expressed as fluorescence units (FU) ± standard error (SE).

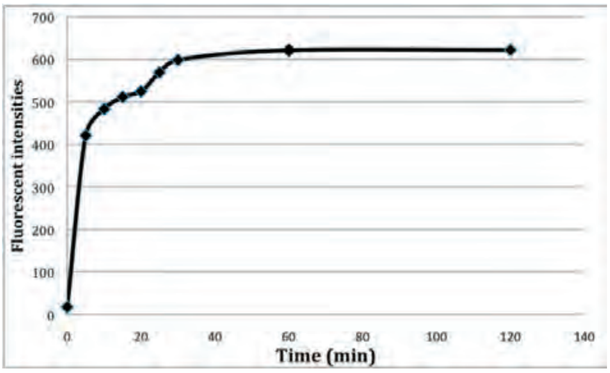
The effects of conditions variables on CHT activity were analyzed by linear regression for each species, and p≤0.05 was considered statistically significant.

Results and Discussion

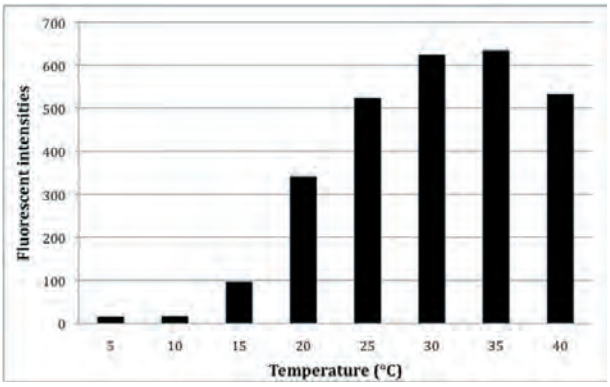
Caiman latirostris CHT plasma activity showed a positive relationship with increasing plasma concentration (Fig. 1). At the very beginning, small amounts of plasma produced a significant increase in CHT activity; 15 µL of plasma, CHT activity was 50% of maximum, approximately. This ability gives this technique an advantage, because with small volumes of plasma, reproducible results with very low variations can be obtained.



CHT activity in plasma of *C. latirostris* showed a positive relationship with time of incubation with substrate. Plasma caiman exhibited CHT activity immediately after 5 minutes of incubation with fluorescent substrate (Fig. 2). Within few minutes of the reaction time, high activity was demonstrated. These results coincide with those observed in similar studies made with dipeptidyl peptidase enzymes (DPPIV) (Siroski *et al*. 2011).

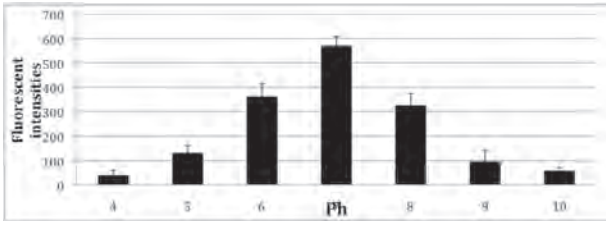


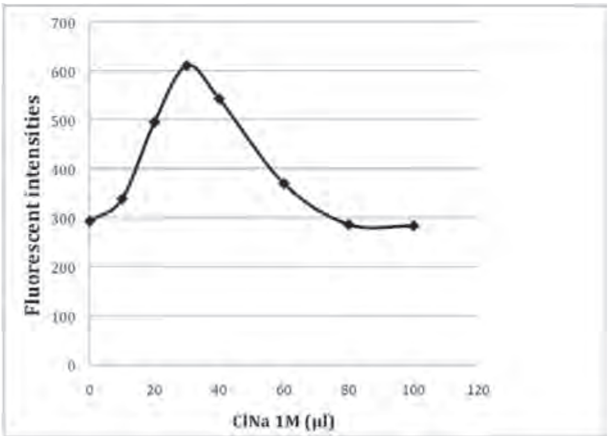
Ectothermic vertebrates are considered appropriate models to assess the influence of temperature on a variety of physiological functions (Pxytycz and Zkowicz 1994). Plasma CHT activity demonstrated a positive relationship with temperature (Fig. 3). At the lower temperatures (5, 10 and 15°C), CHT activity was low ($p<0.05$) until 15°C where it began to increase until 30-35°C. Enzymatic activity was dependent on the incubation temperature during the reaction assay. The activity at low temperature could be attributed to the greater climatic tolerance of *C. latirostris*, more than other species.



Crocodilians have preferences to maintain body temperature within a range of 28-33°C by using natural thermal gradients. This activity was detected at 35°C, approximately, close to caiman temperature preference selected to carry out normal physiological processes (Bassetti 2002).

The assays to evaluate the optimum functioning pH for CHT activity in plasma of *C. latirostris* are on Figure 4. The enzyme activity was highest at pH 7 and it was decreasing to both pH extremes, where practically no activity was detected.





The broad pH profile observed in our samples suggests the possible occurrence of distinct isoforms of macrophage (Renkema *et al*. 1997). It is expected that the pH optimum for each CHT isoform is close to the pH and osmolality of the environment in which it is active *in vivo* and may differ depending on tissue origin. In this case, we found values reasonable based on close pH optimum and salinity of the plasma tissue.

Polimorphonuclears, but not lymphocytes and monocytes, area major source of chitotriosidase in blood. Chitotriosidase hydrolyzes chitin substrates similarly to chitinases that are found in a variety of species (Boot *et al*. 1998), but this study is the first report about the presence and characterization of CHT in crocodilian, even in reptile plasma.

In conclusion, based on the parameters analyzed, it is presumed that the variation of these parameters may be useful to distinguish normal and abnormal organism. Considering the versatility of the results obtained in this study, CHT is a promising component of the caiman immune system and could be used for future applications in the veterinary area, in the study of immune phylogenetic mechanisms and as a biomarker of individual health status.

Literature Cited

Bassetti, L.A. (2002). Comportamento de termorregulaçãoem jacarés-de-papo-amarelo (*Caiman latirostris*) adultos emcativeiro. Tesis de Mestrado, Esc. Super. Agri. Luiz de Queiroz, Univ. São Paulo, Piracicaba, SP, Brazil.

Boot, R.G., Renkema, G.H. and Verhoek, M. (1998). The human chitotriosidase gene. Nature of inherited enzyme deficiency. J. Biol. Chem. 273: 25680.

Hollak, C.E.M., van Weely, S., van Oers, M.H.J. and Aerts, J.M.F.G. (1994). Marked elevation of plasma chitotriosidase activity: a novel hallmark of Gaucher disease. J. Clin. Invest. 93: 1288-1292.

Pxytycz, B. and Zkowicz, A.J. (1994). Differential effects of temperature on macrophages of ectothermic vertebrates. J. Leuk. Biol. 56: 729-731.

Renkema, G.H., Boot, R.G. and Strijland, A. (1997). Synthesis, sorting and processing into distinct isoforms of human macrophage chitotriosidase. Eur. J. Biochem. 244: 279-285.

Zippel, K.C., Lillywhite, H.B. and Mladnich, C.R. (2003). Anatomy of the crocodilian spinal vein. J. Morphol. 258: 327-335.

Pentastomid Community Structure of *Sebekia mississippiensis* in the American Alligator, *Alligator mississippiensis*

Ali Haghighi, Melina Lavihim, Aaron Puertollano, Jennifer Uyan and Marisa Tellez

UCLA, Department of Ecology and Evolutionary Biology, 621 Charles E. Young Drive South, PO Box 951606, Los Angeles, CA 90095-1606, USA

Abstract

Pentastomids parasitizing the lungs of *Alligator mississippiensis* (Crocodylia: Alligatoridae) from Florida and the East and West Zone of Louisiana were studied. Fifty-two of the 65 alligators analyzed (80%) were infected by pentastomids. Species richness was found to be depauperate as lung parasites were identified as juveniles or adults of one species, *Sebekia mississippiensis*. Males exhibited a higher parasitic prevalence than females (87% vs 71%) as well as parasite intensity (21.5 vs 10). Males from the West Zone of Louisiana had a higher prevalence than the East Zone of Louisiana and Florida (92%), but male hosts from Florida had a higher pentatsomid intensity than the other two locations (35.5). Female alligators from the East Zone exhibited a higher prevalence (80%) and intensity (14.1) than the other two locations. Host body size was found to be correlated with higher parasite intensity, which may be a result of the ontogenetic shift of alligators. In general, location, size and diet appear to be important factors in structuring lung parasite community of alligators (Overstreet *et al*. 1985; Hygynstrom *et al*. 1994; Delany and Abercrombie 1986; Boyce *et al*. 1987).

Literature Cited

Overstreet, H.M., Self, J.T. and Vliet, K.A. (1985). The pentastomid *Sebekia mississippiensis* sp. n. in the American alligator and other hosts. Proceedings of the Helminthological Society of Washington 52: 266-277.

Hygynstrom, S.E., Timm, R.M. and Larson, G. (1994). Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska: Lincoln.

Delany, M.F. and Abercrombie, C.L. (1986). American alligator food habits in northcentral Florida. Analysis 50(2): 348-353.

Boyce, W.M., Kazacos, E.A., Kazacos, K.R. and Engelhardt, J.A. (1987). Pathology of pentastomid infections (*Sebekia mississippiensis*) in fish. Journal of Wildlife Diseases 23(4): 689-692.

WORKSHOP REPORTS

Crocodilian Capacity Building Manual Working Group

Participants: Charlie Manolis, Dietrich Jelden, Allan Woodward, Perran Ross, Geoff McClure, Matt Shirley, Paolo Martelli, Samuel Martin

At the 20th CSG Working Meeting, the CSG Executive agreed that a web-based CCBM was an important contribution that the CSG could make to Range States for crocodilians. The Steering Committee directed a working group chaired by Allan Woodward to assess the need for a comprehensive reference document, and suggest a structure for implementing the development of a CCBM (see SC Agenda Item 8.1).

At the 21st CSG Working Meeting, the CCBMWG was directed to assess the ways in which development of a CCBM could be implemented. The group's deliberations are summarised below:

1. The CCBMWG recognised that the successful development of a manual would rely on someone coordinating the project. Charlie Manolis agreed to take on this role temporarily, pending the identification of a permanent coordinator. The CSG Executive recognised that some funding may need to be provided for this "position".

2. The CCBMWG also proposed that:

   a. A revised version of the CCBM outline developed at the 20th Working Meeting (SC Agenda Item 8.1) be distributed by the end of June 2012, and input sought so that a final list of contents can be settled on.
   b. Volunteers be sought to contribute to specific sections of a CCBM. Some people have already indicated that they are able deal with specific sections (eg Dietrich Jelden, Matt Shirley, Allan Woodward, Charlie Manolis, Paolo Martelli, Perran Ross).
   c. The format of a CCBM be firmed up after some initial contributions have been received.
   d. The CCBM be developed in a simple form, with reference to published works, etc. - a "Wikipedia" approach. Matt Shirley indicated that many countries needed very basic information, and not necessarily at the more complex level at which much information is currently available. Although this is an important consideration, it was felt that the CCBM had to start somewhere, and specific "documents" may need to be developed over time to address it.
   e. Firm timelines be established.

Veterinary Science Group Report

The Veterinary Science Group met on 25 May 2012.

Participants: Paolo Martelli, Matt Plummer, Charlie Manolis, Samuel Martin, Charles Caraguel, Beatrice Langevin, Sam Seashole, Val Lance, Geoff McClure, Pablo Siroski, Robby McLeod, Marissa Tellez, Terry Cullen, Mark Merchant, Csaba Geczy, Adam Britton, Willem van de Ven

The Mission of the CSG Veterinary Science group is to:

- provide a platform for the exchange of and access to specific veterinary knowledge and advise the CSG on veterinary matters related to crocodilian conservation;
- contribute to advancing crocodile veterinary medicine and science; and,
- provide support to animals under human care: farms and zoological or educational institutions, biologists and researchers that require veterinary support in their work such as sampling, anesthesia, surgery, etc., conservation, research, NGO and Government organizations investigating *in-situ* mortalities and population health status.

Agenda and report

1. Overview of past 2 year's activities, next 2 years

   Overall the group has fulfilled its mission (see above). The group is mostly active *ad hoc*.

   1.1. There is a feeling that more could be done and the group tried to identify how its level of activity could increase.

An increase in requests for assistance would achieve that because we are a consultative/group. There is insufficient awareness of the existence and mission of the group so we need to increase awareness. Matt Plummer will work on increasing awareness amongst farmers, Marissa Tellez will contact herpetological societies in North America and Africa, Pablo Siroski will do the same in Central and South America. Paolo Martelli will do the same with the AZA, EAZA and ARAZPA.

1.2. Charlie Manolis suggested the inclusion of Cathy Shilton (Australia). Paolo Martelli will contact her.

2. Review website information and reassign tasks

Review of documents to be put on the CSG website. The following are ready to go and will be loaded by the first week of June 2012.

a. Necropsy procedures, with English, French and Spanish versions
b. Checklist of parasites
c. Anesthesia literature
d. Link to histopathology site

The following are pending and have been assigned:

Topic	**Champions**	**Target**
veterinary procedures (general exam, sampling, medication, etc.)	Samuel Martin, Terry Cullen	May 2013
Literature resources	Kent Vliet, Val Lance, Paolo Martelli, Charlie Manolis	pending political and legal issues
Imaging database and techniques	Charlie Manolis, Cathy Shilton	December 2012
Introduction techniques for new animals in captivity	Samuel Martin, Terry Cullen, Geoff McClure	May 2013
Parasite database Excel format	Marisa Tellez	December 2012
Manual for parasite collection and preservation	Marisa Tellez	July 2012
Share information on histopath database technicalities to facilitate adding material	Paolo Martelli	August 2012
Facilitate movement of histopathology slides in and out of USA	Terry Cullen	in place
Scientifically sound study on effect of various electrical parameters on crocodiles subjected to EI	Mark Merchant	Update May 2014

3. Review the list of relevant research topics encouraged by CSG

These were areas of veterinary science and medicine that will benefit crocodile medicine, conservation and biology. This is not a comprehensive or exclusive list. It is intended to stimulate and guide scientists.

- anatomy
- immunology acquired and innate
- Stress: stress indicators, response to stress, stress monitoring, patho-physiological effects of stress
- epidemiology emerging diseases and biosecurity, including at international levels
- nutrition
- health assessment and screening in general and in the context of reintroduction following IUCN Reintroduction Specialist Group
- crocodile-specific veterinary training of managers and veterinarians in various areas
- Behavior, medical and husbandry training of the animals
- husbandry and welfare, electric immobilization
- intellect, cognition
- endocrinology/reproductive physiology
- genetics
- physiology

4. Review of stunning

The Veterinary Science group is not competent to pronounce on political or legal matters on this topic. The views of the members of the group with direct experience of this technique were shared. There was unanimous agreement that:

4.1. Stunning is a term dedicated to delivering electrical current prior to culling. Electrical immobilization is the term dedicated to delivering electrical current for the purpose of temporary immobilization is "electrical immobilization".
4.2. The group unanimously agreed on the following: "like every tool electrical immobilization must be used by trained staff using well maintained equipment. To the best of our observations there are no reasons to consider that EI is more detrimental to the individual or the group it is in than manual capture. There is evidence that it less stressful to the animal (Franklin *et al*.). Studies are underway and more studies are encouraged."

5. Present and assign tasks for the Crocodilian Capacity Building Manual group

See also above Point 2 above. Also:

5.1. Euthanasia/killing methods. Paolo Martelli will draft a document and circulate it to the group to describe humane methods for killing crocodiles. The documents will then be shared with the Executive and posted on the website.
5.2. All members are to share with the CCBM Working Group web resources or other resources the members use. Links can be added to the CSG website.

6. Other matters

Geoff McClure suggested that we need more husbandry specialist participation in the Veterinary Science group and CSG. To this effect he proposed that:

6.1. With Chris Banks, to request people maintaining adult or breeder *C. mindorensis* to submit a 'floor plan' and photo/s of their breeder pen design with comments on the behavior/compatibility of their animals. Submissions will be collated to ascertain any features of pen design that will effect breeding. All submissions will be acknowledged and presented at the next CSG working meeting in 2013. This initiative will be included in a database - it should be noted that there is no current 'studbook'.

6.2. The croc husbandry challenge - to design self-cleaning accommodation for 50 2-year-old crocodiles. Interested people should list the attributes or criteria that should be considered when designing self-cleaning accommodation. The design should consider among other attributes species-specific issues if any, shape, area, land and pond dimensions, and plumbing. Heating, cooling and insulation may be omitted. All submissions should be e-mailed to Geoff McClure. They will be acknowledged and presented at the 2013 CSG working meeting.

Human-Crocodile Conflict Working Group

Participants: Charlie Manolis (Chair), Allan Woodward, Terry Cullen, Colin Stevenson, Rambli Ahmad, Oswald Bracken Tisen, Ahmad Abdul Hamid, John Breuggen, Jennifer Breuggen, Robert Pahl, Tarun Nair, Adam Britton, Joe Wasilewski, Shaun Heflick, Alvaro Velasco, Vic Mercado, Chris Kri Ubang, Robby McLeod

The objectives of the Human-Crocodile Conflict Working Group (HCCWG), established in 2002 (Gainesville), are to provide technical advice and assistance for the avoidance and mitigation of HCC globally. In 2004 (Darwin), it was agreed that the HCCWG would: a. Compile information on crocodile attacks in the form of a database; b. Produce a fact sheet for media use - pre-emptively and after crocodile attack incidents; and, c. Provide guidelines for the avoidance and mitigation of HCC at a national level.

The HCCWG met twice at the 21st CSG Working Meeting, and the results are summarised as:

1. Despite the limited progress on the proposed activities (a-c above) over the last 8-10 years, it was agreed that the HCCWG would continue to operate until the 23rd CSG Working Meeting (May 2014).

2. Database

   Information on crocodilian attacks continues to be collected at a National level in many countries, and this information has often been sent to Rich Fergusson for inclusion in a database. However, as indicated in the HCCWG report to the Steering Committee (Agenda Item 6.2), some information has yet to be placed in the database. The database has not been available to other HCCWG members, and nor has there been discussion on how the database could be utilised effectively in the long-term.

   The importance of a database on HCC was recognised. However, caution is also warranted, as gaps in historical HCC information make lead to misinterpretation of trends. At times data on indirect HCC (ie on livestock) is collected, but at other times it is not. Same situation with "near misses".

   Adam Britton indicated that the HCC database being developed by Brandon Sideleau would most likely be available to the public, but some work remained to be done to integrate search functions, etc. They hope that the final design of the database will allow new information to be entered independently by others. Adam undertook to discuss with Brandon the possibility of CSG linking to their website.

   A HCC reporting form was developed by the HCCWG previously, to allow cases of HCC to be collated for submission to the database. This form will be integrated into the HCC page on the CSG website.

3. Fact Sheet

   No progress has been made. The HCCWG agreed that it is difficult to produce generic document that could be applied at a global level.

4. Guidelines for avoidance and mitigation of HCC

   No progress has been made. The HCCWG agreed that it is difficult to produce a generic document that could be applied at a global level. There is information available on how countries have approached this issue, and case studies may be an avenue through which this type of information could be made available through the website. Specific examples of other mitigation measures (eg aversion learning) could also be included as they are developed.

5. The concept of a mini-symposium at the 23rd CSG Working Meeting (May 2014) was proposed by Allan Woodward. This would allow the HCCWG to produce a tangible "product" that could assist wildlife managers, etc. The feasibility of incorporating a HCC session will be discussed with Mark Merchant (2014 meeting organiser), and if possible a draft agenda will be circulated for input. Invited speakers on Human-Wildlife Conflict, including crocodiles, would be need to be identified. The participation of people from developing countries would also need to be considered.

6. The HCCWG agreed that regular communication was essential. A google group has been established, and this could continue to be used. More regular meetings of the HCCWG was considered desirable, although problematic given the distribution of members and costs that would be involved.

7. Colin Stevenson reported that the Madras Crocodile Bank is organising a mini-symposium on HCC in August 2012, in Bangalore, India, under the auspices of the SCB meeting.

8. As Rich Fergusson has stepped down as Chairman of the HCCWG, Allan Woodward agreed to take on the position until 2014.

Industry Group Report

Participants: Charlie Manolis (Chairman), Matt Plummer, Simone Comparini, Paolo Martelli, Terry Cullen, Charles Caraguel, Yoichi Takehara, Geoff McClure, Greg Mitchell, William Belo, Buddy Chan, Heintje Ong Limketkai, John Caldwell, Chieko Abe, Ben Solco, Daniel Barlis, Careen Belo-Solco, Erik Wiradinata, Marcos Coutinho, Michael Cruz

In the absence of the Industry Vice Chair Don Ashley, Charlie Manolis chaired a meeting of the industry group to review the issues raised in the detailed report to the Steering Committee (see Agenda Item 4.2).

One of the key issues with which Don Ashley has been involved in during 2011-12 relates to welfare, which was given prominence following a recent documentary dealing with the harvest of snakes in Asia for the skin trade. The industry group recognised that opposition to the use of wildlife by some NGOs was often philosophically driven, and that welfare was used as a means to raise "public concern" unduly.

It is difficult for the CSG, which is not legal entity, to come out openly in defence of specific cases (eg current situation in South Africa). The group agreed that efforts should continue through involvement in various forums (eg CITES, IUCN, UNCTAD), but also through individual business contacts and consumers generally, to reinforce the positive benefits of trade on crocodilian conservation. Meeting the "problem" head-on with scientifically based information was considered important.

The issue of whether the group should consider the development of "generic" Best Management Practices to guide industry in countries where no guidelines or codes currently exist, was discussed. BMPs could be addressed within the context of the Crocodilian Capacity Building Manual (see CCBM Working Group Report), but no decision was reached by the group on whether it should be pursued as a specific project.

Tomistoma Task Force Report

The TTF group met on 25 May 2012.

Participants: Colin Stevenson (meeting chair), John Brueggen, Jen Brueggen, Scott Pfaff, Joe Wasilewski, K. Robert Pahl, Steve Conners, Anthony Pine, Rambli Ahmad, Bekky Muscher, Matt Shirley, Mark Bezuijen

Since the 20th CSG Working Meeting in 2010, the TTF has achieved some good progress. An update on this progress was given at the CSG Steering Committee meeting (SC Agenda Item 6.1).

Red List Assessment

The CSG is currently reassessing many crocodilian species under the IUCN Red List. The Tomistoma account is being worked on, with a first draft being circulated to species assessors and reviewers. Once this draft is finalised, it will be distributed to other TTF members for comments. After this, it will be submitted to the CSG for final review and forwarding to the IUCN. At this stage, it seems that Tomistoma will remain as "Endangered".

Mesangat

Lake Mesangat in Kalimantan remains critical to Tomistoma, and is recognised also for its Siamese crocodile population - along with other endangered taxa. Whilst there are talks about attaining RAMSAR site status for Mesangat through the TTF, members familiar with the area are cautious, and recommend moving slowly forward with this. It seems that political sensitivity requires such caution.

There is a further study by Agata Staniewicz planned for Lake Mesangat this year, as well as TTF member Rob Stuebing's continuing work in this region. TTF will continue to seek Rob's advice on the Mesangat situation and return to the CSG with an update so that a way forward can be made.

Bruce Shwedick will contact Fernando and update the group on his project in West Kalimantan.

Sumatra

Sumatra was identified in the 2010 Action Plan for Tomistoma for clarification of the species' status. Mark Bezuijen informed us that there is an NGO working in the area, with whom TTF could perhaps link up. These people know the area, the politics, and the people, and are open to helping us with Tomistoma. This is under the Merang REDD Pilot Project, and involves Peat swamp forest conservation. The meeting agreed that this sounded promising. Mark Bezuijen agreed to follow up with this NGO and report back to TTF.

Sarawak

Another key area in the 2010 Action Plan is Sarawak. Rambli Ahmad told the group that although *C. porosus* was the main focus of crocodile action in Sarawak, there are clearly some Tomistoma populations there. He suggested that training is required of forest officials, and also funding support. TTF members agreed that this is something TTF should follow up on.

Fundraising

The TTF was informed of a new non-profit organisation in the USA formed by Dr. Sam Seashole: the Crocodilian Conservation Institute, South Carolina. This organisation is keen to support Tomistoma and offers an effective way for us to raise funds within the USA. Dr. Seashole will be contacted to ensure that he is supportive of this.

The idea of having further fundraising events such as that held in Miami Zoo in 2006 (with a follow-up planned for 2013) was discussed. Colin indicated that whilst he and Bekky Muscher are in Singapore Zoo following this meeting, they will raise the issue with the curator, who has supported TTF in the past. Similarly, there is the opportunity to hold such an event at Madras Crocodile Bank in India. Colin will keep members updated on both issues.

Tomistoma Fund

The newly formed non-profit in the USA was discussed at a separate meeting with its founder Anthony Pine. The outcome was that this is an opportunity for TTF to collaborate with Anthony on fundraising for Tomistoma, as well as offering Anthony a scientific assessment group that he could run his projects past for review. Anthony will be added to the TTF Google group, and we look forward to positive collaborations with him.

Other

There was a call for us to reassess how we want Tomistoma to be perceived - both in our fundraising and awareness work. Tomistoma is not a publicly well-known name. Species such as the Saltwater Crocodile and American Alligator are well-known and readily identifiable to the public, and other crocodilians within the region are Critically Endangered, and hence will have the main focus of study proposals and fund-raising.

Suggestions were that we approach Tomistoma conservation from the habitat perspective: if we drive for peat swamp forest conservation, and use Tomistoma as a representative species within that habitat. This is something that will be discussed within the TTF group itself and an approach can be decided on.

The Tomistoma Husbandry Manual is still in preparation. Given the difficulty in breeding Tomistoma outside of range states, this manual will provide some important information on maintaining and breeding the species in zoos around the world. However, perhaps there is a need for TTF to research/compile some detailed breeding-specific information in order to really improve this facet of keeping Tomistoma and establishing proper breeding groups in zoos.

Summary

The CSGs Tomistoma Task Force has had some good progress toward several of the targets detailed in the 2010 Action Plan. This progress is set to continue in the following period, with several projects already lined up and good leads on other work as well as collaborations that will help us achieve our goals.

Siamese Crocodile Working Group

Participants: Heng Sovannara, Luon Nam, Sam Han, Oudomxoy, Kristian Robert Pahl, Steven Platt, Kumthon Suaroon, Bundit Kullavanijaya, Chanthone Phothitay, Charlie Manolis, Smith Thummachua, Terry Cullen, Yosapong Temsiripong

A meeting was held on 23 May 2012. Participants included government representatives from Cambodia, Lao PDR and Thailand, and researchers working in the Range States (see above).

Yosapong reported that Dr. Parntep Ratanakorn had asked him to discuss the establishment of a Siamensis Crocodile Task Force. The main goal of this Task Force would be to improve networking and communication about *C. siamensis* conservation activities within and between Range States. Proposed positions are: Chairman: Dr. Parntep Ratanakorn (Chairman), country contacts: Cambodia, Heng Sovannara; Vietnam, TBC; Indonesia, TBC; Lao PDR, Chanthone Phothitay; Thailand: Bundit Kullavanijaya, Yosapong Temsiripong.

Specific Terms of Reference will be developed as soon as the Task Force is approved by the CSG Executive. The Task Force would operate under the umbrella of the CSG. During the short period of the meeting, several issues were discussed, some of which could be addressed by the Task Force:

1. Capacity Building: regional training and workshop, community based conservation. Dr. Ratanakorn hopes to have a Sub-regional Workshop for the Siamensis Crocodile Task Force at Mahidol University, Bangkok. Training material will be developed. Community-based conservation has been developed in Lao PDR and Cambodia, which can be shared among Range States. Cross border co-operation has been discussed to stop international illegal trade in live *C. siamensis*.

2. Captive Management: standard marking system, hybridization, trade obstacles. marking system, Cambodia offer to mark wild crocodiles and released crocodiles with both microchip and scute-clipping. Other range states may have more systems. There are still other issues not yet discussed in the meeting for example, hybridization. There is a need to develop a better understanding of the degree to which hybrids can be discerned from external morphology (morphometrics, scale and colour). Farmer Association is another issue not yet discussed. However, Thailand and Cambodia have already established such associations. that work closely with Government.

3. Restoring wild population: re-introduction program. Terry Cullen offered to test DNA upon request. Some re-introductions have already occurred (eg Vietnam in 2000, Cambodia in 2004, and Thailand in 2005). The Thai Government plans to release in Kaeng Krachan National Park and is preparing an awareness program. There is no demand for collecting wild crocodiles into farms. Moreover, each country already has internal control of the trade and movement of the animals. Problem in Vietnam around Cat Tien NP is that poor people may occasionally poach wild crocodiles for food, not for commercial purposes. Robert Pahl proposed that each country set up core area for crocodiles, Cambodia consider stopping fishing in known crocodile habitat around Tonle Sap, and an incentive program for accidentally caught wild crocodiles in exchange for rice. Steve Platt suggested a population viability analysis to prioritize potential release sites.

In summary, Government policy in range states is to sustainably use this species by following the country master plan to continue re-introducing purebred *C. siamensis* into protected areas as well as facilitate trade of the species by helping legal trade in terms of issuing practical regulation and reducing trade obstacles. The transfer of the species from CITES Appendix I to Appendix II was discussed and proposal will be developed in parallel to the increasing wild population and better protection, which will need advice from CSG.

Jamaican Crocodile Conservation Working Group

During discussion of SC Agenda Item 2.8.1 (Jamaican Crocodile Conservation; prepared by P. Ross, B. Wilson, F. Mazzotti, M. Cherkiss, L. Henriques), the Chair asked Perran Ross, Allan Woodward and Joe Wasilewski to convene a working group and develop a recommended plan of action.

The working group met on 21 May, and following consultation with people who were not present at the meeting (Byron Wilson, Frank Mazzotti, Mike Cherkiss, Jeff Beauchamp), but who have been involved with the issue, the following "6-step" action plan was submitted.

The problem is not unique to crocodiles in Jamaica, but is one component of limited internal capacity and complex social and economic issues affecting the conservation of many Jamaican endemic and endangered species, including but not limited to: Jamaican iguana, Jamaican hutia, Yellow- and Black-billed parrots, "many species of endemic birds", skink species, Jamaican skink, ~80% of island's 21 endemic frog species, sea turtle species, Jamaican boa, American Crocodile.

In response, the CSG should do the following:

1. Identify external international NGO and government partners who have interest in any of these species [eg San Diego Zoo, International Iguana Foundation, Disney Company (Iguanas), AZA SSP (Dino Ferri and Jamaican boa), Amphibian groups (to be named), Audubon Society, WCS or WWF, Iguana Specialist Group, Sea Turtle Specialist Group, Bat Conservation International]. Mike Fouraker, Director of the Fort Worth Zoo, has recently established an NGO called the Caribbean Conservation Alliance.

2. Convene a meeting somewhere in the USA to form a consortium and strategize an approach. This meeting should take place in the next few months.

3. Reach out to identify and recruit internal (Jamaican) partners with interest and capacity/leverage to provide support for conservation efforts (any company that has a crocodile, turtle, bird or any other wildlife species in their logo).
   a) Sandals
   b) International Bank of Jamaica

c) Appleton rum
d) Red Stripe beer
e) Dole Company (?)
f) Air Jamaica
g) Royal Caribbean Cruise Line (or other cruise lines that visit Jamaica)
h) Ecotourism Lodges
i) Hope Zoo/Tour boat facility
j) Partnering within the entertainment industry (eg The Bob Marley Foundation)?

4. Initiate an outreach and public education program with Jamaican partners. Here, the primary link would be JET (Jamaican Environment Trust), run by Diana McCauley, arguably the island's most competent and effective environmental advocate. JET has an environmental lawyer on board.

5. Establish, fund and monitor effective protected areas at crucial locations (ie Hellshire Hills/Manatee Bay, Font Hill, Black River. Establishing the Hellshire Hills area as a "World Heritage Site").

6. Acquire funding to conduct a systematic countrywide survey to identify the current status of crocodiles and their habitat, particularly the extent, distribution and success of nesting.

Steps 1 and 2 would initiate this process. The CSG Steering Committee is requested to empower Perran Ross, Joe Wasilewski, Byron Wilson and Frank Mazzotti to start Step 1.