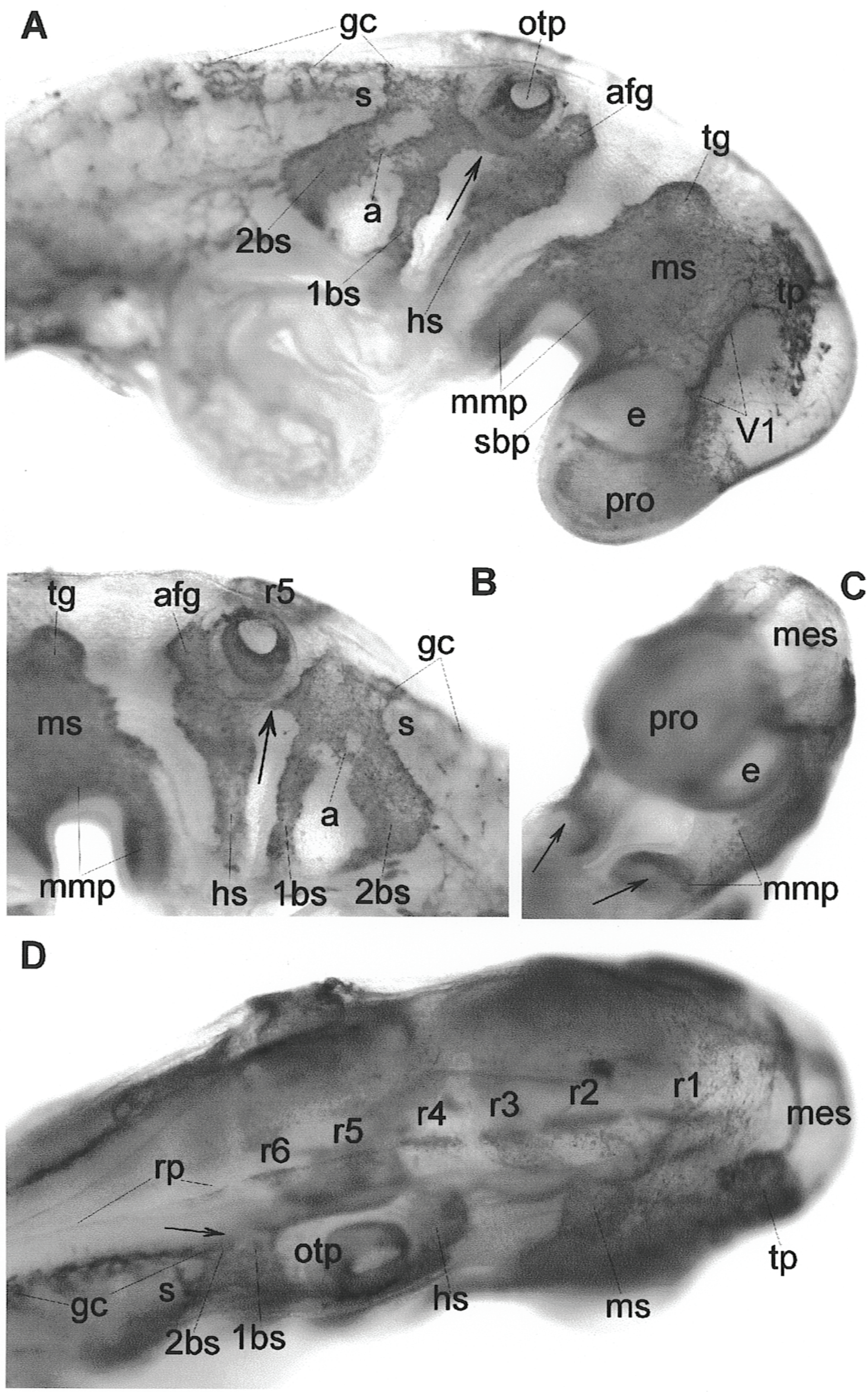

Figure 4. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage D - Day 4 (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.

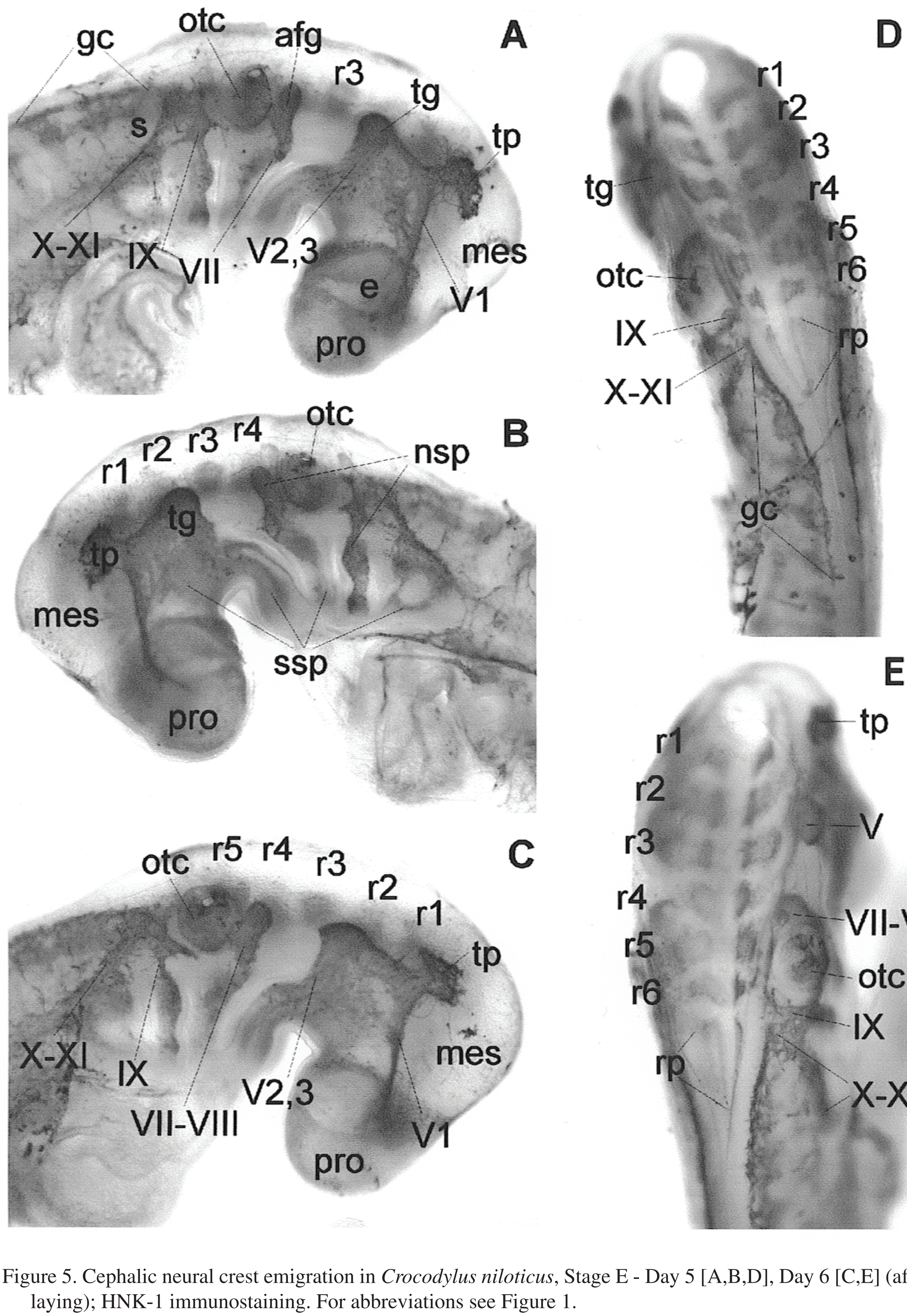

Figure 5. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage E - Day 5 [A,B,D], Day 6 [C,E] (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.

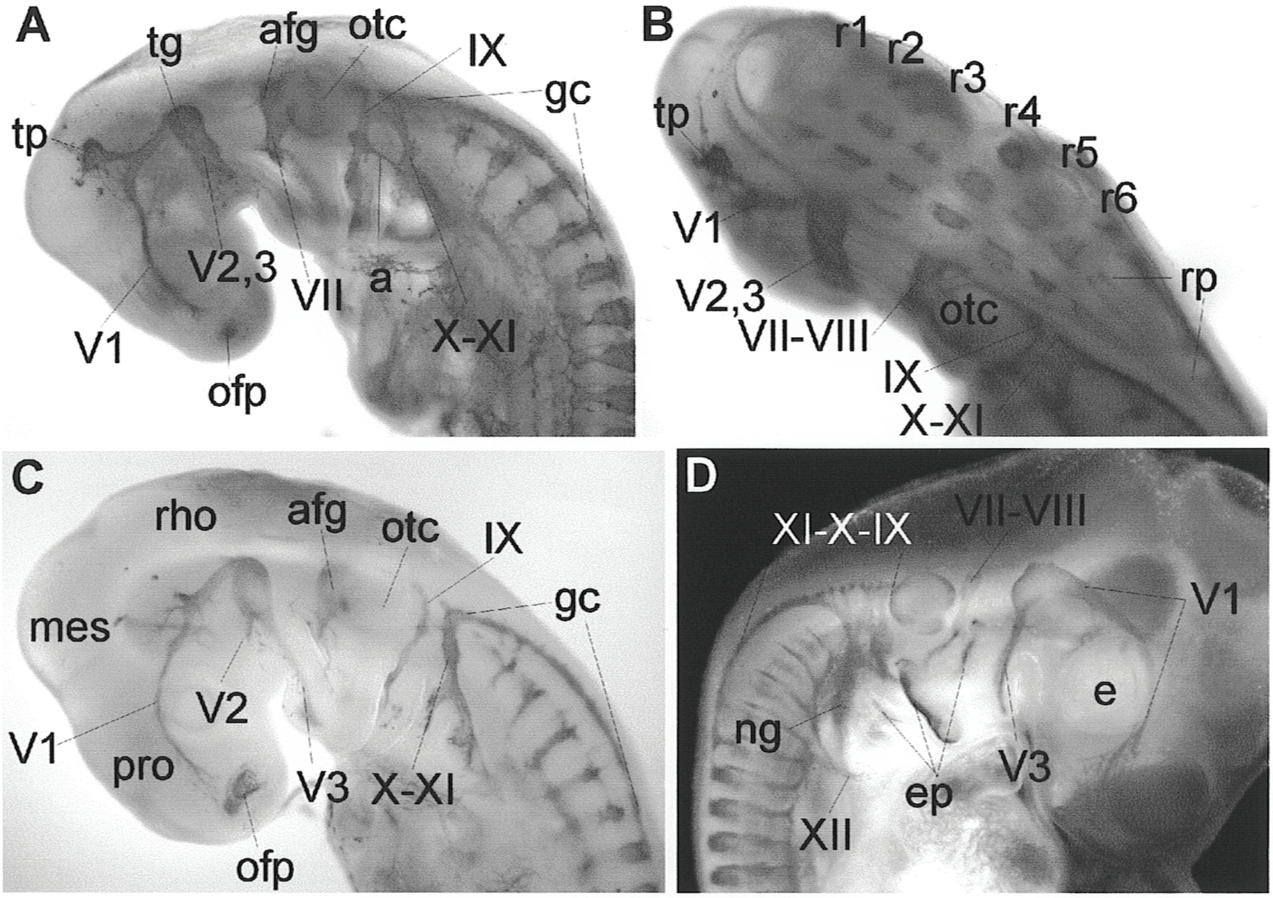

Figure 6. Cephalic neural crest emigration in *Crocodylus niloticus*, Stage F - Day 7 [A,B]; Stage G - Day 8 [C]; Day 11 [D] (after egg laying); HNK-1 immunostaining. For abbreviations see Figure 1.

Distribution of Mercury in the American Alligator (*Alligator mississippiensis*), and Mercury Concentrations in the Species Across its Range

Liberty Moore, I.L. Brisbin, C.H. Jagoe, R.M. Elsey, T.C. Glenn, S.B. Castleberry and C.S. Romanek.

Two studies were conducted to examine mercury concentrations in the American alligator. The first was conducted on alligators from the Rockefeller Wildlife Refuge (RWR), Louisiana, to determine how mercury is distributed among body organ/tissue compartments. Samples from body organ/tissue compartments were tested for mercury (Hg) and stable isotope (^{13}C and ^{15}N) signatures. Relationships between body organ/tissue compartments and non-invasive samples were examined to determine whether concentrations in non-invasive samples could be used to monitor populations non-lethally. Mercury concentrations in all organ/tissue compartments were correlated with each other, body size, and ^{15}N signatures. Mercury was highest in the blood, followed by kidney and liver. Because mercury concentrations from non-lethal samples were correlated with those of the internal tissues, non-lethal sampling methods may be a viable method of indexing mercury in body tissues. The second study involved examining tail muscle and liver samples from wild alligators from the southeast to determine if mercury concentrations varied geographically in the species. The highest Hg concentrations were found in alligators from Glynn County, Georgia and southeast Alabama, while the lowest were found in the alligators from the RWR and the alligator farm. Differences among locations suggested that alligators could be used as biomonitors of mercury in the locations they inhabit.

A Primary Study on Metal Elements of Chinese Alligator *(Alligator sinensis)* Eggs of the Changxing Population

Xu Qianghua[1], Fang Shengguo[1], Wang Zhiping[2], Wang Zhenwei[2] and Hao Yunfei[2]

[1]College of Life Sciences, Zhejiang University, Hangzhou, 310029, Zhejiang, China and The Key Laboratory of Conservation Genetics and Reproductive Biology for Endangered Wild Animals, Ministry of Education, China (sgfang@mail.hz.zj.cn);
[2]Changxing Nature Reserve and Breeding Research Center for Chinese Alligator, Zhejiang, China

Metal concentration especially the heavy ones in eggs affects the development of young alligators. In order to know the living conditions of the Chinese alligators in Changxing, we surveyed the metal concentration in their eggs. Eight metal elements: magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd) and chromium (Cr) are investigated in different parts (eggshell, shell membrane and yolk) of fertilized and unfertilized eggs of Chinese alligators of Changxing population, by the Inductively Coupled Plasma Atomic Emission Spectrometry (ICP–AES). Metal concentrations exhibited distinct concentration orders for the eight elements in different parts of both types of eggs. Furthermore, the different parts of the egg showed dissimilar metal accumulation levels. In addition, the distribution and accumulation of Cu, Zn, Pb and Cd were compared in the corresponding parts of unfertilized eggs of Chinese alligators of Changxing and Anhui populations, and found that: the Changxing population showed much lower heavy metal accumulations.

Influence of Pesticides, Micronutrients, and Fatty Acids on Hatch Rates of Wild, Florida Alligator Eggs

Allan R. Woodward[1], H. Franklin Percival[2] and Dwayne A. Carbonneau[1]

[1]Florida Fish and Wildlife Conservation Commission, 4005 South Main Street, Gainesville, FL 32601, USA (allan.woodward@fwc.state.fl.us, Dwayne.carbonneau@fwc.state.fl.us); [2]USGS, Florida Cooperative Fish and Wildlife Research Unit, Building 810, PO Box 110485, University of Florida, Gainesville, FL 32611-0485, USA (percivalf@wec.ufl.edu)

American alligator (*Alligator mississippiensis*) egg viability (the probability of an egg hatching) has been variable among Florida lakes. Lakes Apopka, Griffin, Jesup, Hancock, Monroe, George, and Okeechobee have exhibited chronically depressed egg viability since monitoring began in the 1980s. Further, Lakes Apopka and Griffin have experienced acute declines in egg viability during the last 20 years, followed by recoveries. We examined the relation of egg viability with nest and clutch characteristics to see if natural factors were associated with depressed egg viability. No obvious associations were detected between nest material and egg viability. Clutch size from areas with depressed egg viability is greater than high viability areas and may be associated with nutrient levels. Lakes with chronically depressed egg viability have been associated with agricultural effluents. Therefore, we examined the association of egg viability with organochlorine (OC) compounds and nutrient levels on two areas with chronically low egg viability (Lake Apopka and Lake Griffin) and two areas with high egg viability (Lake Orange-Lochloosa and Lake Woodruff National Wildlife Refuge). We found concentrations of OC compounds, DDE and toxaphene, to be significantly greater on Lake Apopka egg yolks than in yolks from lakes Griffin, Orange-Lochloosa, and Woodruff, but we could not detect a significant linear association between egg viability and these compounds. We did detect an indication of a threshold effect - eggs with concentrations of DDE or toxaphene $\geq$1 ppm had a lower probability of hatching than those with concentrations <1.0 ppm. We also examined the association of egg viability with vitamins A and E, which are important in early development of embryos. Vitamin A concentrations in egg yolks did not differ significantly, but Vitamin A concentrations were lower on Lakes Apopka and Griffin relative to reference lakes.

Ecotoxicology of Crocodiles in Central America

Thomas R. Rainwater, T.H. Wu, A.G. Finger, J.C. Cañas, L. Yu, K.D. Reynolds, G. Combiatore, B. Barr, W.B. Karesh, John B. Thorbjarnarson, Steven Platt, G.P. Cobb, T.A. Anderson and S.T. McMurry

Over the last 30 years, numerous studies have documented exposure of wild crocodilians to environmental contaminants, particularly organochlorine (OC) pesticides and metals. Recent evidence of population declines and reproductive impairment in American alligators (*Alligator mississippiensis*) inhabiting contaminated wetlands in Florida, USA has increased concerns over the effects of these chemicals on other crocodilian populations living in contaminated habitats. In Central America, habitat loss and direct persecution by humans are the greatest conservation concerns for Morelet's (*Crocodylus moreletii*) and American (*C. acutus*) crocodiles; however, exposure to environmental contaminants may present a subtle yet significant long-term threat to populations in this region and warrants greater attention. We recently reported OCs and mercury in *C. moreletii* and *C. acutus* eggs from Belize. In this paper, we present new data on contaminants detected in crocodile tissues from Belize as well as results of a study examining biological effects of contaminant exposure on wild *C. moreletii*. In addition, we also present the first report of contaminants in *C. acutus* in Costa Rica. Finally, we identify data gaps and provide recommendations for future ecotoxicological studies on Central American crocodilians.

NMR Studies of Water Transport and Metabolism in Crocodile Erythrocytes

Christopher J. Garvey[1,2], Kerie Hammerton[1], William A. Bubb[2], Bogdan E. Chapman[2] and Philip W. Kuchel[2]

[1]Australian Nuclear Science and Technology Organisation, Menai, NSW 2234, Australia;
[2]School of Microbial and Molecular Biosciences, University of Sydney, NSW 2006, Australia

Vertebrate blood is a chemically and physically complex fluid that serves largely a transport function. About 20% of the volume of crocodilian blood is contained within red blood cells (RBCs). Blood is metabolically active with each RBC consuming energy to maintain a transmembrane ionic disequilibrium and to maintain its shape via an energy-consuming cytoskeleton. Both aspects support the role of the RBC as a gas transporter. The cell membrane contains many membrane transporters that facilitate solute transport across it. There are also cytoskeletal proteins associated with the anion transporter band 3, and in RBCs from many species a water transporter, aquaporin. There are some fundamental differences in the physiology and biochemistry of crocodilian RBCs compared with their mammalian counterparts; these are linked to the regulation of oxygen affinity by haemoglobin that have led us to investigate the biochemistry and water transport in actively metabolising RBCs using the non-destructive technique of pulsed nuclear magnetic resonance (NMR) spectroscopy. In most vertebrates organic phosphates are the key regulators of the affinity of O_2 for haemoglobin. In crocodiles HCO_3^- ions fulfil this role (Grigg *et al.* 1999). There is an intimate connection between metabolic activity and oxygen affinity and in the case of the HCO_3^- it is formed directly from CO_2 as oxygen is consumed in the cell, while for organic phosphates in mammals there is complex metabolic control involving many chemical species (Mulquiney *et al*. 1999). On the other hand, the transport of HCO_3^- through crocodilian RBC membranes appears to be fundamentally similar to that in humans (Jensen *et al.* 1998).

^{1}H, ^{13}C and ^{31}P NMR spectra were acquired from suspensions of *Crocodylus porous* RBCs. The time courses of metabolism by crocodile RBCs yielded high-resolution spectra and identified the fact that carbon monoxide causes a marked decline in metabolic rate. Like in humans both glucose and inosine are substrates for crocodile RBCs. We also measured the water transport rates in crocodile RBCs using an NMR Mn-doping method. High quality data were obtained for a range of temperatures. Thus, an Arrhenius analysis revealed a temperature dependence of the exchange rate that is like that found with birds; it implies a lack of specific aquaporin exchange pathways in the RBC membrane. Water diffusion in and around crocodile RBCs was studied using *q*-space analysis based on pulsed field gradient spin-echo (PGSE) NMR spectroscopy. The *q*-space plots reflected a larger size distribution in the crocodile RBCs than human RBCs confirming optical microscopy measurements.

Literature

Grigg, G.C., Wells, R.M.G. and Beard, L.A. (1993). Allosteric control of oxygen binding of haemoglobin. J. Exp. Biol. 175: 1127-1134.

Jensen, F.B., Wang, T., Jones D.R. and Brahm J. (1998). Carbon dioxide transport in alligator blood and its erythrocyte permeability to anions and water. Am. J. Physiol. 274: R661-R671.

Mulquiney, P.J., Bubb, W.A. and Kuchel, P.W. (1999). Model of 2,3-bisphosphoglycerate metabolism in the human erythrocyte based on detailed enzyme kinetic equations: *in vivo* kinetic characterisation of 2,3-bisphosphoglycerate synthase/phosphatase using ^{13}C and ^{31} P NMR. Biochem. J. 342: 581-596.

Diving Behaviour of Freshwater Crocodiles (*Crocodylus johnstoni*) in the Wild: Correlations with Heart Rate and Body Temperature

Craig E. Franklin[1], Frank Seebacher and Mark Read

[1]School of Life Sciences, The University of Queensland, Brisbane, Australia

The aim of this study was to describe the diving behaviour of the freshwater crocodile *Crocodylus johnstoni* in the wild, and to assess the relationships between diving, body temperature and heart rate. We captured freshwater crocodiles from a permanent waterhole (approx. 150 m x 20 m, with a maximum water depth of 3.5 m) at Lakefield National Park, Queensland, Australia, during July 2003. Time-depth recorders, temperature sensitive radio transmitters, and heart rate transmitters were deployed on six *C. johnstoni* (4.0-26.5 kg), and data were obtained from five animals. Crocodiles showed the greatest diving activity in the morning (6:00-12:00), and were least active at night, remaining at the water surface. Surprisingly, activity pattern was asynchronous with thermoregulation and activity was correlated to light rather than to body temperature. Nonetheless, crocodiles thermoregulated, and showed a typical heart rate hysteresis pattern (heart rate during heating greater than heart rate during cooling) in response to heating and cooling. Additionally, dive length decreased with increasing body temperature. Maximum diving length was 119.6 min, but the greatest proportion of diving time was spent on relatively short (<45 min) and shallow (<0.4 m) dives. A bradycardia was observed during diving, although heart rate during submergence was only 12% lower than when animals were at the surface.

Movements of *Crocodylus porosus* in the Kimberley Region of Western Australia: Integrating Genetic and Radio-Tracking Data

Winston R. Kay[1], Nancy N. Fitzsimmons[2] and Gordon C. Grigg[1]

[1]The University of Queensland, Brisbane, QLD 4072, Australia (wkay@zen.uq.edu.au);
[2]University of Canberra, ACT 2601, Australia (Nancy.FitzSimmons@canberra.edu.au)

VHF radio tags were attached to 16 estuarine crocodiles, which were tracked between October 2001 and May 2003. During the same period, 123 tissue samples were collected from three Kimberley river systems spanning a broad geographical range. Genetic diversity was similar in all three populations examined and inbreeding coefficients indicated there was only moderate differentiation among populations (F_{ST} = 0.08). However, differences in allele frequencies among populations were highly significant. Furthermore, assignment tests designated 80% of individuals to their population of origin and identified only five individuals (4%) as first generation migrants. Radio-tracking data corroborated genetic data, which indicated *Crocodylus porosus* shows strong site fidelity. Furthermore, male and female crocodiles showed distinctly different patterns of movement. Females occupied a small core area (15 ± 7 ha) on the main channel of the Ord River during the dry season and moved distances of up to 62 km to nesting habitat during the wet season. Males moved considerable distances along the Ord River throughout the year. Rates of male movement appeared to be bi-modally distributed and did not significantly differ between three size classes. There were significant seasonal differences in rates of male movement, with the highest mean rates occurring during the summer wet season (4.0 ± 5.4 km/d).

Life History of *Caiman yacare* in the Brazilian Pantanal

Marcos Coutinho[1], Zilca Campos[2], Gordon Grigg[3] and Hamish McCallum[3]

marcos.Coutinho@ibama.gov.br, zilca@cpap.embrapa.br, ggrigg@zen.uq.edu.au, hmccallum@zen.uq.edu.au

The understanding of population dynamics requires knowledge about age-dependent schedules of birth and death, together with their relationship to population rate of increase, age and size at maturity and reproductive performance. These parameters are, therefore, major components of the biological background required for development of wildlife conservation and management strategies. In this paper we present some of the data obtained from a long-term study of caiman (*Caiman yacare*) life history in the Pantanal Wetland, Brazil. Firstly, we focused on feeding and body condition and how they change during ontogeny and in response to seasonal changes in the environment. This was followed by an analysis of reproductive biology, with the main goal of integrating physiological and demographic data to further extend the understanding of the relationships between gonad activity, body condition and environmental variables. Next, a quantitative assessment of caiman growth was made, based on cross-sectional and longitudinal sampling. Finally, patterns in size and sex-specific growth rates were described and an attempt made to determine the ways in which individual growth relates to the environment and life history traits. The results provide important insights into the ecology of caimans, and also the evolution of crocodilian life histories

Movements of Adult-Sized Estuarine Crocodiles (*Crocodylus porosus*) Tracked by Satellite Telemetry

Mark A. Read[1], Gordon C. Grigg[2], Craig E. Franklin[2] and Steve Irwin[3]

[1]Queensland Parks and Wildlife Service, PO Box 2066, Cairns, QLD 4870, Australia; [2]Department of Zoology and Entomology, The University of Queensland, St Lucia, QLD 4072, Australia; [3]Australia Zoo, Glasshouse Mountains Tourist Route, Beerwah, QLD 4519, Australia

We report preliminary results from a study of movement by mature *C. porosus* using satellite telemetry. Determining the movement patterns of any cryptic wild animal is always difficult, but when the animal is also shy, semi-aquatic and potentially dangerous to capture and manipulate, it becomes particularly challenging. Movement patterns of estuarine crocodiles (*C. porosus*) could not be studied by direct observation, even if individuals could be recognised. Some data has been gained successfully from crocodiles and alligators by conventional radio telemetry, but the observer or the receiving equipment needs to be close to the subject and there is too much potential for intrusion to modify the behaviour of these naturally shy and wary animals. Broad-scale, long-distance movements have been recorded using mark-recapture techniques, but this technique provides no information on movements between captures. The use of satellite telemetry avoids most of these difficulties because location data can be gained remotely, without the observer needing to be nearby, several times a day and for months at a time.

This paper summarises the results of a pilot study of six adult-sized estuarine crocodiles (1 female, 2.65 m TL; 5 males, 3.14 to 4.93 m TL) fitted with satellite transmitters, a world first for this species. The satellite transmitters provided high quality position locations for periods ranging from five weeks to more than nine months, allowing movement patterns and home ranges to be determined. Highlights of the preliminary data include observations of regular use of the adjacent ocean by four of the six animals and apparent homing behaviour by a translocated *C. porosus*.

The Influence of Weather Conditions on Caiman Night-counts

Fabianna Sarkis-Gonçalves, Ana Maria V. Castro and Luciano M. Verdade

Animal Ecology Lab, ESALQ, University of São Paulo,
PO Box 09, Piracicaba, SP, 13418-900, Brazil (lmv@esalq.usp.br)

Abstract

Although often assumed as imprecise and inaccurate, most surveys on crocodilians' populations are based on night counts. At the present study, two observers conducted 52 night counts of broad-snouted caimans (*Caiman latirostris*) in a 12-month period at the facilities of the Caiman Project of the University of São Paulo in Piracicaba, State of São Paulo, Brazil (22°42.557' S, 47°38.246' W). Besides possible individual observers' bias we evaluated the influence of the following weather variables on the precision and accuracy of night counts: air and water temperature, rain, wind, and moonlight (phase and visibility). Night-counts can be precise, highly correlated with real population size, and reliable in long-term studies even with different observers. Weather conditions such as rain, wind, and ambient temperature did not influence night-counts in the controlled conditions of the present study. Moonlight and caiman body-size influenced the number of animals counted (the darker the better, and the smaller the animal the more accurate the counting). Future studies on the influence of aquatic vegetation on the efficiency of night counts are urged.

Introduction

Although species are internationally recognized as the legal unity of conservation (Hemley 1994; Moulton and Sanderson 1997), populations are possibly the most adequate unities of management (Caughley and Gunn 1996). According to Caughley (1977), wildlife management should have one of the following goals: raise a population that has been depleted, control a population that is too dense, harvest a population for a continuous yield, or leave it alone but with an eye on it. The last applies to populations that do not fit into any of the former categories. The first is usually the main goal of conservation programs, the second is usually the main goal of wildlife control programs, and the third is the main goal of harvest programs. However, to diagnose the population status and its best management option among the four above it is necessary to have a good idea about its abundance in both space and time (Caughley and Sinclair 1994).

Estimating wildlife abundance is a sampling procedure which usually requires scientific approach and statistical methodology involving replication in space and time or at least in one of them depending on what kind of diagnostics is intended to be made (Krebs 1989; Skalski and Robson 1992). Ecological censuses generally involve one or some of the following goals: describing the interest of sites, estimating population size, monitoring population changes, determining the habitat requirements of a species, determining why species have declined, monitoring habitat management, and monitoring population dynamics (Sutherland 1996).

The following techniques have been developed for surveying crocodilians: interviews and opportune personal observations, surveys from artifacts, daylight ground counts, daylight surveys from aircraft, and night counts (Magnusson 1982; Mourão *et al*. 1994). Night counts are usually done from a moving boat with the aid of a spotlight. The reflective tapetum of the crocodilian's eyes glows red in a spotlight and can be seen at a considerable distance (Chabreck 1966).

Although night-counts are reasonably assumed to be an inaccurate abundance index (Abercrombie 1995; Abercrombie and Verdade 1995), they may be relatively precise (ie with a low standard error) when replicated (Bayliss 1987). For these reasons night counts have been extensively used in surveying and monitoring crocodilians populations (Messel *et al*. 1980; Brazaitis *et al*. 1988; Messel and Vorlicek 1989a, 1989b, 1989c; Thorbjarnarson and Hernández 1992; Velasco and Ayarzaguena 1995; Mourão and Campos 1995).

The following information can be reasonably taken from crocodilians night counts: population age/size structure, population sex ratio, and distribution of habitats in the area surveyed (Magnusson 1982, 1993, 1995; Magnusson and Mourão 1997). Those are the basic variables for the establishment of mathematical models of population fluctuation (Nichols 1987; Abercrombie and Verdade 1995; Johnson 1996).

Environmental factors, such as ambient temperature, wind speed, luminosity, vegetation and others can influence the number of animals counted at night (Bayliss 1987). However, since it is virtually impossible to know the real populations of crocodilians in the wild, experimental design has been rarely used to determine the efficiency of the method (Larriera *et al*. 1992; Pacheco 1996). This is the main goal of the present study.

Materials and Methods

Fifty-two night counts of broad-snouted caimans were conducted from May 1996 to May 1997 at the facilities of the Caiman Project of the University of São Paulo in Piracicaba, State of São Paulo, Brazil (22°42.557' S, 47°38.246' W). The night counts were conducted by two observers from 2130 to 2230 h on a weekly basis.

The animals were divided into five separate pens (16 x 4 m) of young (SVL < 50cm) and four pens (12 x 10 m) of adults (SVL $\geq$60 cm) (Table 1). Each young- and adult-pen contained a cemented pool (12 x 2 m x 75 cm deep and 9 x 6 m x 100 cm deep, respectively). Young-pens were placed in line, as well as the adult-pens, but the two facility groups were located approximately 250 m far from each other. All enclosures were located on fenced areas with restricted visitation and no electric light. The disposition and number of caimans per enclosure remained constant during the period of study (Table 1).

Table 1. Numbers of caimans per enclosure. J1-J5= Young-pens; AR1-AR4= Adult-pens.

Enclosure	No. of Animals
J1	20
J2	16
J3	34
J4	31
J5	10
AR1	4
AR2	5
AR3	6
AR4	6

During night-counts, observers approached quietly and separately and stayed out of the pens focusing the animals with a 12 V 15,000 c.p. sealed-beam spotlight [as described by Woodward and Marion (1978)] at an approximate distance of 10 to 20 m from the animals. Batteries were fully charged upon initiation of each session. Observers counted individually and secretively the animals by the reflection of the spotlight in their eyes. The animals were introduced to the pens at least six months before the beginning of the present study and were previously habituated to the presence of the observers.

Besides possible individual observers' bias we evaluated the influence of the following weather variables on the precision and accuracy of night counts: air and water temperature, rain, wind, and moonlight (phase and visibility). Temperature was measured with a bulb thermometer (1°C precision). Rain and wind were treated as "nominal scale" variables (Freund and Wilson 1992) with the following levels: absent, low, moderate, and strong.

In order to compare observers precision we used correlation analysis (Sokal and Rholf 1995). In order to establish statistical relationships between observers counts and real populations we used regression equations (Brown and Rothery 1993). In order to evaluate the influence of weather conditions on the efficiency of night-counts we used analysis of covariance (ANCOVA) (Zar 1996) having the weather conditions as covariates. Statistical analyses were run in Minitab for Windows 13 (Minitab 2000).

Results

There was a high correlation between observers (P<0.000, r= 0.995). There was also a high correlation between observers and real population (P<0.000, r= 0.995) and no significant variation between observers along the study period (ANCOVA, P= 0.677).

The following linear models could be established between observers' night-counts and real populations (N= real population, Nc= night-count):

N= 2.02711 + 1.09778Nc$_1$ (P<0.000, r^2 = 0.919 for Observer 1)

N= 2.99757 + 1.07920Nc$_2$ (P<0.000, r^2 = 0.920 for Observer 2)

Neither air temperature (11°C min., 31°C max.) nor water temperature (12°C min., 30°C max.) influenced night-counts (ANCOVA: P= 0.681 to 0.772; ANCOVA: P= 0.762 to 0.853, respectively). Similarly, neither rain (ANCOVA, P= 0.391) nor wind speed (ANCOVA, P= 0.875) significantly influenced night-counts.

On the other hand, moon phases influenced night-counts (ANCOVA, P<0.000). The Analysis of Mean (ANOM) (Ott 1983; Ramig 1983) showed the following results: New (a) ≥ First quarter (ab) ≥ Second quarter (bc) ≥ Full (c), with different letters meaning different results at 95% confidence level.

Moon presence/absence influenced night-counts (ANCOVA: P= 0.032; ANOM: Absent>Present). Body-size influenced night-counts (ANCOVA: P= 0.003; ANOM: Young>Adult).

Discussion

In controlled situations such as the present study night counts can be highly correlated with real population (ie accurate). In addition, night counts from distinct observers can be highly correlated (ie precise), and consistent along time (ie reliable). However, the present study does not take into account the influence of floating vegetation which can significantly affect animals detectability. There was no aquatic plant at the pools during the present study. Vegetation can affect night-counts because they can physically prevent observers of detecting the animals. Since vegetation can drastically change both in time and space even in small scale during monitoring programs this factor should be experimentally tested in future studies.

Surprisingly, at the present study we found different patterns than previous studies involving caimans and other crocodilians. A positive correlation between the number of animals counted and the maximum air temperature of the day was found for non-hatchlings *Alligator mississippiensis* (Woodward and Marion 1978), *Crocodylus niloticus* (Hutton *et al*. 1989), *Caiman latirostris* (Larriera *et al*. 1992), and *Melanosuchus niger* (Pacheco 1996). Small crocodilians seem to thermoregulate differently from the adults being active at lower temperatures (Diefenbach 1975a, 1975b). However, at the present study neither air nor water temperature at the moment of the counting significantly affected the number of animals sighted. The temperature range during the present study (from 11 to 31°C and from 12 to 30°C for air and water, respectively) quite likely covers the normal ambient temperatures the species experience in the wild in São Paulo State, Brazil. Therefore, the captive environment has not dramatically affected this variable.

On the other hand, there is a strong relationship between temperature and feeding behavior in heterotherms such as crocodilians (Lang 1987; Diefenbach 1988; Verdade *et al*. 1992), in a way that animals need to attain certain thermal (ie metabolic) levels in order to favor prey apprehension, ingestion, and digestion. Considering that feeding behavior is drastically modified in captivity - where basically all food is furnished "for free" at roughly regular intervals - thermoregulatory behavior can possibly explain why ambient temperature did not affect night counts, contrary to the pattern found in the wild in other studies.

Wind speed was the environmental variable that had the greatest effect on *Melanosuchus niger* night counts (Pacheco 1996) either because of its association (ie negative correlation) with ambient temperature or because crocodilians actively avoid the wave action caused by strong winds (Mazzotti 1989). However, at the present study the occurrence of wind did not affect the number of animals counted. A possible explanation for this is that there was no significant wave action due to the wind because of the small area of the pools and the possible windbreak action of the fences.

The cloud cover had a consistent negative effect on *Melanosuchus niger* counts either because of its possible association with wind speed (Pacheco 1996) and by extension with ambient temperature or because of possible disorientation of animals (as described by Murphy (1981) for juvenile alligators under full cloud cover). However, at the present study cloud cover and the occurrence of rain did not significantly affect night counts. A possible reason for this is its possible association with ambient temperature, not found correlated with night counts at the present study as described above.

Surprisingly Larriera *et al*. (1992) did not find any significant correlation between moonlight and night counts of *Caiman latirostris*. The most developed sense organ of crocodilians seems to be the vision (Bellairs 1971). Moonlight quite likely increases animals detectability by the observers. However, it also possibly improves observers detectability by the animals which usually results in their retreat or diving which in its turn makes them no longer visible (Bayliss 1987). This agrees with the pattern found at the present study where both moon phase and presence consistently affected the number of animals counted, decreasing from new to full moon. The evident association between moon phase and luminosity is reinforced at the present study by the consistent relationship between moon visibility (ie presence or absence) and the number of animals counted, significantly higher when moon is not visible than otherwise.

The efficiency of night counts at the present study was also influenced by caimans body size similarly to previous studies (Giles and Childs 1949; Woodward and Marion 1978; Pacheco 1996). Young individuals were more detectable than adults possibly because adults tend to be more wary (Webb and Messel 1977; Hutton *et al*. 1987; Pacheco 1993; Verdade *et al*. 2002).

Rarely - to say the least - wild populations of crocodilians can be monitored under controlled situations such as the present study. However, the experimental manipulation of environmental variables in order to better understand how they influence night counts of crocodilians in the "real world" is desirable. It is virtually impossible to assess the real number of individuals from a wild population of caimans or crocodiles, which is necessary to determine the local accuracy - not only precision - of the method and validate populational fluctuation models. This is usually only feasible under controlled experiments.

Conclusions

Night-counts can be precise and highly correlated with real population size. Linear models can be established between observers' night-counts and real population size. Night-counts are reliable in long-term studies even with different observers. The accuracy and precision of night-counts can be affected by the moonlight (the darker the better) as well as by animals' body size (the smaller the animal the more accurate the counting). However, weather conditions such as rain, wind, and ambient temperature can be surprisingly irrelevant. Future studies on the influence of aquatic vegetation on the efficiency of night counts are urged.

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Literature

Abercrombie, C.L. (1989). Population dynamics of the American alligator. Pp. 1-16 *in* Crocodiles: their Ecology, Management, and Conservation. IUCN: Gland.

Abercrombie, C.L. and Verdade, L.M. (1995). Dinâmica populacional de crocodilianos: elaboração e uso de modelos. Pp. 33-55 *in* Conservación y manejo de los crocodylia de America Latina. Volume 1, ed. by A. Larriera and L.M. Verdade. Fundación Banco Bica: Santo Tomé, Santa Fe, Argentina.

Bellairs, A. d'A. (1971). The senses of crocodilians. Pp. 181-191 *in* Crocodiles. Proceedings of the 1st Working Meetingof the Crocodile Specialist Group. New York, 15-17 March 1971. IUCN: Gland.

Bayliss, P. 1987. Survey methods and monitoring within crocodile management programmes. Pp. 157-175 *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.

Brazaitis, P., Yamashita, C. and Rebelo, G. (1988). CITES Central South American Caiman Study Phase I: Central and Southern Brazil. CITES: Geneva, Switzerland.

Brown, D. and Rothery, P. (1996). Models in Biology: Mathematics, Statistics and Computing. John Wiley and Sons: Chichester, England.

Caughley, G. (1977). Analysis of Vertebrate Populations. John Wiley and Sons: Chichester, England.

Caughley, G., and Sinclair, A.R.E. (1994). Wildlife Ecology and Management. Blackwell: Cambridge, Massachusetts, USA.

Caughley, G. and Gunn, A. (1996). Conservation Biology in Theory and Practice. Blackwell: Cambridge, Massachusetts, USA.

Chabreck, R.H. (1966). Methods of determining the size and composition of alligator populations in Louisiana. Proc. Annu. Conf. S.E. Assoc. Game Fish Comm. 20: 105-112.

Diefenbach, C.O. da C. (1975a). Thermal preferences and thermoregulation in *Caiman latirostris*. Copeia 1975: 530-540.

Diefenbach, C.O. da C. (1975b). Gastric function in *Caiman crocodilus* (Crocodylia: Reptilia) I. Rate of gastric digestion and gastric motility as a function of temperature. Comp. Biochem. Physiol. 51A: 259-265.

Diefenbach, C.O. da C. (1988). Thermal and feeding relations of *Caiman latirostris* (Crocodylia: Reptilia). Comp. Biochem. Physiol. 89: 149-155.

Freund, R.J. and Wilson, W.J. (1992). Statistical Methods. Academic Press, Boston.

Giles, L.W. and Childs, V.L. (1949). Alligator management of the Sabine National Wildlife Refuge. J. Wildl. Manage. 1391): 16-28.

Hemley, G. (1994). International Wildlife Trade; A CITES Sourcebook. Island: Washington, D.C.

Hutton, J.M., Loveridge, J.P. and Blake, D.K. (1987). Capture methods for the Nile crocodile in Zimbabwe. Pp. 243-247 *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.

Johnson, D.H. (1996). Population analysis. Pp. 419-444 *in* Research and Management Techniques for Wildlife and Habitats, ed. by T A. Bookhout. The Wildlife Society: Bethesda, Maryland, USA.

Krebs, C.J. (1989). Ecological Methodology. HarperCollins: New York.

Lang, J. (1987). Crocodilian 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 and Sons: Chipping Norton.

Larreira, A. and Del Barco, D. (1992). Environmental variables and its incidence on *Caiman latirostris* counts. Pp. 256-260 *in* Crocodiles. Proceedings of the 11th Working Meeting of the IUCN-SSC Crocodile Specialist Group. Victoria Falls, Zimbabwe, 2-7 August 1992 IUCN: Gland.

Magnuson, W.E. (1982). Techniques for surveying crocodilians. Pp. 389-403 *in* Crocodiles. Proceedings of the 5th Working Meeting of the IUCN-SSC Crocodile Specialist Group. Gainesville, Florida, USA, 12-16 August 1980. IUCN: Gland.

Magnusson, W.E. (1993). Práticas de campo na pesquisa com jacarés. Pp. 71-80 *in* Anais do III Workshop sobre Conservação e Manejo do Jacaré-de-Papo-Amarelo (*Caiman latirostris*), ed. by L.M. Verdade, I.U. Packer, M.B. Rocha, F.B. Molina, P.G. Duarte and L.A.B.M. Lula. São Paulo, SP, Brasil, 26-28 October 1992. ESALQ/ USP: Brazil.

Magnuson, W.E., and Mourão, G.M. (1997). Manejo extensivo de jacarés no Brasil. Pp. 214-221 *in* Manejo de Vida Silvestre para a Conservação. Sociedade Civil Mamirauá, ed. by C.B. Valladares-Pádua, R.E. Bodmer and L. Cullen, Jr. Mamirauá, AM: Brasil.

Mazzotti, F.J. (1989). Structure and function. Pp. 42-57 *in* Crocodiles and Alligators, ed. by C.A. Ross. Golden: Sydney.

Messel, H. and Vorlicek, G.C. (1989a). A model for the population dynamics of *Crocodylus porosus* in northern Australia. Pp. 184-227 *in* Crocodiles: Their Ecology, Management, and Conservation. IUCN: Gland, Switzerland.

Messel, H. and Vorlicek, G.C. (1989b). Status and conservation of *Crocodylus porosus* in Australia. Pp 138-163 *in* Crocodiles: Their Ecology, Management, and Conservation. IUCN: Gland, Switzerland.

Messel, H. and Vorlicek, G.C. (1989c). Ecology of *Crocodylus porosus* in northern Australia. Pp. 164-183 *in* Crocodiles: Their Ecology, Management, and Conservation. IUCN: Gland, Switzerland.

Messel, H., Vorlicek, G.C., Wells, A.G. and Green, W.J. (1980). Surveys of the tidal river systems in the northern territory of Australia and their crocodile populations. Monograph 14: Tidal Waterways of Van Diemen Gulf. Ilamaryi River, Iwalg, Saltwater and Minimini Creeks and Coastal Arms on Cobourg Peninsula Resurveys of the Alligator Region Rivers. Pergamon: Sydney.

Minitab. (2000). Minitab for Windows Release 13. Minitab, Inc. State College, PA, USA.

Moulton, M.P. and Sanderson, J. (1997). Wildlife issues in a changing world. St. Lucie: Delray Beach, Florida.

Mourão, G.M., Bayliss, P., Coutinho, M.E., Abercrombie, C.L. and Arruda, A. (1994). Test of an aerial survey for caiman and other wildlife in the Pantanal, Brazil. Wildlife Society Bulletin 22: 50-56.

Mourão, G.M. and Campos, Z. (1995). Survey of broad-snouted caiman *Caiman latirostris*, marsh deer *Blastocerus dichotomus* and capybara *Hydrochaeris hydrochaeris* in the area to be inundated by Porto Primavera Dam, Brazil. Biological Conservation 73: 27-31.

Murphy, P.A. (1981). Celestial compass orientation in juvenile American alligator (*Alligator mississippiensis*). Copeia 1981: 638-645.

Nichols, J.D. (1987). Population models and crocodile management. Pp. 177-187 *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.

Ott, E.R. (1983). Analysis of Means: A graphical procedure. Journal of Quality Technology 15: 10-18.

Pacheco, L.F. (1993). Abundance, distribution, and habitat use of crocodilians in Beni, Bolívia, Bolívia. Thesis, University of Florida, Gainesville, USA.

Pacheco, L.F. (1996). Effects of environmental variables on black caiman counts in Bolívia. Wildlife Society Bulletin 24(1): 44-49.

Ramig, P.R. (1983). Applications of the analysis of means. Journal of Quality Technology 15: 19-25.

Skalski, J.R., and Robson, D.S. (1992). Techniques for wildlife investigations: design and analysis of capture data. Academic Press: San Diego.

Sokal, R.R. and Rholf, F.J. (1995). Biometry. Third edition. Freeman: New York.

Sutherland, W.J. (1996). Why census? Pp. 1-10 *in* Ecological Census Techniques: A Handbook, ed. by W.J. Sutherland. Cambridge University: Cambridge, U.K.

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.

Velasco, A. and Ayarzaguena, J. (1995). Situación actual de las poblaciones de baba (*Caiman crocodilus*) sometidas a aprovechamiento comercial en los llanos venezolanos. Publicaciones de la Asociación de Amigos de Doñana 5: 1-71.

Verdade, L.M., Michelotti, F., Rangel, M.C., Cullen, L. Jr., Ernandes, M.M. and Lavorenti, A. (1992). Manejo alimentar de filhotes de jacarés-de-papo-amarelo (*Caiman latirostris*) em cativeiro. Pp. 77-91 *in* Anais do II Workshop sobre Conservação e Manejo do Jacaré-de-Papo-Amarelo (*Caiman latirostris*), ed. by L.M. Verdade and A. Lavorenti. Piracicaba, SP, Brasil, 7-8 October 1991. ESALQ/USP.

Verdade, L.M., Zucoloto, R.B. and Coutinho, L.L. (2002). Microgeographic variation in *Caiman latirostris*. Journal of experimental Zoology 294(4): 387-396.

Webb, G.J.W. and Messel, H. (1977). Crocodile capture techniques. Journal of Wildlife Management 41: 572-575.

Woodward, A.R. and Marion, W.R. (1978). An evaluation of factors affecting night-light counts of alligators. Proc. Conf. Southeast. Assoc. Game Fish Wildl. Agencies 32: 291-302.

Zar, J.H. (1996). Biostatistical Analysis. Prentice Hall: Upper Saddle River, New Jersey.