modeling effort, Across Trophic Level System Simulation (ATLSS), is being developed to compare the future effects of alternative hydrologic scenarios on the biotic components of the systems (ATLSS, 1999). Due to the varying scales at which trophic interactions occur, and the importance of population structure and individual behavior for population prediction in higher trophic level organisms, use of a single modeling approach is not appropriate (ATLSS, 1999). The alligator's role in the trophic dynamics of the Everglades is significant and will be an integral component of the ATLSS model. Characteristics of alligator home ranges and daily movements can be used to determine possible responses to restoration projects (such as response scenarios to the backfilling of canals, and movements to areas of the Everglades that may become more suitable habitat due to restoration efforts). Information concerning alligator home range and daily movement are needed for the ATLSS modeling effort as well as to improve management strategies for this keystone species.

Objectives

The objectives of the study were: (1) to estimate home range size and daily movement of alligators in the Everglades; and (2) to determine if differences in these parameters existed between genders, habitats, study areas, and seasons.

Methods

Study Areas

The first of two study areas was in Water Conservation Area 3A North (WCA) in South Florida (Figure I; Morea, 1999). The marsh of WCA was dominated by sawgrass (*Cladium jamaicense*) that formed thick monocultures interspersed with patches of depression potholes, wet prairie, slough, cattail (*Typha* spp.), and tree islands. Potholes were naturally occurring depressions in the marsh that were as small as 1 m^2 and 10 to 40 cm deeper than the surrounding sawgrass marsh. Wet prairies were most often dominated by maidencane and spikerush (*Eleocharis cellulosa*) that formed low stature communities known as flats (Loveless, 1959). Slough habitats in WCA were restricted to the southeastern section and were dominated by tall patches of sawgrass interspersed with patches of white-water lilies and bladderworts.

Radio-tagged alligators were located in two of the four canals located in WCA. The Miami Canal flowed southeast through WCA. Water flows were controlled by a large pump station located at the northwestern corner of WCA and a weir located approximately 7 km south of the pump station. The Miami Canal had large spoil banks on either side of the canal that were dominated by Brazilian pepper (*Schinus terebinthifolius*) with levee breaks approximately every 100 m. Levee breaks allowed water to flow between the canal and surrounding marsh. The I-75 canal had an east-west orientation and was bordered by Alligator Alley to the south and natural marsh to the

north. Waters flowed from the marsh into the canal and under Alligator Alley through several canal underpasses.

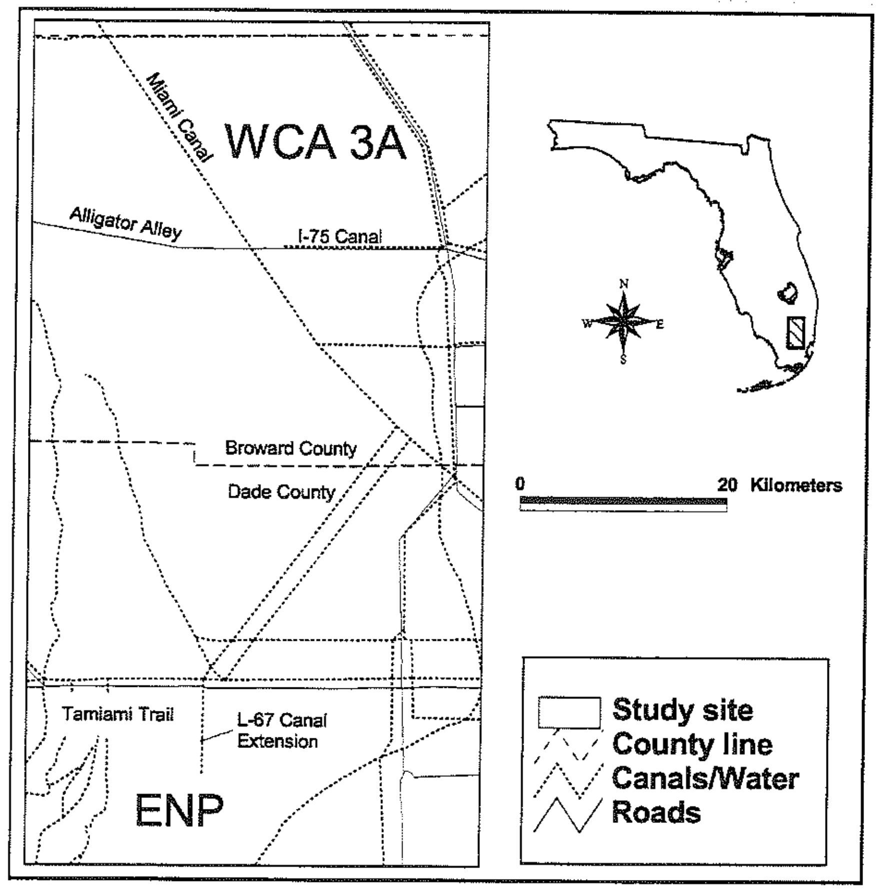

Figure I. General location and map of Water Conservation 3A North (WCA) and Shark River Slough region of Everglades National Park (ENP).

The second study area was located in Shark River Slough within Everglades National Park (Figure I; Morea, 1999). The area was south of Tamiami Trail (US Hwy-41) and included the L-67 Canal extension. Two main habitats, slough and sawgrass, were interspersed throughout the study area. The slough habitat had a longer hydroperiod than the sawgrass marshes and was dominated by spikerush, maidencane, white water-lily, bladderwort, sparse sawgrass and contained numerous tree islands (Lodge 1994). A thick layer of algae (periphyton) was present over most of the slough. The area was not open to recreational vehicles and the habitat was less disturbed then areas outside the park.

The L-67 Canal extension had a north-south orientation and flowed approximately 14 km from the Tamiami Trail into the center of Shark River Slough. The canal was bordered on the east by a large spoil bank that allowed travel by truck. The canal was border on the west by slough and sawgrass marsh. Coastal-plain willow (*Salix* *caroliniana*) and wax myrtle (*Myrica cerifera*) were common along the spoil bank. The willows often formed thick stands along the western edge of the canal.

Capture and Transmitter Implantation

Sixteen alligators in WCA and 15 alligators in ENP were captured and equipped with an AVM model SB2 transmitter in the 166-170 MHz range. Alligators were captured from an airboat using capture darts and snares (Morea, 1999). Capture sites were recorded using a global positioning system (GPS). Capture habitat, environmental measurements, and time of capture were noted. Alligators were transported to a boat ramp where total length, snout-vent length, head length, hind foot length, tail girth and gender were recorded. Each alligator was marked with a sequentially numbered # 6 Monel tag on the first single sagital scute and a # 3 Monel tag on the right hind foot.

Captured alligators were weighed with a Chatillon 12 Kg, 25 Kg or 270 Kg scale. The animals were given a dose of Medetomidine to sedate them just prior to surgery (D. Gross, personal communication). Subsequently, the alligator was secured to a 2.40 m X 0.70 m surgery table and Isoflurine gas was delivered through a rubber mask placed over the alligator's snout (D. Gross, personal communication). The implantation site was scrubbed with a Betadine solution. A radio-transmitter, with an appropriately sized battery, was sterilized and surgically implanted intramuscularly anterior to the hind limb. The incisions were sutured and sealed with surgical glue. Alligators were then given a dose of Atipamezole Hydrochloride to reverse the initial dosage of Medetomidine. The alligators were held for 24 to 48 hours after the surgery for observation and recovery. The alligators were then released at the exact capture location.

Home Range

Alligators were located on a weekly basis with initial locations recorded within 3-5 days after release. Study animals were located with a 4 MHz model R4000 ATS radio-receiver connected to an airboat-mounted Telonics RA-3A 3-element null-combiner antenna system with a telescoping 6.1 m mast. A Telonics RA-2A 2-element hand held yagi antenna was used when tracking by small aircraft and when field conditions limited the use of the more accurate null-combiner system. After an alligator's position had been determined, the location was recorded with a hand held Trimble Scoutmaster GPS unit equipped with a DCI (Differential Corrections Inc.) real-time differential correction (DGPS) data receiver. The DGPS receiver provided 10 m accuracy. Time, date, air temperature, water temperature, and habitat were recorded for each weekly location.

Weekly location data were used to calculate home range size. Home range size was determined by a 95% adaptive kernel (AK) model using Ranges V (Institute of Terrestrial Ecology, Wareham, United Kingdom). A 0.5 smoothing parameter (H value) was used for all calculations of home range size using the AK method. Default settings were used for contours fitted to fixes, grid cell size (40 X 40 m), and grid detection and rescaling. A 75% AK was calculated to estimate core areas of activity (Staus, 1998).

Fix dispersion was determined from the kernel home range model and is a measure of spatial variability among all fixes for a given animal. Greater fix dispersion meant that an animal was found to frequent a larger area within its home range on a regular basis. A ratio of 75% AK/ 95% MCP was calculated to quantify the proportion of the entire home range (95% MCP) that was used most frequently by each alligator (Staus, 1998). MCP estimates of home range length and width were used to determine if differences existed in home range shape between marsh and canal alligators (i.e., if longer and more narrow, then the home range would be more linearly shaped).

A series of one-way analyses of variance (ANOVAs) were used to test for differences in home range size between genders, habitats (marsh vs. canal), study areas (WCA vs. ENP), and seasons (year – 22 September 1997 to 21 September 1998; fall – 22 September 1997 to 20 December 1997; winter – 21 December 1997 to 20 March 1998; spring – 21 March 1998 to 20 June 1998; summer – 21 June 1998 to 21 September 1998; wet – 1 July 1997 to 31 December 1997; dry – 1 January 1998 to 31 June 1998) using SAS (SAS Version 6.12; SAS Institute Inc.). If the ANOVA showed a significant difference ($P \leq 0.10$), a Duncan's multiple range test was conducted to detect differences among all possible comparisons (Ott, 1993). The 95% AK home range estimates were used for statistical analyses.

Daily Movement

Daily movement was estimated from 4 weeklong intensive tracking samples conducted once during each fall, winter, spring, and summer from 7 November 1997 to 31 July 1998 in WCA and ENP. A roving "tower" method was used to estimate daily movements. At least three towers were established to triangulate on each study animal located in marsh habitats. Towers consisted of a 2 m PVC pipe marked with orange flagging and reflective tape to increase visibility in both light and dark conditions respectively. Towers had unique identification numbers and a DGPS position was recorded at each tower. Additional towers were set up when a radio-tagged alligator moved beyond the range of the original set of towers such that each radio-tagged alligator being tracked was always located within a polygonal area encompassed by a set of towers.

Animals tracked in the L-67 Canal extension (ENP) were located from the levee that borders the canal to the east. An animal's location was determined from three or more bearings taken from a hand held yagi antenna with a hand held compass. A DGPS position and environmental measurements were recorded at each bearing location.

Animals tracked in the Miami Canal were located from an airboat using a continuous tracking method. Once a signal was detected, a bearing to the alligator was determined. The bearing to the animal was tracked as the airboat continued its movement within the canal until the animal's exact position could be determined. Environmental measurements were recorded and a position was taken using a DGPS unit.

These procedures were repeated until three or more bearings were recorded for each study animal (excluding alligators located in the Miami Canal). Locations were obtained approximately twice during a 24-hour period for each weeklong intensive sample. Locations were presumed to be auto-correlated, which was deemed unimportant for estimating the minimum linear distance an alligator moved in a 24-hr period.

Ranges V was used to estimate the minimum linear daily movement (m/24-hr). An analysis of variance (a series of one-way ANOVAs) was used to test for differences in daily movements between genders, habitats, study areas, and seasons using SAS. If the ANOVA showed a significant difference ($P \leq 0.10$), a Duncan's multiple range test was conducted to detect differences among all possible comparisons.

Results

Home Range

Home range size was estimated for 16 radio-tagged alligators in WCA and 15 radio-tagged alligators in ENP. Home range size for alligators located in WCA and ENP were not significantly different ($F_{1,28} = 0.03$; $P = 0.860$). Therefore, the data were pooled for tests of seasonal differences in home range size for gender and habitat.

Annual home range size for male alligators was significantly greater than females ($F_{1,28} = 6.30$; $P = 0.018$; Figure II). Male home ranges were 5 times larger in the spring, nearly 4 times larger in the summer, 4 times larger in the fall, and 1.5 times larger in the winter than those of females (Figure II). Female alligators exhibited high site fidelity and had nearly identical home range sizes among seasons.

Male alligators had significantly longer ($F_{1,29} = 5.32$; $P = 0.029$) and wider home ranges ($F_{1,29} = 3.07$; $P = 0.090$) than females (Table I). Male alligators had significantly larger 95 % MCP home ranges than female alligators ($F_{1,29} = 7.45$; $P = 0.011$). Mean number of core areas ($F_{1,29} = 4.67$; $P = 0.039$) and core area size ($F_{1,29} = 8.34$; $P = 0.007$) for female alligators were significantly less than for male alligators. Male and female alligators used similar amounts of their home range in core areas.

Home range size for marsh alligators successively decreased from fall to summer to winter to spring (Figure III). Mean home range size for canal alligators decreased from spring to summer to fall to winter. Alligators located in canals had more linearly shaped home ranges than marsh alligators ($F_{1,29} = 3.66$; $P = 0.065$) (Table I). Canal and marsh alligators had similar numbers of core areas and used similar amounts of their home range in core areas. Female ($F_{1,10} = 1.10$; $P = 0.32$, $R^2 = 0.12$) and male ($F_{1,20} = 0.10$; $P = 0.11$, $R^2 = 0.05$) alligator home range size tended to decrease with an increase in total body length.

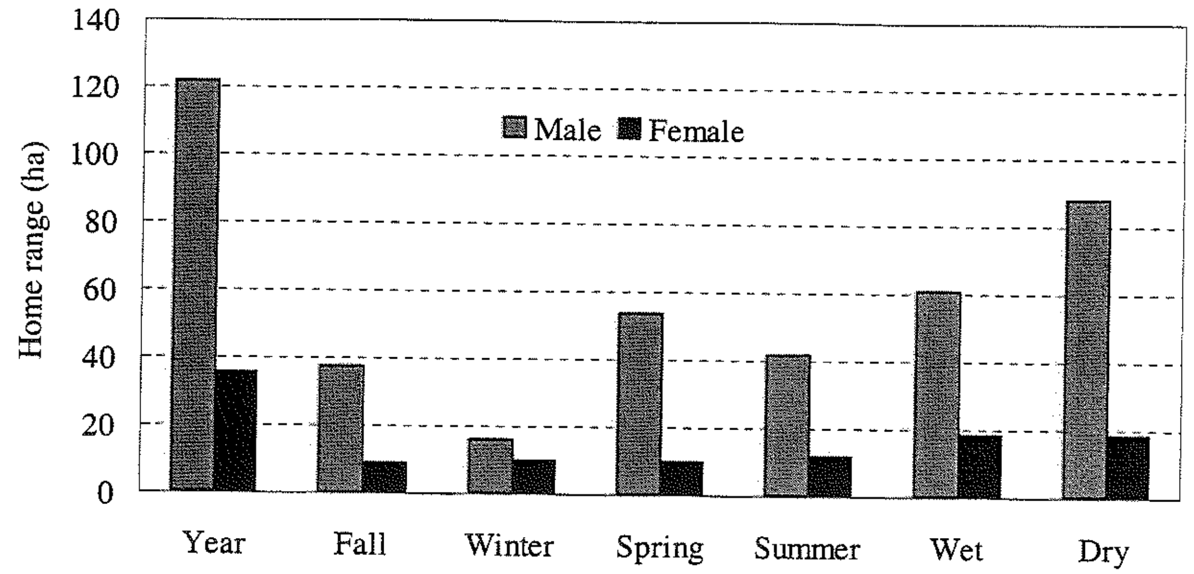

Figure II. Mean annual and seasonal home range size (95% adaptive kernel) of radio-tagged male and female alligators located in Water Conservation Area 3A North and Everglades National Park from 1 July 1997 to 21 September 1998.

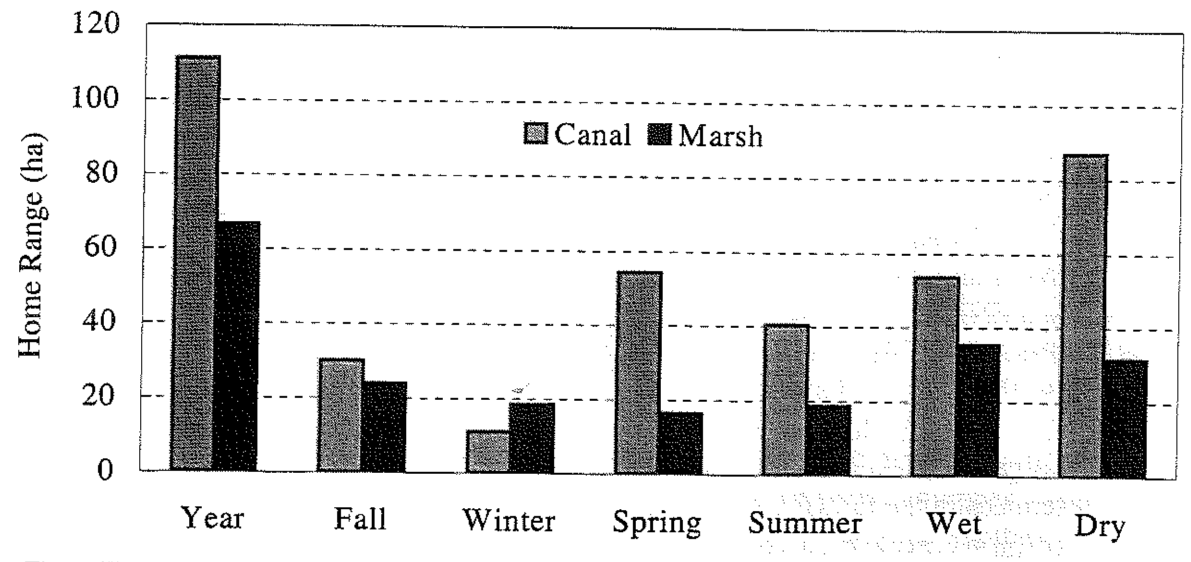

Figure III. Mean annual and seasonal home range size (95% adaptive kernel) of radio-tagged canal and marsh alligators located in Water Conservation Area 3A North and Everglades National Park from 1 July 1997 to 21 September 1998.

Table I. Annual minimum convex polygon (95%) and adaptive kernel (75%) home range size for radio-tagged marsh alligators in Water Conservation Area 3A North and Everglades National Park located from 22 September 1997 to 21 September 1998. Range length and width were estimated from 95% minimum convex polygons and number of core areas were from 75% adaptive kernel polygons.

Comparison	Gender		Habitat	
	Male	Female	Marsh	Canal
No. of locations	780	440	527	693
Range length (m)	2937.24[a]	1255.94[b]	1535.57[a]	2922.09[b]
Range width (m)	430.06[a]	301.32[b]	426.28	354.11
95% MCP (ha)	114.97[a]	35.65[b]	75.31	95.14
75% AK (ha)	49.42[a]	16.94[b]	30.20	43.45
Core areas	1.80[a]	1.18[b]	1.62	1.56
AK/MCP	0.48	0.48	0.47	0.49

Means with different lower case letters were significantly different ($P < 0.05$).

Movement

Mean daily movement (m/24-hr) was estimated for 16 radio-tagged alligators in WCA and 15 radio-tagged alligators in ENP. Movement for alligators located in WCA and ENP were not significantly different ($F_{1,84} = 1.07$; $P = 0.305$). Therefore, the data were pooled for tests of seasonal differences in home range size for gender and habitat.

Male alligators moved significantly more in a 24-hour period than female alligators ($F_{1,11} = 25.60$; $P = 0.0004$) (Figure IV). Males moved significantly more than females in the fall ($F_{1,18} = 10.18$; $P = 0.005$), winter ($F_{1,22} = 5.20$; $P = 0.033$), and spring ($F_{1,10} = 6.91$; $P = 0.016$). Movements for male alligators decreased from spring to summer to fall to winter (Figure IV). Movements for female alligators decreased from spring to fall to winter to summer.

No significant differences were found in the mean daily movements of marsh and canal alligators ($F_{1,86} = 1.94$; $P = 0.167$). Both marsh and canal alligator (male and female) mean daily movement decreased from spring to summer to fall to winter (Figure V).

Discussion

Home range size and daily movement of adult alligators varied according to gender, temperature, reproductive efforts, habitat, and water level. Other factors such as food availability, competition, anthropogenic disturbances, and major weather events may have influenced alligator movements, but were less likely to have lasting effects during normal years.

Gender

Male alligators had larger home ranges and moved more on a daily basis than females. Males used more of their home range during regular daily movements and tended to regularly traverse their home range, particularly those located in marsh habitats. Male alligators were also found to have greater home range sizes than females in the Rockefeller Refuge, Louisiana (Joanen and McNease, 1970; Joanen and McNease, 1972) and in Newnans Lake, Florida (Goodwin and Marion, 1979; Table II).

Radio-tagged alligators in the Everglades exhibited a high affinity for a particular portion of the natural marsh or section of a canal; however, males were likely to have 2 or more preferred core areas within their home range. Male core areas were larger than those of females. Male movements within core areas were more dispersed and movements between core areas expanded their home ranges whereas females tended to limit their movements within small core areas.

Body size was similar for radio-tagged male and female alligators. Therefore, energy needs based on body size probably did not result in the differences of movements between genders. Greater movements of males were probably attributable to territory maintenance. While maintaining large home ranges males would have experienced increased energy expenditures. Restricted home range size and daily movements observed for females would have minimized energy expenditures and allowed potential breeders to maximize their body condition while maintaining a potential nest site. These differences between males and females were consistent throughout both study areas.

Both male and female alligator home range size tended to decrease with increasing size (total length). Larger sized animals would be better equipped to defend their preferred core areas and would less likely be forced into marginal habitats. Mature adults also would have learned how to best use their natural environment to obtain the needed resources resulting in a smaller home range.

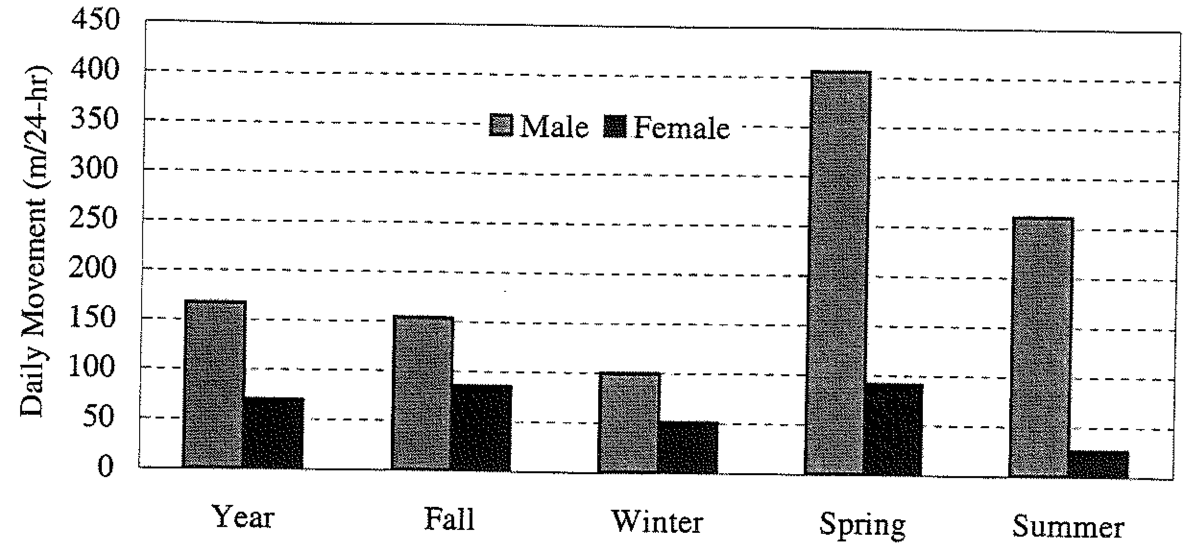

Figure IV. Mean annual and seasonal daily movement of radio-tagged male and female alligators located in Water Conservation Area 3A North and Everglades National Park estimated from 4 seasonal intensive weeklong samples conducted from 7 November 1997 to 31 July 1998.

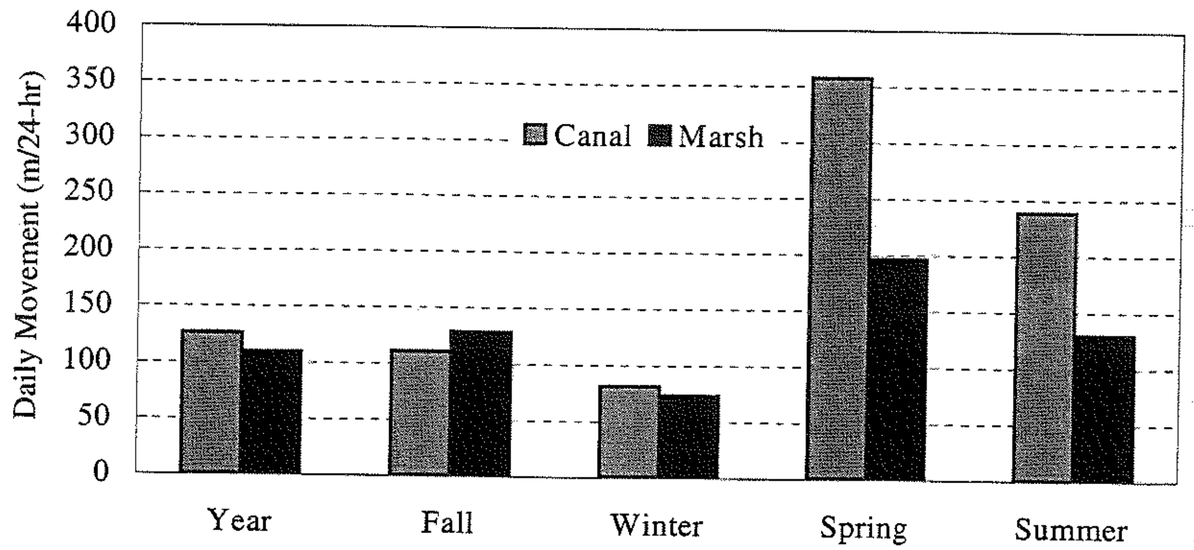

Figure V. Mean annual and seasonal daily movement of radio-tagged canal and marsh alligators located in Water Conservation Area 3A North and Everglades National Park estimated from 4 seasonal intensive weeklong samples conducted from 7 November 1997 to 31 July 1998.

Temperature

Alligator home range size and daily movement vary according to seasonal and daily temperature variation. In the Everglades, increased home range sizes and daily movements were observed with increasing temperatures. Home range sizes and daily movements were greatest during periods of elevated temperatures that existed from late spring to early fall. Alligator home range size and daily movement also was positively correlated with environmental temperatures in other studies (Chabreck, 1965; Joanen and McNease, 1970; Joanen and McNease, 1972; McNease and Joanen, 1974; Goodwin and Marion, 1979; Taylor, 1984; Rootes and Chabreck, 1993; Table II and III).

During the winter, alligators had decreased home ranges and daily movements. Alligators were found to bask throughout the day during the winter and would reach their highest temperatures late in the day (Howarter, 1999). This would have allowed them to maintain higher body temperatures during the cooler night hours.

Alligators were found to use the same holes, depression potholes, and shrub complexes throughout the year as thermal refugia from extreme hot or cold temperatures. Alligators had larger home ranges, and greater daily movements during the spring due to increasing temperatures and to the onset of the breeding season. Once the breeding season ended and temperatures peaked during the summer months, alligator movements were confined to more restricted core areas, as thermoregulatory needs seemed to restrict alligator movement. Summer female movements were affected more by reproductive efforts than temperature as nesting females had smaller home ranges than non-nesting females (Morea, unpublished data).

Movements of Everglades alligators were greater in the winter than in more northern areas. Alligators in Louisiana remained in holes or dens during the winter in a semi-torpor state (McIlhenny, 1935). Alligators in the Everglades face warmer fall and winter temperatures than those in more northern areas. This resulted in greater home ranges and daily movements for the fall and winter months. Everglades alligators were found to be quite active during the fall. Temperatures in the fall were comparable to spring temperatures and thus favored regular movements.

Reproductive Efforts

Increased movements and home range size can be attributed to increased reproductive activity as alligators expend tremendous amounts of energy in the pursuit of reproductive opportunities. Adult alligators, particularly males, had larger home ranges, and moved more on a daily basis during the spring breeding season.

Table II. Mean seasonal home range size (ha) for adult (>183 cm) radio-tagged alligators located in Rockefeller Refuge, Louisiana; Newnans Lake, Florida; and the Everglades (this study) calculated with a 100% minimum convex polygon model.

Season	Male Rockefeller Refuge[1]	Male Newnans Lake[2]	Female Newnans Lake[2]	Male Everglades[3]	Female Everglades[3]
Spring	224	257	16	64	19
Summer	679	95	13	57	22
Fall	393	38	10	58	24
Winter	0	9	6	31	16

[1]Joanen and McNease, 1972.
[2]Goodwin and Marion, 1979.
[3]This study.

Table III. Mean daily movements (m/24-hr) for radio-tagged adult (> 183 cm) radio-tagged alligators located in the Rockefeller Refuge, Louisiana, a cypress lake in Louisiana, and the Everglades (this study).

Season	Immature (< 183 cm) Rockefeller Refuge[1]	Female Clear-Smithport Lake[2]	Male Rockefeller Refuge[3]	Female Everglades[4]	Male Everglades[4]
Fall	205	3	587	86	154
Winter	139	1	0	51	100
Spring	303	27	763	91	406
Summer	281	46	855	27	261

[1]McNease and Joanen, 1974.
[2]Taylor, 1984.
[3]Joanen and McNease, 1972.
[4]This study.

Both male and female alligators had the greatest mean daily movement during the breeding season. Male alligators moved throughout their home ranges during the breeding season visiting 7 or more hole habitat types, presumably in the search for females. Females moved more on a daily basis during the breeding season, but remained within their preferred core areas. Therefore, mating opportunities were more dependent on male movements.

The breeding season for alligators takes place in April and May and adults of both sexes move much more during that period (Chabreck, 1965). Increased home range sizes have been found to coincide with the alligator's spring breeding season in other studies (Joanen and McNease, 1970; Joanen and McNease, 1972; Goodwin and Marion, 1979; Table II). Adult females were found to move the most during the breeding season in the Rockefeller Refuge, Louisiana (Joanen and McNease, 1970) and Lacassine National Wildlife Refuge, Louisiana (Rootes and Chabreck, 1993). Adult female alligators located in Clear-Smithport Lake, Louisiana and male alligators located in Rockefeller Refuge, Louisiana moved more during the spring breeding season than during the fall or winter, however, the movements were less than those observed during the summer (Table III).

Male alligators were found to maintain large home range sizes during each season of the year (excluding winter) suggesting that some level of territory maintenance exists throughout the year. The larger home range size of male alligators encompassed several female home ranges allowing males to maximize their breeding opportunities. Neither male nor female alligators moved to deep open water for breeding purposes. It was presumed that breeding took place within female alligators preferred core area habitats (i.e., holes, potholes or canals). For example, male 54917 (ENP) moved from hole to hole in the slough during the breeding season and occupied more than 7 holes within a week. This male was found to use only 3 of the 7 holes during the summer. Females apparently utilized several of the holes as 2 of the holes were found to have nests and hatchling alligators were heard vocalizing from another.

In the Lacassine National Wildlife Refuge in Cameron Parish, southwestern Louisiana, no differences were found between nesting and non-nesting females in either mean home range size or daily movement during the summer nesting season suggesting that nesting status and the presence of a previous year's brood did not restrict the movement of adult female alligators (Rootes and Chabreck, 1993). However, in the Everglades, adult female alligators were affected by reproductive efforts moreso during the nesting season than the breeding season. Nesting females were found to have smaller home ranges and decreased daily movements as compared to non-nesting females (Morea, unpublished data). Once females constructed a nest, they were found to remain at or near the nest site in small guard pools, caves, and holes or in the marsh near their nests. For example, female 54942 (ENP) had a large hole at the south end of a small tree island located in the slough and a smaller secondary hole located in thick sawgrass approximately 100 m northwest of the larger hole. This female repeatedly moved from her large primary hole to her smaller secondary hole during the fall, winter, and spring seasons. She then nested on a small tree island located approximately 60 m southwest of her large primary hole and spent the majority of her time in the spikerush slough within 15 m of the nest. Her regular movements were altered and constricted by her nesting effort.

Habitat

Structural differences between canal and marsh habitat types were presumed to affect alligator home range size and movement in the Everglades. Canal alligators had a larger home range than marsh alligators. McNease and Joanen (1974) hypothesized that differences in habitat utilization of alligators in the Rockefeller Refuge, Louisiana was partially responsible for different movement patterns and home range sizes. Alligators located in the natural marsh, where extended travel was relatively difficult due to thick vegetation, probably tended to restrict movement and home range size, whereas, alligators located in deep-water areas (i.e., canals), which offered convenient, unimpeded travel lanes, tended to elevate home range sizes (McNease and Joanen, 1974).

Everglades alligators located in canals had unrestricted open water travel lanes that allowed them to traverse long distances over a short time period (i.e., 24 hrs). Long distance movements of short duration, particularly by males, attributed to the greater seasonal home range size of canal alligators. Canal alligators tended to have longer, more linear home ranges than marsh alligators, which were related to these movements.

Water Level

Alligator movement increases with increased water level (Chabreck, 1965). In the Everglades, water levels fluctuate between the wet season (summer/fall) and the dry season (winter/spring). Water levels in the Everglades marshes and sloughs begin to lower during the winter and reach their lowest levels during the spring and early summer. Fish and other aquatic prey species were observed in greater concentrations in holes and depression potholes throughout the marsh during the dry season (Loftus and Kushlan, 1987; Kushlan, 1974). The naturally occurring drydowns and the resultant congregation of aquatic prey provided a plentiful energy source for both male and female alligators just prior to the rigorous spring breeding season. However, prolonged drought periods stress alligators and can result in diminished reproduction, poor body condition and even increased mortality.

During the dry season, canal alligators had a much larger average home range size than did alligators located in the natural marsh. Canal water levels varied little as the deep, open waters of the canals allowed alligators to move freely throughout the year. The presence of water in canals throughout the year also allowed alligators in these environments to avoid any adverse conditions that marsh alligators would endure during prolonged droughts. In WCA during the 1997-1998 dry season, standing water was only found in alligator holes, deep depression potholes, and airboat trails. During this time, marsh alligator movement was restricted to a hole or from hole to hole.

When marshes are flooded as a result of rainfall, alligator movement increases (Chabreck, 1965). Although alligators can survive on dry ground, they prefer to be in deep water and travel considerable distances to find it during exceptionally dry periods (Chabreck, 1965). Alligator daily movement in canals was not heavily impacted during the dry season as canals were always at or near their water holding capacity. During the dry season an influx of alligators from the surrounding marsh became apparent as 30 to 40 alligators could be found basking on a single levee break. Hines et al. (1968) found that water level fluctuation affected the movement of alligators in WCA and that during dry periods juveniles and adult males moved into canals from the bordering marsh. During times of high water levels, canal alligators were more likely to travel into the marsh. Alligator movements between canals and surrounding marsh habitats were most often limited to a few hundred meters and rarely exceeded a kilometer. Therefore, it is unlikely that canals attract alligators from interior marshes during periods of normal rainfall. However, movements between marsh and canal habitats may vary during periods of abnormal rainfall.

Conclusions

Alligator home range size and daily movement were affected by gender, temperature, reproductive efforts, habitat, and water level. Male home ranges were considerably larger than for female alligators except during the winter. Alligator home range size and daily movements generally increased with increasing temperatures. Excessively hot temperatures in summer appeared to limit movements and resulted in smaller home ranges than in the spring. Large spring home ranges for male alligators were probably due to the onset of the breeding season and increasing temperatures. Female alligators remained within their preferred core areas throughout the year and female marsh alligators did not seek deep open water for breeding purposes. Females with a recently hatched pod remained at the nest site and eventually sought preferred habitats (i.e., potholes, holes, low mixed marsh, etc.), which were usually near the nest site.

Linear movements of canal alligators were unimpeded by vegetation and other physical barriers. Marsh alligators had to travel through thick vegetation and during periods of low rainfall, were required to traverse portions of the marsh with little or no water. Smaller home ranges for marsh alligators were thus probably attributed to thick vegetation that impeded movements and limited movements due to extreme temperatures.

The spring breeding season and the summer nesting season were the most critical for adult male and female alligators respectively. Male alligators had greater movements during the breeding season and females moved least during the nesting season.

Temperature greatly affected alligator movements in the Everglades. Mean daily movement was least in winter for adult males and second least for females (the least movement for females occurred during the summer nesting season). Cool temperatures restricted most movements to the warmer daylight hours or to dawn and dusk periods. As temperatures increase so do alligator movements. However, extreme hot conditions forced alligators to move less and confined most movements to the cooler evening hours.

Acknowledgements

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Temperature-dependent sex determination on *Caiman latirostris*. Research update.

Carlos Piña[1] & Paula Donayo[2]

Abstract.

Eleven of 22 species of crocodiles have shown Temperature-dependent sex determination. The only reference to Caiman genera refers to *Caiman crocodilus* (Campos, 1993). This paper is the first reference to temperature-dependent sex determination in *Caiman latirostris* (broad-snouted caiman).

We incubated 11 clutch under four temperature treatments (29, 31, 33 and 34.5 ±0.5°C); eggs of different clutch were randomly assigned to different treatments. Sex classification of caimans was done by direct gonads observation.

Incubation period was related to temperature treatment during three years of research. Under normal humidity condition there was no differences on hatchling success again treatments.

Sex analysis of caimans shown that 33°C produce males (100%), 31 and 29°C produce females (100%).

Introduction

There are two different strategies on sexual determination among vertebrates, Genotipic Sex Determination (GSD) and Environmental Sex Determination (ESD), existing strategies using both of them in different rates (Janzen, 1992; Girodont *et al.*, 1994).

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ESD have been cited into three groups of reptiles, lizards, turtles and crocodiles (Crews, 1994; Lang y Andrews, 1994). Only 11 of 22 species of crocodiles have shown temperature incidence on sex determination (Lang y Andrews, 1994). This paper is the first reference to temperature-dependent sex determination in *Caiman latirostris* (broad-snouted caiman).

Our goal is determinate if temperature during incubation influences sex determination of hachtlings of *Caiman latirostris*, and rates of sex produced at 29°, 31°, 33° and 34.5° C.

Materials and methods.

We collected nest from natural habitats and from Proyecto yacare breeding stock. Natural nests were harvested within the first 20 days of incubation (time deduced from incubation period of eggs at 31°C).

We incubated 337 *Caiman latirostris* eggs from 11 nests during three years of research. Eggs used in the experiment were marked individually and randomly assigned to temperature treatments (29, 31, 33 and 34.5°C).

Incubators were plastic containers, with water on bottom and the eggs above a grille covered by nest material. We used electricity resistance as heaters and thermostat of 0.5°C precision as control of temperature. Temperature was recorded into the eggs chamber.

We assisted hatch once hachtling started call. Animals were identified by two tags, one in each leg.

Hachtling success was calculated as # of hachtling / # of eggs in treatment. Sex classification of caimans was done by direct gonads observation. On figure1 and 2 we show differences among males and females gonads.

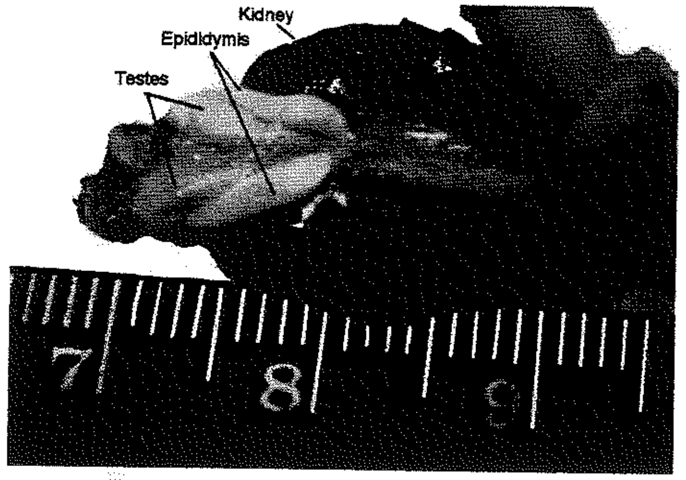

Figure 1: Male gonads of *Caiman latirostris*, produced at 33°C. Units on scale are cm.

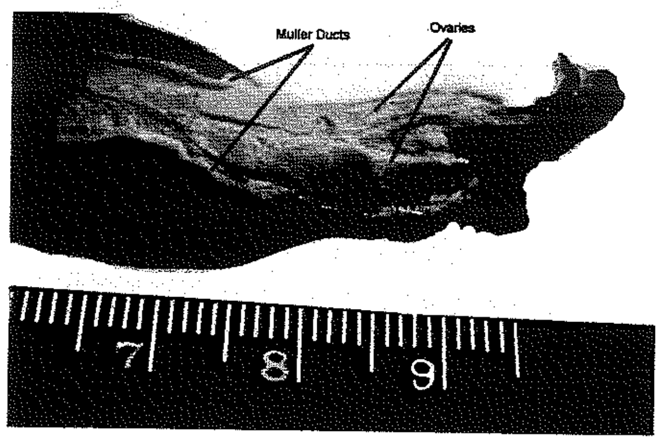

Figure 2: Female gonads of *Caiman latirostris*, produced at 29°C. Units on scale are cm.

We used χ^2 analysis for testing independence of sex and temperature treatment. Incubation period was analyzed by ANOVA, using nest as blocking and incubation as factor.

Results

Table 1: Hachtling success by treatment and year.

Temperature	1997	1998	1999
29°C	33/70	16/21	5/15
31°C	30/70	16/21	9/15
33°C	9/70	14/21	14/16
34.5°C	*	*	6/18

* During 1997 and 1998 we did not incubate at 34.5°C.

In 1997 we had a great loose of eggs at 33°C (61 of 70; 87%). This low hatchling success could be due to humidity excess on incubators at 33°C. During 1998 and 1999 we have controlled humidity and there were no difference on hatchling success among treatments (Table 1, Fig 3).

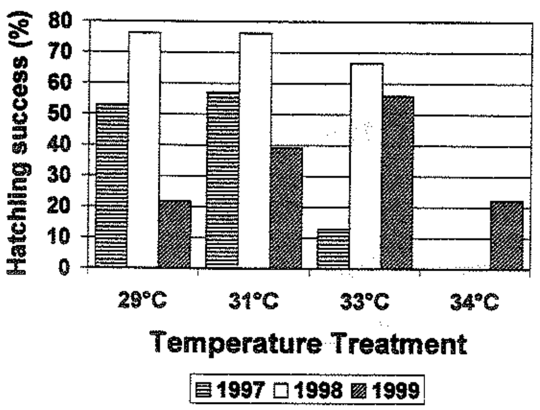

Figure 3: Hatchling success express as percentage at different treatments during three years of research. If we exclude 1997 from analysis there was no difference on hachtling success among temperatures treatments (29, 32 and 33°C; χ^2= 2,577; P= 0,276; D.F.= 2). We did not analyzed 35.5°C treatment because we have information from just one year.

Incubation period was related inversely to temperature treatment during three years of research (P< 0.001) and it was different among nests (P< 0.001). At 31°C incubation period was 66.78; 62 and 74.2 days (1999, 1998, and 1997), at 33°C 64.07; 55.9; and 71.9 days (0.96; 0.9 and 0.97 times that of 31°C), at 29°C it was 78.47; 72.5; and 82.2 days (1.05; 1.17 and 1.11 times that of 31°C). Incubation period during 1999 of the nest that produced hachtlings in all treatments showed no differences among 33° and 34.5°C, but both were shorter then 31° and 29°C (Fig. 4).

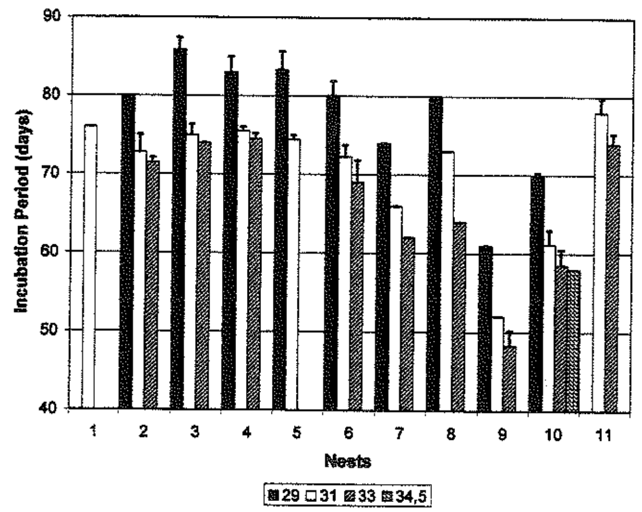

Figure 4: Incubation period of each nest. From 1 to 6 are 1997, from 7 to 9 are 1998 and the rest from 1999. In nests were there were hachtlings at all temperatures, differences are clear to observe, the biggest difference was among 29° and 31°C.

Sex was highly influenced by incubation temperature (χ^2 = 42,6; D.F.= 3, P< 0,001). Males were produced at 33°C (17 of 17), females were produced at 29° and 31°C (9 of 9 and 16 of 16 respectively). During 1999, at 34.5°C, the animals sexed shown presence of males and females (6 males and 3 females).

There were some embryos that could not develop completely, most of them stop development in the last stages. Those embryos were sexed and their sex was the same of the hatched animals at that temperature (33°C only males, 29° and 31°C only females). This observation let us reject that temperature acts stopping embryo development if they are not the default sex produced at that temperature.

Discussion and conclusions

Preliminary results of this work show that temperature has a strong effect on sex determination in Caiman latirostris, and there is no differences which those observed in other species of crocodiles (Ferguson y Joanen, 1983; Lang y Andrews, 1994; Leslie *et al.*, 1996). As in *Alligator mississippiensis* (Lang y Andrews, 1994) incubation at 34.5 produce males and females, unfortunately our sample is low to compare sex ratio at this temperature.

There was no difference among years (1999,1998 and 1997) or among nests (11 nests) in sex ratio produced at different treatments, so sex determination is independent of year and nest.

Temperature affects embryo development speed and so incubation period, similar result to previous studies in the specie (Larriera *et al.*, 1996; Piña *et al.*, 1997) and in other reptile species (Allsteadt y Lang, 1994). That difference could be explain because caimans are ectotherm, and the 'outside' temperature could influence on metabolic rate of embryo and speed up or down development during embryogenesis.

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"*Caiman latirostris* as guard of environmental pollution"- Report of advance

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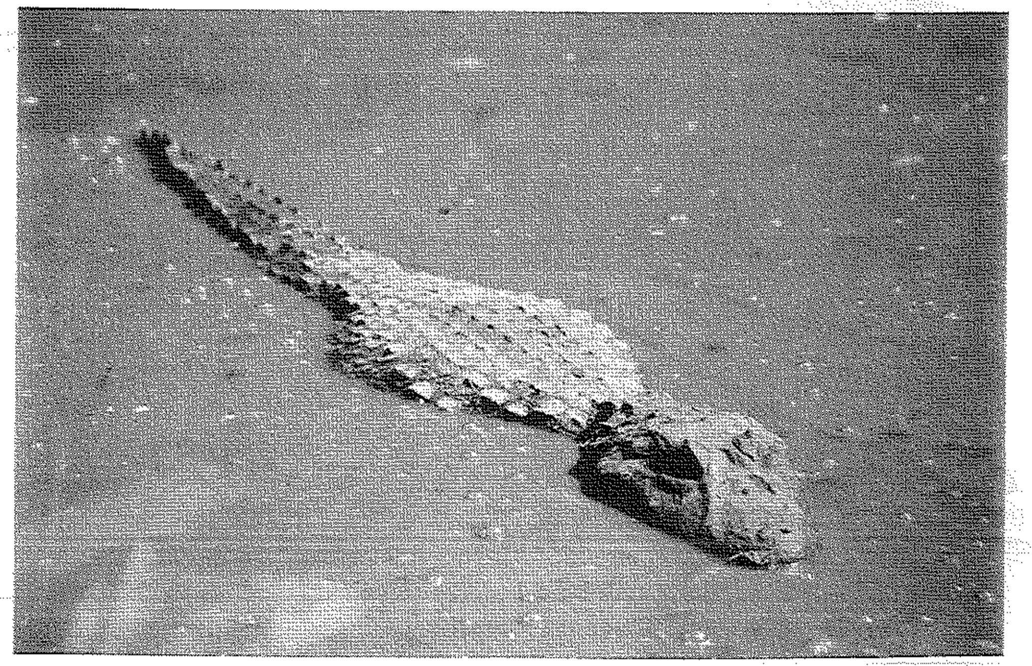
Summary

Environmental pollution due to agricultural quemical substances cause adverse effects to birds reproduction, caimans, rats and human beings.
Polichlorades derivative from organochlorades pesticides such as PCDD (polychlorodibenzo-p-dioxin), DDT (triclorodietano) and their derivatives, PCDF (polychlorodibenzofuran) are acummulated in acuatic vertebrates and invertebrates. The bioavailability of these compounds in fresh water courses and the sediments of their beds, as well as the bioaccumulation in bivalves and another invertebrates, cause toxic effectsthat may include reproductive and disorders and even death. Organochlorades have an estrogenic effect. It has also been noticed that DDE doesn't have much affinity with the estrogen receptor but that it is a strong antagonist of androgenic receptors.



Besides from the estrogenic and anti-adrogenic effects of organochlorades we would have to add the potencial genotoxic effect (i.e.: direct alterations on DNA sequence), both precesses end up in an increase and/or disorder in celular proliferation in sensible tissues. Based on what we have said, to investigate levels of environmental pollution due to chemicals of strogenic action in biological patternes we could do it through direct or indirect methods. That is to say, measuring organochlorades levels in tissues or, indirectly evaluating the estrogenic effects in biological patterns (i.e.: celular proliferation and/or synthesis of induced proteins). Vitelogenine is a molecular high weight protein induced by estrogens (Eg) and is synthesized in the liver of oviparous specie. Once it is synthesized, it start circulating to be captured by the ovocite that is growing and becomes part of the yolk that will breed the embryo in its early stadiums. Vitelogenine synthesis is induced by Eg, and this process is established during the animal reproductive maduration, the Eg administration or also by agonist substances. When substances with this estrogenic ativity (as DDT and its derivatives, plastic industry wastes, or surfactants) pollute hydric courses, it has been noticed that males fish living there have a vitelogenine circulating value significantly higher.

Objectives

General:

- Develop a biological pattern, making use of an animal specie of great distribution in our region as guard of environmental pollution. Everything will be focused on evaluation of environmental pollutans of estrogenic action (i.e.: organochlorades pesticides and PCBs)

Specific:

- Develop specific antibody against yacaré (*Caiman latirostris)* vitelogenine (protein induced by Eg and synthesized in the liver of oviparous specie) for adjusting enzimoinmunoassay (EIA).
- Establish the profiles of sexual esteroid hormones (i.e.: progesterone and androgens) in young animals and adults as complementary method to determie sex and be able to make a relationship between vitelogenine levels in males *versus* females obtained from their natural habitat.
- Determine circulating levels and vitelogenina hepatic concentration in males yacarés bred in captivity (isolated from pollution and given growing dosis of Eg.
- Determine vitelogenine levels in male animals captured ¡n their natural habitat (taking into account regions of high and low probability of pollution).

Methodology

Antigen Isolation: Yacaré serum of females treated with Eg through internal jugular vein technique will be isolated up to the level of cervical vertebra. Isolation of that antigen will be carried out using precipitation methods. Once vitelogenine has been purified, it will be used to inmunize rabbits.

Antibody Purification: Ab directed to the different epitopes of vitelogenine will be purified.

Development of EIA for vitelogenine: There will be 3 strategies to work on with the necessary variations for this Ag in particular.
1- Competitive with the antigen fixed to the plaque.
2- Competitive with the Ab fixed to the plaque.
3- Ag capture with Ab fixed to the plaque.

Inmunohistochemistry for vitelogenine: Identification and vitelogenine quantification in yacare liver biopsy will be optimized.

ACTUAL SITUATION OF AN INTRODUCED POPULATION OF MORELET'S CROCODILE *Crocodylus moreletii* TO LA ESPERANZA RANCH, VILLAFLORES MUNICIPALLY, CHIAPAS, MÉXICO.

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INTRODUCTION

La Esperanza ranch is located in Villaflores municipally of the state of Chiapas at 16°18'317" North, 93°21'400" West and 610 m.a.s.l. It was founded in 1952 with the main goal of cattle and agriculture (fig. 1). In 1964 three lagoons were constructed beside a small temporal stream, they togheter cover an area of seven hectaries (fig. 2).

Some years after the lagoons construction, some fish species and fresh water turtles were introduced. In 1970 a couple of *Crocodylus moreletii* collected on Usumacinta river at Catasajá Municipally, Chipas, measuring between 60 to 120 cm. (Class II) and were putted in one lagoon. Five years before many hatchlings were observed and growing successfully. Due to their migration instinct they dispersed to the other two lagoons.

In 1995, a population census were conducted by Sigler and Mandujano, and about 40 crocodiles were seen. The class conformation was: 10 Class II (60 - 120 cm.), 15 Class III (120 - 180 cm.) and 15 Class IV (180 - 240 cm. of total lenght); and the sex ratio 1:2 (males:females). The Class I were not seen, this class includes neonates and yearlings (less than 60 cm. of total lenght).

Historical reports show the extraction of two female crocodiles Class II and three Class III who been donated in 1992 to the breeding centre of Buenaventura, pretty close to La Esperanza. Also in the past five years the dead of four Class IV crocodiles (2 males : 2 females) were documented by drowning in fishing nets. In 1999, two Class IV females captured to bring them to Miguel Alvarez del Toro Zoo, in the state capitol (fig. 3).

METHODS

Actual studies in the place initiated in June 1999 and tend to know the size of the population, the reproduction time, nesting and hatchlings success. These activities are carrying out by day and night surveys (fig. 4).

RESULTS

Preliminary results indicate:

1. That 17 crocodiles inhabit the three lakes, most of them are adults (fig. 5).
2. There are 8 crocodiles in the up lake (2.5 ha) : 4 Class III, 3 Class IV and 1 Class V.
3. There are four crocodiles in the medium lake (2.5 ha) : 2 Class III and 2 Class V.
4. There are five crocodiles in the bottom lake (2 ha) : 3 Class III and 2 Class IV.
5. One recaptured crocodile number 401 marked in 1995 when measured 50 cm. of total length and on July 1999 measured 150 cm. of T.L.(fig. 6).
6. The presence of three nests located in the surroundings of the medium lake at 4, 12 and 22 meters from water edge (figs. 7,8,9).
7. The nesting success were observed because the three nests produce hatchlings.
8. Hatchling success will be estimated a year before when hatchlings will be one year old.

DISCUSSION

In this ranch located in the center of Chiapas state there are not historical reports of natural incidence of *Crocodylus moreletii*, so we consider this specie exotic for this region.

The environmental conditions of the ranch are quit different from those reported to the specie in their natural distribution range, nevertheless *Crocodylus*

moreletii have done well in this place if we consider their population growth starting of two juvenile crocodiles.

Also due the temperature condition there is a strong possibility of female hatchlings and these is reflected in the sex ratio (1:2); also possible is the lost of eggs inside nests and hatchlings because the low temperatures registered year around.

We have big suspects that some other juvenile crocodiles reported in neighbor ranches belong to the original group of La Esperanza. There is the possibility of *Crocodylus moreletii* colonizing other parts of the Tablon river which goes to Suchiapa, Santo Domingo and Grijalva rivers. In this two last rivers, the Miguel Alvarez del Toro Zoo personnel has collected two Morelet´s crocodile, were there only must exist *Crocodylus acutus*.

The intentional extraction of 7 and the death of two adult females must cause the decrease of the population growing.

Taking these data in mind, we are going to simulate a population growing curve to appreciate the possibilities of this group of Morelet´s crocodiles since they start in 1970. These may show than the recover of this specie is possible and specially than *Crocodylus moreletii* is an adaptable organism to changes in their environment.

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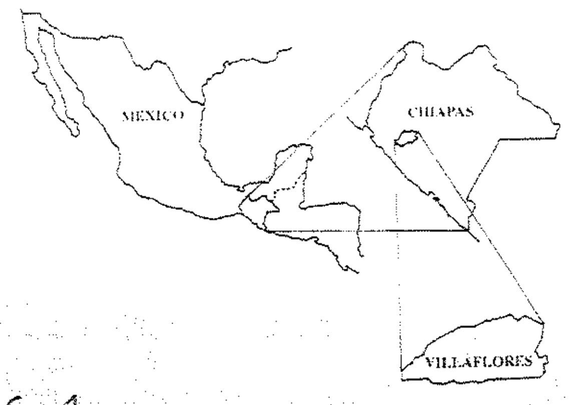

FIG. 1

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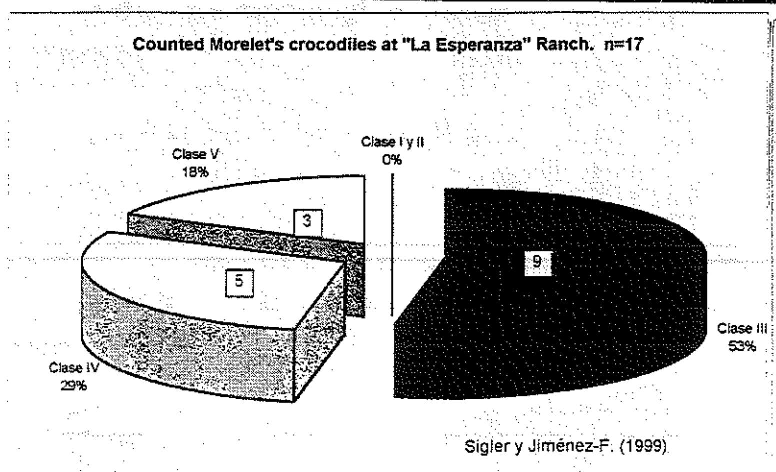

FIG. 9

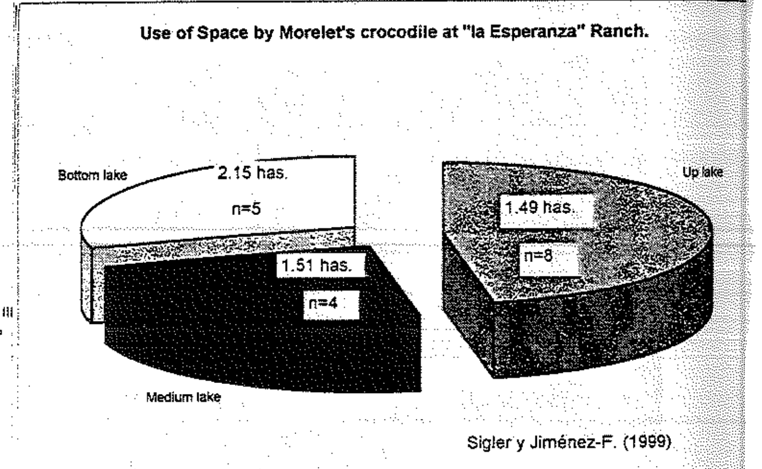

FIG. 10

ESTATUS DE *Crocodylus moreletii* EN EL PARQUE NACIONAL LAGUNA DEL TIGRE, PETEN, GUATEMALA.

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RESUMEN.

Este trabajo presenta los resultados de tres años de estudios con *Crocodylus moreletii* en el Parque Nacional Laguna del Tigre, Departamento de Petén, Guatemala. La primer parte, consistió en una evaluación del hábitat potencial de la especie para todo el departamento de Petén, a través del Sistema de Información Geográfica de ProPetén; obteniéndose que la mayor parte del hábitat potencial de la especie sufría algún impacto humano. La región norte de Petén presentó el menor impacto humano, y la mayor cantidad de hábitat potencial se localizó en el extremo Noroeste de Petén, dentro del Parque Nacional Laguna del Tigre.

El siguiente paso del estudio consistió en una prueba piloto en donde se probó una metodología estandarizada para la detección de cocodrilos; así mismo, se realizaron observaciones de estructura poblacional, uso de hábitat, reproducción, un análisis de amenazas y una propuesta de manejo de la especie dentro del Parque Nacional.

Como parte de las recomendaciones del estudio anterior, se extendió el muestreo a la mayoría de cuerpos de agua importantes dentro de todo el Parque Nacional, obteniéndose los primeros registros y densidades de la especie en muchos sitios dentro del área protegida. Se realizaron también análisis de estructura poblacional, uso de hábitat y reproducción.

NOTA:

- Este trabajo estaría incluido dentro del siguiente tema: **"Recent advances in crocodilian research"**, y sería una **Presentación.**

THE CROCODILE POPULATIONS OF SOLENTINAME, NICARAGUA 1998.

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Solentiname is a group of little islands located in the southeast section of the Nicaraguan fresh water lake. Here, populations of both species (*Caiman crocodilus* and *Crocodilus acutus*) coexist, having survived to several years of uncontrolled harvest. Rumors of the continued reduction of the populations got me to the islands to estimate abundance indices and analyze the distribution of both species, as well as the recruitment potential. Other information compiled comprehend the historical tradition of hunting crocodiles and caimans of the archipelago.

Night spot light counts were conducted, the abundance indices where calculated for each of the islands (individuals / km of perimeter), distribution maps where elaborated based on the sightings locations. The number of active adult females where calculated according to the number of hatchlings groups; a population model was constructed with different hunting levels in order to provide the local NGO´s some long term pictures of the populations. Also, interviews where conducted with local old men to compile the historical harvest information.

A total of 30 individuals where observed, of which only two where caimans. The size classes comprehended individuals from 1 to 5 feet of total length. 0.44 individual per kilometers is the crocodile abundance calculated. Three groups of hatchlings where found, of which one corresponded to a two year old crocodiles, these where found near a one year old group, what makes me think that they can be related groups (from the same mother). So a number of at least two active crocodile adult females live in the archipelago. For caimans, the only two observation where found very apart, what make me think they come from different mothers, so at least two active adult caiman females are breeding in the islands. A 20 % harvest could reduce the populations almost to extinction in about ten years.

The principal hunters of crocodiles and caimans are foreign fishermen, which use boats with overboard motors. The main hunting devices are fishing hooks, fire guns and a wood stick with sharp ends, which they call "Villarda". The hunting season comprehend the months of February, March, April and may which are the dry season months. The hunting of crocodiles and caimans was a traditional activity among the islands habitants, it is not until the years 60 when the intensive hunting begun. The skins where then sold in Costa Rica and some cities in Nicaragua.

Actually, the islands are protected under the category of Historic Monument.

Status of Siamese Crocodile *Crocodylus siamensis* in Laos

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Introduction

Siamese crocodile *Crocodylus siamensis* historically occurred in Vietnam, Laos, Cambodia, Thailand, and parts of Malaysia and Indonesia, but has drastically declined throughout its range and is currently regarded as one of the most endangered crocodilians in the world (Ross 1998). Viable populations no longer exist in Thailand, although individuals persist at scattered localities (Kreetiyuntanont 1993, Ratanakorn et al. 1994, Suvanakorn and Youngprapakorn 1987). The results of a recent survey in Vietnam indicate that wild populations no longer occur (Platt 1999, Platt and Tri in press). There are no recent records of wild *C. siamensis* in Malaysia and Indonesia, although captive animals held in farms in Kalimantan, Indonesia were reported to have been captured locally (Ross 1998). Populations probably remain in Cambodia, but security concerns have hampered field investigations (Nao 1998). *Crocodylus siamensis* is listed as Critically Endangered on the IUCN Red List (IUCN 1996), and on Appendix I of CITES (Convention on International Trade in Endangered Species of Flora and Fauna; WCMC 1998).

In Laos *Crocodylus siamensis* has been reported to occur in a number of locations in the Mekong River basin, although by the early 1990s populations were considered reduced and even locally extirpated from some sites (Sawathvong 1994). However depleted, the Laos and Cambodia populations have been considered the only remaining large wild populations of *C. siamensis* in the world (Ross 1998). Although surveys designed specifically to find crocodiles have not yet been conducted in Laos, we herein summarize the current status of *C. siamensis* based on the findings of over seven years of general wildlife surveys conducted throughout the country. This paper is an expanded version of the *C. siamensis* account in Stuart (1999).

Status in Laos

Historically, *C. siamensis* was probably abundant in Laos in appropriate habitat. For example, Bassenne (1912) wrote (in translation) "...on the sandy river-banks [near Pakxan, northern Laos], crocodiles stretched their long, scaly bodies...One of the attractions of traveling up the Mekong was to shoot at these large saurians." Likewise, Wharton (1966), writing on observations of hunting activities by local people along the Lao-Cambodian border in the 1950s and 60s, stated "Every permanent water hole...is repeatedly visited...Crocs (*C. siamensis*) are captured in drying up stream beds within heavy gallery forest such as along the Tonle Repou [Cambodian name of Nam Lepou River which forms part of the Lao-Cambodian border]."

From late 1992 - 1999, several non-governmental organizations carried out surveys in existing and proposed protected areas (called National Biodiversity Conservation Areas, or NBCAs) throughout Laos to determine the distribution and status of wildlife (Duckworth et al. 1999). From 1992 to 1998 these surveys focused mostly on birds, mammals, and habitat assessments, and the survey team composition reflected this; from 1998 to present the surveys focused on general amphibians and reptiles. No surveys that specifically employed methodologies for finding crocodiles (e.g. night spotlighting on large water bodies) were undertaken, except for a brief investigation by Davenport et al. (1997) that followed consistent reports of a local population of crocodiles, and in 1993 in Xe Pian NBCA by J. W. Duckworth (personal communication) who spotlighted for eyeshine at rivers and waterholes for a few hours on each of several nights. Despite the limitations, these general surveys represent at least 330 biologist-weeks of effort (Timmins and Duckworth 1999 + B. L. Stuart unpublished data) spent mostly in relatively remote, undisturbed areas of Laos. Although much of this time was spent in forest, many surveys required travelling by boats, following river courses on foot, or surveying for other species in riverine habitat, marshes, and other wetlands that were presumably suitable for crocodiles.

During the course of these recent surveys, the only evidence of crocodiles came from a single unprotected locality, Nong Khe wetland (= "crocodile wetland" in Lao language) in Sanamsai District, Attapu Province. In January 1997 at Nong Khe, night vocalizations of crocodiles were heard and fresh feces, slides and tracks were observed (Davenport et al. 1997). In February 1998 at Nong Khe, a 1.5 m crocodile was seen basking on a grassy bank and a fresh set of feces was found (S. Khounthikoumane, Division of Forest Resource Conservation, verbally 1999). Two sites, Xe Pian NBCA (approximately 2,375 km^2) and Dong Khanthung Proposed NBCA (approximately 2,230 km^2) appear the most likely to support remaining crocodiles in Laos, as they each contain large areas of low-lying wetlands (Figure 1). Also, Nong Khe lies near the northeastern border of Xe Pian, and the Nam Lepou River mentioned in (Wharton 1966) flows along the southern border of Dong Khanthung. However, a total of 65 biologist-weeks of survey effort in Xe Pian and 11 biologist-weeks in Dong Khanthung (Timmins and Duckworth 1999) resulted in no sightings or signs of crocodiles.

Salter (1993b) and Sawathvong (1994) reported the occurrence of crocodiles throughout Laos based on interviews of local people conducted from 1988 to 1993. However, it has since been learned that reports of crocodiles can be over-optimistic, as frequently villagers report crocodiles to be present, but after labored

interviewing it is found that perhaps only a few people had apparently seen a crocodile first hand and in recent years. Subsequent interviews at a number of these sites by one of us (BLS) have concluded that crocodiles are probably absent there (Stuart 1999). It remains unclear whether these discrepancies resulted from different interviewing techniques of the authors, or whether the initial reports referred to populations that people could remember but which had already been extirpated. Local reports of harvest and trade of crocodiles before 1993 are reviewed by Baird (1993) and from 1993-1995 by Stuart (1999). However, a skull and 2-meter skin in the Vientiane Morning Market in 1997 (R. J. Tizard, personal communication), remains the only observed, contemporary trade record of a potentially wild crocodile that can be traced. The vendor reported that the skull and skin came from an animal captured in the Nam Ngum River (northern Laos), downstream of the Nam Ngum Reservoir. As these parts were not carefully identified, the possibility remains that they belonged to a captive hybrid from the Ban Keun Zoo or a farm in Thailand.

The records and reports of wild crocodiles in Laos are confidently assumed to be *C. siamensis*. Although some authors claim that estuarine crocodile *C. porosus* occurs throughout Southeast Asia (e.g. Cox et al. 1998), it is doubtful that records in Laos refer to this species. *Crocodylus porosus* today seems limited on mainland Southeast Asia to coastal estuaries, as is the case in Cambodia (MRCS/UNDP 1998) and Thailand (Ross 1998).

Based on the extreme paucity of field and trade records, and widespread reports by villagers of decline and disappearance, it is concluded that *Crocodylus siamensis* remains in Laos only in small, remnant populations. In a recent review of the conservation status of wildlife in Laos, Stuart (1999) assigned *C. siamensis* to the category At Risk in Laos, which was the highest risk category possible for an extant species in the country.

Threats in Laos

The main threat to crocodiles in Laos is attributed to unsustainable harvesting by local people for consumption and the sale of skins, eggs, and live animals to Thailand (Baird 1993). Some villagers reported in interviews that they hunted crocodiles opportunistically or accidentally caught them in fishing nets (Sawathvong 1994), while others targeted crocodiles with set lines and perhaps night spotlighting (Claridge 1996). Unsustainable harvesting is a common problem shared by most megafauna in Laos; trade-driven hunting is the main factor pushing wildlife species in Laos to extirpation, followed closely by subsistence hunting. The species in Laos most sensitive to hunting are those such as *C. siamensis* which occur in edge habitats or open wetlands; species without large populations in remote dense forest where they can escape hunting are unlikely to remain viable under current harvesting pressure (Duckworth et al. 1999).

Crocodiles in Laos are also threatened by habitat loss through drainage and clearing of wetlands for conversion to agricultural lands. Nong Khe wetlands, the only known recent locality and perhaps last stronghold for crocodiles in Laos, is currently a site proposed for peat extraction (R. J. Timmins, in litt. 1999). However, the problem of habitat loss is closely linked with the main threat of harvesting, as increased use of wetlands exposes remaining crocodiles to higher risk of being killed. For example, the construction of hydropower dam reservoirs may flood breeding sites, but more seriously it allows hunters with boats easier access to crocodiles (Claridge 1996). If hunting were controlled, habitat loss would be only a cause of local extirpations, not a nationwide population collapse.

Conservation

At present, active conservation programs for crocodiles in Laos do not exist. Crocodiles are listed as a Prohibited Category I species and officially protected year-round from hunting and trading (LPDR Ministry of Agriculture and Forestry 1991). However, forestry officials usually lack the resources and often the incentive to effectively control hunting and trade of wildlife, although a gun-collecting campaign has been somewhat successful in certain parts of the country (Timmins and Duckworth 1999). Borders with neighboring countries remain porous and international wildlife trafficking is rampant. The designated and proposed National Biodiversity Conservation Areas in Laos are multiple-use areas that remain inhabited with people, and guidelines on the restrictions of wildlife use within them remain unclear. Rather, passive conservation efforts whereby large tracts of wetlands are maintained probably offers the most significant protection for Lao populations of *C. siamensis*. Although current harvesting pressures in Laos doom all but the most remote and inaccessible crocodiles, re-introducing captive stock can be an objective if tracts of suitable habitat remain when hunting pressure is reduced from current levels.

Despite a drastic decline of wild populations throughout its range, large numbers of *C. siamensis* are bred successfully in Thai and Cambodian crocodile farms, and to a lesser extent in Vietnam, Indonesia, and some European and American zoos (MRCS/UNDP 1998, Ross 1998). A large group of crocodiles is also maintained at the Ban Keun Zoo near Vientiane, and in July 1999 crocodile eggs and stuffed hatchlings were seen for sale outside the entrance to the zoo (H. Nooren and G. Claridge, in litt. 2000). According to zoo staff, two of the adult animals originated from southern Laos, while the rest came from Thai crocodile farms (R. J. Timmins, verbally 1999). Two crocodiles displayed in 1988 at a private zoo in Vientiane were reportedly captured from the Mekong River near Savannakhet (Salter 1993a). This private zoo no longer exists, but the possibility remains that these were transferred to Ban Keun Zoo and represent the two Lao animals remaining there. Unfortunately, in the 1960s many crocodile farms in Thailand began to hybridize C. *porosus* with *C. siamensis* for improved skin quality and growth rates (Cox et al. 1998), and therefore many of the Ban Keun Zoo animals are probably hybrids. At least one farm in Vietnam has also begun hybridizing the exotic Cuban crocodile *C. rhombifer* with *C. siamensis* (MRCS/UNDP 1998). Other farms

may begin hybridizing *C. rhombifer* with *C. siamensis* as well. For example, in December 1999 we observed at least five adult *C. rhombifer* at the largest commercial crocodile farm in Siem Reap, Cambodia, housed with *C. siamensis* in enclosures that contained nesting facilities. Hybridization of *C. siamensis* in commercial crocodile farms threatens the genetic integrity of captive stock and diminishes chances for supplementing wild populations in the future with reintroduced captive animals. Under the current situation, research efforts to genetically identify pure captive *C. siamensis*, and to maintain these animals in legitimate *ex-situ* breeding programs, are probably the most important short-term conservation measures for crocodiles in Laos.

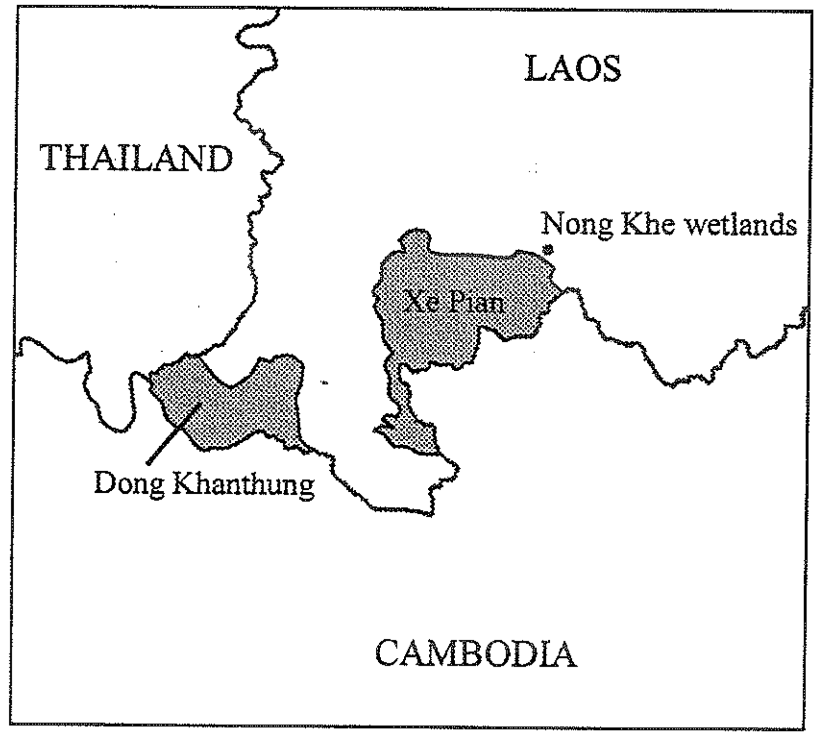

Fig. 1. Location Map. See text.

Updated Global Status

Based on what we know of the status of *C. siamensis* in Laos and elsewhere, it appears that most remaining and therefore most globally important populations of *C. siamensis* are in Cambodia. Field surveys have not yet been conducted in Cambodia, but preliminary data lead us to hope that wild populations still exist. Many residents of Prek Toal floating village on the Tonle Sap (=Great Lake) in Cambodia raise *C. siamensis* in floating pens, and these crocodile farmers told us in December 1999 that although very rare, wild stock could still be harvested in a few areas of Tonle Sap. Furthermore, these farmers reported that recent economic problems in Thailand had lessened the export demand crocodiles and that prices had fallen. At the time of interviewing the farmers had little incentive to harvest additional animals from the wild. Field surveys for crocodiles are planned by the Cambodian government and the Wildlife Conservation Society to begin later this year (2000).

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Figure 1. Significant areas mentioned in the text on the status of crocodiles in Laos. Map by Emma Jones.

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Notes on the Distribution and Current Status of Crocodiles in Sulawesi, Indonesia

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The fauna on the island of Sulawesi (Figure 1), formerly known as Celebes, has been well documented with studies dating from the nineteenth century (Wallace, 1869; Guillemard, 1886; Hickson, 1889). This fauna is the most distinctive in Indonesia with high levels of endemism among terrestrial mammals, birds, and reptiles (Whitten et al., 1987). However, the crocodiles of Sulawesi have received scant scientific attention and their current status and distribution has not been investigated (Ross, 1986; Cox, 1992). Early accounts suggest crocodiles were formerly widespread (Mundy, 1848; Guillemard, 1889), but populations are now believed reduced to scattered remnants due to a combination of commercial over-hunting and degradation of wetland habitats (Cox, 1992). We herein summarize available reports and present additional information gathered during recent fieldwork in Sulawesi (Table 1).

The estuarine crocodile (*Crocodylus porosus*) is the only crocodile definitely known to occur in Sulawesi (Groombridge, 1987). Historically *C. porosus* was found in coastal habitats, lakes, and rivers throughout the island (Whitten et al., 1987). Old records exist for Lake Tempe (Mundy, 1848), Maros River (Guillemard, 1889), and Lake Poso, and the Butaioda'a, Onggak, and Dumoga Rivers (Sarasin and Sarasin, 1905 as cited in Whitten et al., 1987). According to these accounts *Crocodylus porosus* was so abundant that many riverside villages were surrounded by tightly woven bamboo fences to protect people and livestock from the ravages of marauding crocodiles (Whitten et al., 1987).

Although *C. porosus* remains subject to persecution in Sulawesi (Cox, 1992), there is a notable paucity of contemporary distributional and status data. Groombridge (1982) regarded the survival prospects for *C. porosus* in Sulawesi as "poor." Crocodiles continue to be harvested for meat, and we found adult *C. porosus* for sale in the wildlife markets of Manado. Formerly common in the Sausu and Tambarana Rivers, populations disappeared after a transmigration scheme (designed to resettle people from Java to less densely populated islands) was established nearby, although scattered individuals may persist (Groombridge, 1982). Likewise, our interviews indicate extant crocodile populations no longer occur in Lake Poso (Halam Taula, pers. comm.). Remnant populations are reported in Matanu and Mahalona Lakes (Cox, 1992), Sungai Malili River (Cox, 1992), and Randangan Estuary (Groombridge, 1982). Crocodiles are present in the Sangihe Talud Islands, and two were observed in 1997 (Jon Riley, pers. comm.) on Karakelang. According to local villagers, a "few crocodiles" remain in the mangrove swamps of this island (Jon Riley, pers. comm.). Although mangrove destruction threatens the continued viability of this population, villagers do not kill crocodiles because of religious taboos (Jim Wardill, pers. comm.).

Substantial *C. porosus* populations may exist in the Ancona, Cerekan, and Parakayu Rivers where habitat is largely intact and crocodiles are locally protected as a totem animal (Cox, 1992). According to Whitten et al. (1987), *C. porosus* are also common in the Aopa Swamp, a 31,400 ha peat swamp forming the northern portion of Rawa Aopa-Watumohae National Park. MacKinnon (1981) suggested *C. porosus* occurred in Bongani Nani Wartabone (formerly Dumoga-Bone) National Park on the basis of "unsubstantiated reports from villagers," and in 1998 a park guard encountered several large crocodiles in the Dumoga River (Oji, PHPA, pers. comm.).

In October 1998 we examined five *C. porosus*, ranging in size from a juvenile (total length [TL] ca. 75 cm) to large adults (TL ca. 200 to 240 cm), held captive near Manado. Specific locality data were unavailable, but all were reportedly collected as juveniles near Gorontalo and Kotamobagu in northern Sulawesi. We also visited two crocodile farms near Palopo and Masamba in southern Sulawesi on 23 October 1998. These farms held about 130 locally collected *C. porosus*, suggesting hitherto unreported populations probably occur in southern Sulawesi.

The occurrence of other species of crocodilians in Sulawesi remains problematic. Schmidt (1935) speculated that an unidentified *Crocodylus* inhabited the inland freshwater lakes of Sulawesi. Additionally, *Crocodylus raninus*, a species resurrected by Ross (1990) on the basis of ventral and post-occipital scutellation, and cranial osteology of material collected from Borneo, could also occur in Sulawesi.

The Siamese crocodile (*Crocodylus siamensis*) is generally believed to be restricted to Vietnam, Laos, Cambodia, and Thailand (Groombridge, 1987). However, museum specimens are available from Sulawesi that are morphologically consistent with *C. siamensis* from mainland Southeast Asia (Ross, 1986), although we are unaware of any recent records. Furthermore, additional *C. siamensis* specimens are available from Sumatra, Bangka Island, Java, and Borneo (Ross, 1986), and living *C. siamensis* were recently found on Kalimantan (Ross et al., 1998).

Observations made at the already mentioned crocodile farms in southern Sulawesi suggest the occurrence of either *C. siamensis* or a hitherto unreported species of crocodile in Sulawesi. During a visual inspection of approximately 130 crocodiles, we noticed several with well-developed post-occipital scutes (Figure 2). We noted one subadult (TL ca. 120 cm) with four post-occipitals at a farm near Palopo, and three adults (TL ca. 240, 200, and 300 cm) with three, four, and six post-occipital scutes, respectively, at a farm near Masamba. These crocodiles were all collected as juveniles from undetermined localities in southern Sulawesi. Similarly, Cox (1992) inspected 37 juveniles from Sulawesi at a facility near Ujung Pandang, and stated "large post-occipital scalation ... [was noted] ... in most individuals."

The taxonomic status of the crocodiles we observed is uncertain. The distinctive interorbital ridge of *C. siamensis* (Brazaitis, 1973a) was absent, and post-occipital scutes are lacking or poorly developed in *C. porosus* (Brazaitis, 1973b; Ross, 1990). They may be assignable to *C. raninus*, which is characterized by four well-developed post-occipital scutes and 25 transverse rows of ventral scales (Ross, 1990). Unfortunately we were unable to examine ventral scalation, and *C. raninus* cannot be distinguished from either *C. novaeguineae* or *C. mindorensis*, solely on the basis of post occipital scutellation (Ross, 1990). The latter two species could potentially occur in Sulawesi, although they have not been previously reported.

There are unconfirmed reports of the false gharial (*Tomistoma schlegelii*) from the Marissa River in northern Sulawesi (Groombridge, 1982; Sebastian, 1994). Elsewhere, *T. schlegelii* is associated with sluggish rivers and peat swamps (Bezuijen et al., 1998; Simpson et al., 1998; Steubing et al., 1998), the latter notable for its absence in Sulawesi. The Aopa Swamp is the only significant peat swamp in Sulawesi (Whitten et al., 1987), and a thorough crocodile survey has yet to be undertaken. Bezuijen et al. (1998) consider it unlikely that a breeding population of *T. schlegelii* occurs on Sulawesi.

In conclusion, further investigation into the distribution and status of crocodiles in Sulawesi is clearly warranted. Surveys are urgently needed to assess the status of known crocodile populations, and to identify additional crocodile populations, especially those which could benefit from protective measures. Special attention should be devoted to surveys of inland lakes and the Rawa Aopa-Watumohae National Park. This protected area encompasses the only major peat swamp in Sulawesi, and may harbor a significant population of *C. porosus*. Moreover, Aopa Swamp is the only area where a breeding population of *Tomistoma schlegelii* is likely to occur in Sulawesi. Finally, we concur with others (Ross, 1986; Cox et al., 1993), who stated that Indopacific crocodiles are in urgent need of taxonomic review.

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Table 1. Summary of recent locality records for crocodiles in Sulawesi, Indonesia.

Location	Comments and source
Ancona, Cerekan, and Parakayu Rivers	Significant populations of *C. porosus* may remain. Protected by local religious beliefs (Cox, 1992).
Aopa Swamp	*C. porosus* common (Whitten et al., 1987); habitat suitable for *Tomistoma schlegelii.*
Bongani Nani Wartabone National Park.	Unsubstantiated reports by villagers of *C. porosus* (Mackinnon, 1981). Recent sightings in Dumoga River (Oji, pers. comm.).
Gorontalo-Kotamobagu	Captive *C. porosus* originated from undetermined localities in this region (this study).
Marisa River	Unconfirmed sightings of *Tomistoma schlegelii* (Groombridge, 1982; Sebastian, 1994).
Matanu and Mahalona Lakes	Remnant populations of *C. porosus* (Cox, 1992).
Randangan Estuary	Remnant population of *C. porosus* (Groombridge, 1982).
Sangihe Talud Islands	Recent sightings of *C. porosus* on Karakelang Island (Jon Riley, pers. comm.).
Sungai Malill River	Remnant population of *C. porosus* (Cox, 1992).

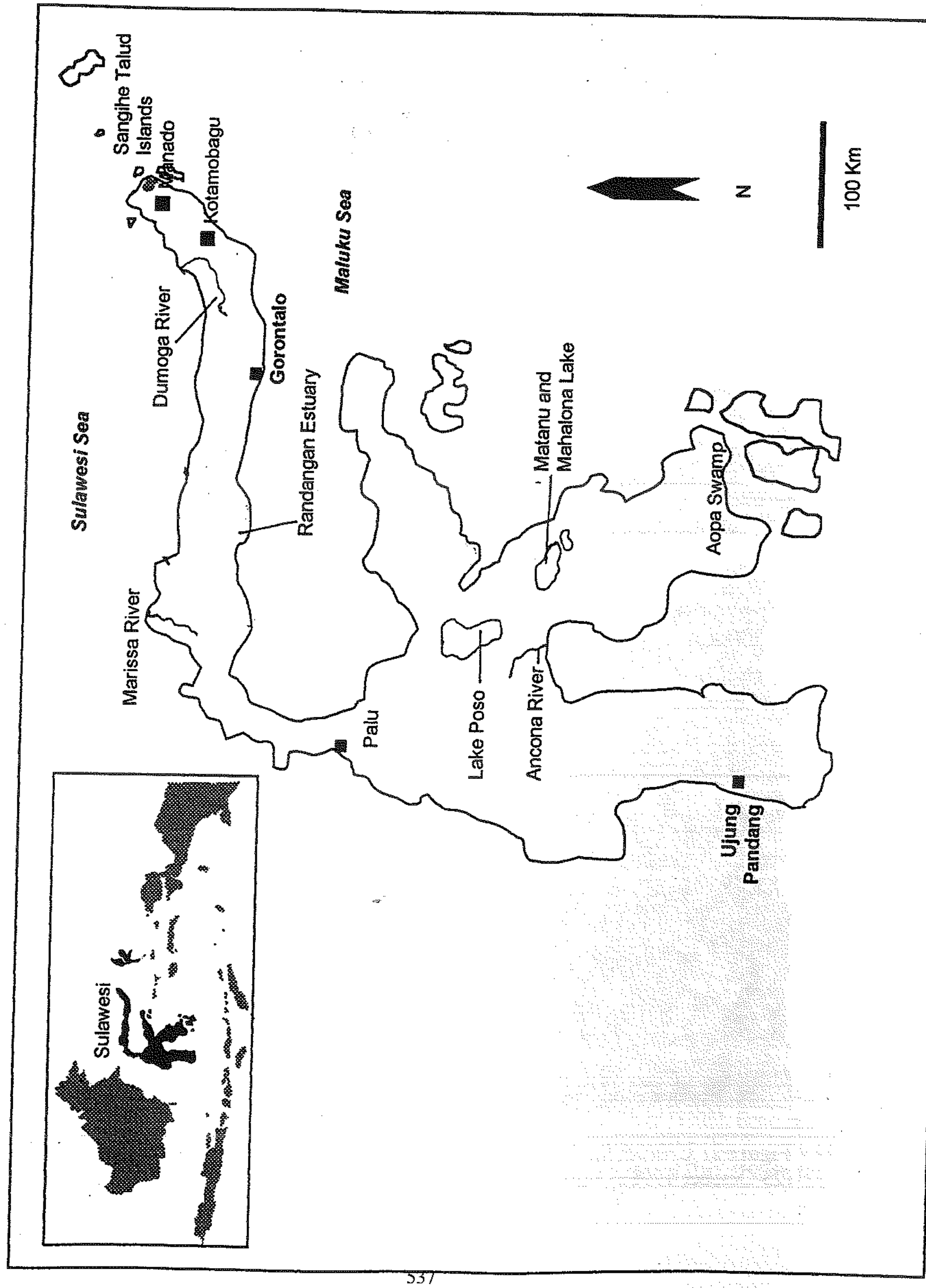

Figure 1. Map of Sulawesi showing approximate location of most areas mentioned in text.

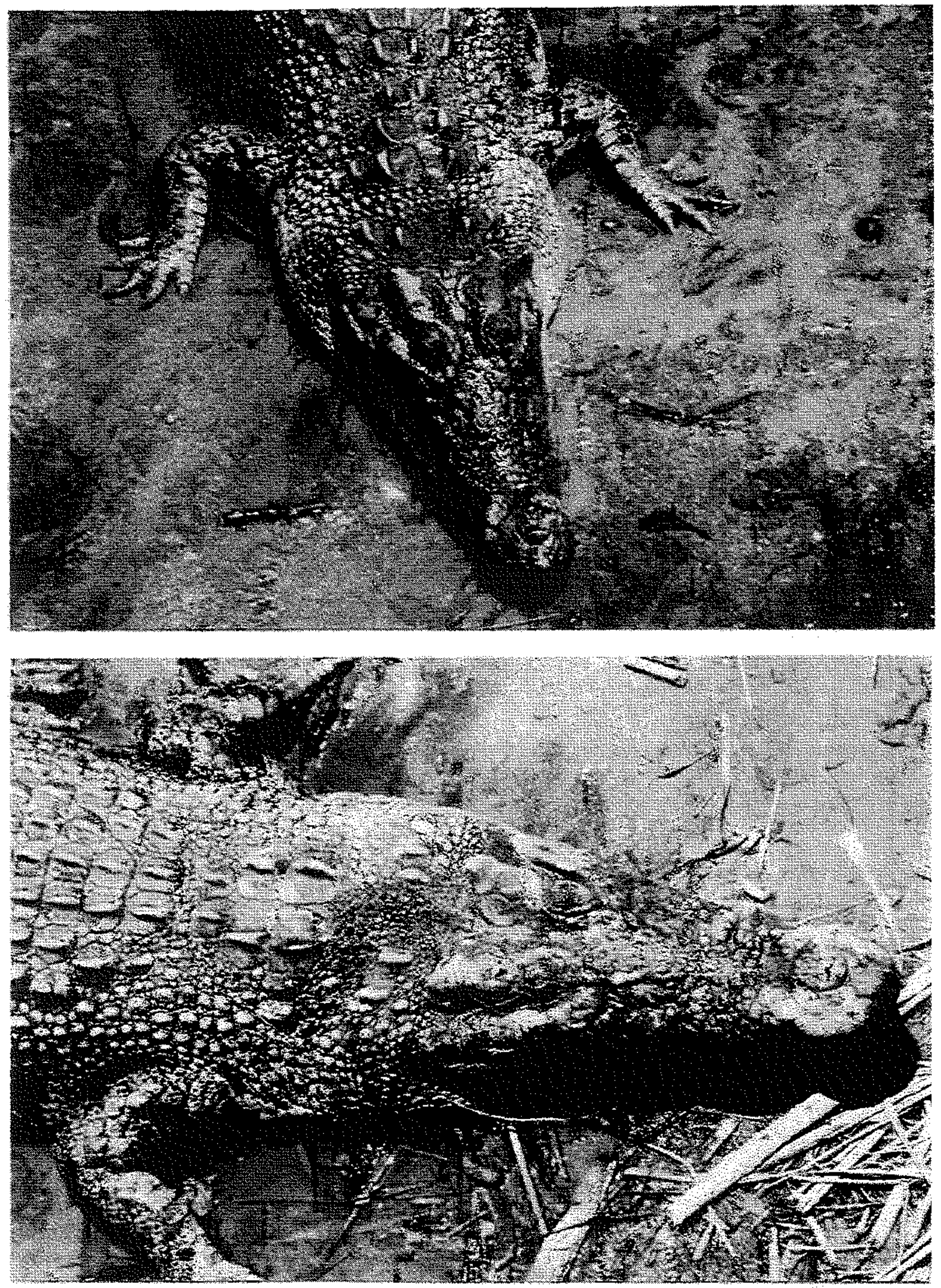

Figure 2. *Crocodylus* sp. photographed at a crocodile farm in Masamba, Sulawesi (23 October 1998). Note well-developed post-occipital scutes.

REPORT ON THE STATUS OF CROCODILIANS IN THE CAMEROON FOREST ZONE

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SUMMARY

Field records from about half of Cameroon's principle river systems in the forest zone are compiled with preliminary notes on the status and management of Africa's three crocodile species. The most widespread species found was Osteolaemus tetraspis, with Crocodylus niloticus occurring only locally, and C. cataphractus found to be very scarce. Habitat degradation, both terrestrial and aquatic, together with subsistence hunting and trapping are factors directly associated with the decline in population distributions, densities and age-class structures. The illegal use of organochlorines in fishing has become an increasing ecological problem throughout the country, and subsequent lack of food availability combined with a prevalence of toxic contaminants may be significant limiting factors for fish-eating riparian species, in particular C. cataphractus as well as some otter species.

INTRODUCTION

Over a ten-year period (1990-99) I visited crocodilian habitats at 35 locations in the Cameroon forest zone. These included 27 sites on 6 major river systems (Mungo, Nyong, Dibamba, Wouri, Cross, and Dja), 3 crater lakes, as well as several stillwater forest pools and swamps. The majority of records however originate from the South West and Littoral Provinces located in the west of the country. Due to a lack of information on the status of crocodilians in this part of Africa, I compiled a brief summary of my observations, and outline here some of the salient research and management issues currently facing crocodiles in the region.

STUDY SITES & METHODS

A summary of field records is given based on field data collected during the course of other forest survey and inventory work. Techniques included nighttime torchlight surveys by wading and bank-side searches on foot, boat and pirogue, and low-level aerial surveys. A total of about 100 nights over the 10-year period were dedicated to searching for crocodilians. In addition, notes taken from interviews with fisherman and specialist crocodile hunters are referred to where identification was verified by direct field observations by the author.

List of sites visited: Akonolinga swamps (1993); Dimbamba River (1997, 1998); Dibombe River and tributaries (Wouri system)-Bakaka Forest Reserve (1993, 1994, 1997, 1998); Mungo River and tributaries (Jide and Ekeb), Bakossiland (1990, 1992, 1993, 1994,1997, 1998); Mt Kupe Forest (1990-99); Makone River (Cross system) - Takamanda Forest Reserve (1998); Munaya River (northern Cross system) - Mawne Forest Reserve (1998); Oyi River (1998), Benoue River (1993); Mbu River -Banyang Mbo Wildlife Sanctuary (1994); Lake Barombi Mbo (1993); Lake Edib - Bakossi Mts. (1992, 1993, 1994, 1998); Lake Beme (1992); Korup National Park (1994); Nyong River (1993); Dja River; swamp forest in the Dja Faunal Reserve (1993).

Intensive surveys were made over a 10km stretch of the Makone River by river wading and walking riparian transects during 2 weeks in February 1998 and over a 10-km stretch of the Munaya River by boat during 2 weeks in December 1998. Both rivers are tributaries of the Cross River and lie in the region of the Takamanda and Mawne Forest Reserves in the South West Province. In addition, several minor stillwater breeding sites of Ostoelaemus were repeatedly visited in the Bakossi and Bakaka forests over the ten-year period.

Local hunters and fishermen have been very helpful in the field and were normally an important component of any field excursion, and over 120 were interviewed in Pidgin English on the local occurrence of crocodiles. Ostoelaemus are widely known as "alligators" and Crocodylus spp. are generally called "crocodiles", but distinction between the two species C. cataphractus and C. niloticus is rarely made, and often confused. Generally speaking, ethnozoological records were regarded as unreliable for the purposes of specific determination and, in some cases, for recording presence or absence. Experience has shown that weighting too much time and effort on ethnozoological interviews at the expense of fieldwork can be counterproductive. Of note here is the earlier report of Abercrombie (1978), who clearly misinterprets the local names for the respective crocodile species in Cameroon. Even with photographs, simple distinctions between species are often difficult to communicate and understand, and a number of times an individual has actually said to me "no" when they meant "yes", based on simple misinterpretations of context between myself and the interviewee. A common difficulty often occurred when a fisherman claimed that a crocodile lived in "his" local pool or river, and in several cases and after further discussions, this claim was eventually found to refer to his own "spirit animal" into which he transformed at night.

SPECIES ACCOUNTS

OSTEOLAEMUS TETRASPIS

FIELD RECORDS: Found in all forests visited: Bakaka Forest Reserve (1993, 1994, 1997,1998); Mungo River and tributaries (Jide and Ekeb), Bakossiland (1990, 1992, 1993, 1994,1997, 1998); Mt. Kupe Forest (1990-99); Makone River (Cross system) - Takamanda Forest Reserve (1998); Mbu River -Banyang Mbo Wildlife Sanctuary (1994); Dibamba River (1998); Akonolinga swamps (1993); Lake Barombi Mbo (1993); Lake Edib - Bakossi Mts. (1992, 1993, 1994, 1998); Lake Beme (1992); Korup National Park (Lawson 1993; pers. obs. 1994); Nyong River (1993); swamp forest in the Dja Faunal Reserve (1993).

NOTES: High altitude sub-montane population discovered at 1150 m altitude at Lake Edib (Bakossi Mts) - a bog-eyed crater lake located in tropical montane cloud forest. Locally abundant in Takamanda Forest Reserve in the Makone River where population is undisturbed and probably near to carrying capacity. At this site every slow-moving stretch of water between 0.5 and 2 m deep was occupied and although sometimes seen in pairs, adults were generally partitioned by tree-falls which formed natural dam-like barriers across the river. On average, large adults of 2 m length were located at about 300 m intervals (3 individuals per km). In addition, evidence of O. tetraspis was found in all of the sandy creeks leading to the river. Juveniles were not seen in this river (but were seen in similar habitat in the Mungo River). Species not limited to swamp forest. Found to occur in most forest ponds and lakes, marshes, and smaller slow-moving rivers with sand or silt substrate. In large rivers the species is limited to tributaries and swampy creeks, and is absent from rocky fast-flowing watercourses. The species is often a component in the diet of rural

people and individuals are occasionally seen for sale on the roadside or at market. Adults are trapped with wire snares baited with giant land snails, or killed directly using a machete.

STATUS: Widespread and locally common in remote areas of sparse human population throughout the Cameroon forests. Minor breeding sites to be found within walking distance of most lowland forest enclave villages. Evidence of subsistence hunting pressure locally. Threatened from subsistence trapping and deforestation.

CROCODYLUS NILOTICUS

FIELD RECORDS: Nyong River (3 large adults on sandbar) 1993; Korup National Park (possibly extinct, Lawson, 1993); Oyi River (large adult on sandbar) 1998; Munaya River (single adult); Makone River - high density of adults and juveniles. In addition, two subadults were seen in the Benoue River in the Northern Savannas in 1993.

NOTES: In the Makone River adults were found in all of the deep pools of the river during the dry season. Each pool was occupied by between one and three adults between 2 and 4.5 m in length. Density apparently limited to the number of pools available suggesting that the population was near to the carrying capacity of the river. Juveniles and subadults favoured the overhanging derelict Indian bamboo plantations bordering the river. In contrast in a separate 2-week survey of the Munaya River by boat, only a single C. niloticus was seen near the confluence of the Mawne River. The Munaya is heavily exploited with gill-nets and synthetic agro-chemical poisons, and crocodiles are hunted regularly.

STATUS: Locally occurring in the forest zone in major rivers only. Populations depleted or extinct in places, but patterns of distribution and status remain poorly understood. Other viable populations may persist in the unsurveyed Oyi (Cross) River, Sanaga and Dibamba Rivers, and in the southern border region with the Congo.

CROCODYLUS CATAPHRACTUS

FIELD RECORDS: Single isolated records were made from: Mungo River 3 km north of Kumba bridge 1992; Nyong River 25 km west Mbalmayo 1993; skull from Mbu River Banyang Mbo 1992; Ndian River, Korup National Park (Lawson, 1993).

NOTES: No dead animals ever seen offered for sale. Possibly absent from Makone and Munaya Rivers (Cross system) 1998. The species is very secretive and apparently rare, at least in the South West Province.

STATUS: Endangered in South West Province. Viable populations may persist in the unsurveyed Sanaga, Nyong and Dibamba River systems, and in the south-east forests and border region with the Congo.

Undetermined Crocodylus spp. recorded from Lake Barombi Mbo 1993; Lake Beme 1992; Dja River 1993.

DISCUSSION

Many forest villages in Cameroon are dependent on rivers and lakes for subsistence and as an economic resource, and freshwater fish are significant components of rural economy throughout the lowland forests. While most rural activities are a legitimate and necessary part of daily life, in many places fishing and hunting of aquatic and riparian fauna are unsustainable.

In central and southern Cameroon, the distribution and status of crocodilians is poorly known, and these less disturbed areas may support more viable refuges for crocodiles than in the west of the country. Crocodilians occurring within certain protected areas appear to be as equally exploited as those found in non-protected areas. Elsewhere, rates of deforestation continue to increase together with human population of the forest zone, and habitat degradation poses a significant threat to crocodilians. Where fishing is intensive, young crocodilians are widely reported as drowning in gill-nets in both lakes and rivers, -a hazard unpopular with fishermen. Crocodiles are often hunted locally and either consumed like other bushmeat, or sold at market. However, enhanced legislative measures on the control of hunting for subsistence purposes are unlikely to be useful in the protection and conservation of crocodiles in Cameroon. As in much of Africa, crocodilian leather products are sold at major tourist markets, but their origin is not known and they may be imported.

The illegal poisoning of rivers with agro-chemical as a means to catch large numbers of fish is a widespread and regular occurrence in most rivers in the country. The practise originated from traditional methods using certain fruits and barks in the water to temporarily bring fish to the surface, which had a minimal observable effect on river ecology. Over the past 20 years or so, readily available toxic plantation pesticides have been substituted for natural forest products with dramatic effects on fish and other aquatic life. The use of organochlorines and soluble copper oxide as synthetic ichthyotoxins may have significant negative effects on the aquatic ecosystem and on the reproductive biology of crocodilians. Depleted fish stocks, and intensive use of gill-nets, have been associated with low densities of otters and absence of C. cataphractus in at least one river, and this pattern may be replicated elsewhere

Research priorities should include stratified field surveys of crocodilian populations within major river systems in order to understand distribution patterns, classification of the status of populations, and identification of trends and threats. Studies are also needed on the extent and exact effects of biomagnification of organochlorines and other synthetic compounds, and potential levels toxic to respective species. If the possible deleterious consequences on populations were determined, the results could have far reaching implications along the food chain for both wildlife and humans. Furthermore, such studies may be instrumental in demonstrating the risk to authorities and rural communities of introducing such contaminants into the environment.

In developing an approach to research and management of crocodilians in the region, other aquatic and riparian faunal groups should be considered in order to understand the wider ecological and socio-economic processes, and provide a scientific basis towards developing formal management intervention policies in river systems. Several regional studies on the monitoring and conservation of fish assemblages have facilitated further work in this field (e.g. Reid 1991, Toham, A. K. and Teugels, G. G. 1998). Preliminary data now exists for the status and distribution of Cameroon's threatened manatees (Grigione & Powell 1989), and the goliath frog (Wild, in prep). Survey work is currently in progress by Birdlife International on the Cameroon avifauna which includes several wetland sites (D. Thomas, M. Languy, pers. com) and this work aims to integrate findings with other faunal groups in a conservation and management context. Since 1991, preliminary work on the taxonomy, distribution and ecology of Cameroon's dragonfly fauna offers potential for water quality monitoring in the future (G. Vick, D. Chelmick and O. Mesumbe, pers. comm). However, little is known on the status and distribution of Cameroon's riparian mammals, aquatic turtles and other lowland riparian amphibian species.

Although a sound legislative basis exists for river management, the Government of Cameroon lacks an administrative structure specifically equipped to deal with river management policies, in particular the control of pollution and fishing. Cameroon benefits from relatively numerous, well-funded conservation programmes run by an increasing variety of organisations. Crocodilian populations generally appear, however, to be equally exploited within protected areas as they are elsewhere. Moreover, the wider issues of freshwater hydrology management, conservation of aquatic communities, and the important economic role of rivers and their exploitation have received little attention in the lowland forests to date. Field projects lack management options for hydrological systems, while conservation NGO's lack programmes effectively incorporating rivers into their national or regional strategies. Clearly there is a need to establish a scientific basis for the sustainable management of the nation's rivers, and to develop and formalise an effective river management system.

The profile of river management issues and the value and conservation of the freshwater biota will need to be raised in order to place crocodilians on the conservation agenda in Cameroon. At the institutional level, programmes for research, monitoring and management of river systems need to be integrated into existing forest management plans. Formal co-operation between a diversity of partners, including those of government and traditional authorities, industry, development projects and public engineering works, donors, NGO's and regional opinion leaders, are needed in order to facilitate opportunities and strategies for conservation and development. In addition, it will be necessary to enhance the capacity of the Government to enforce current protective legislation and play its role in effective management of river resources and wildlife conservation.

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IUCN/Species Survival Commission

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

The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. A volunteer network comprised of nearly 7,000 scientists, field researchers, government officials and conservation leaders from 188 countries, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

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

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