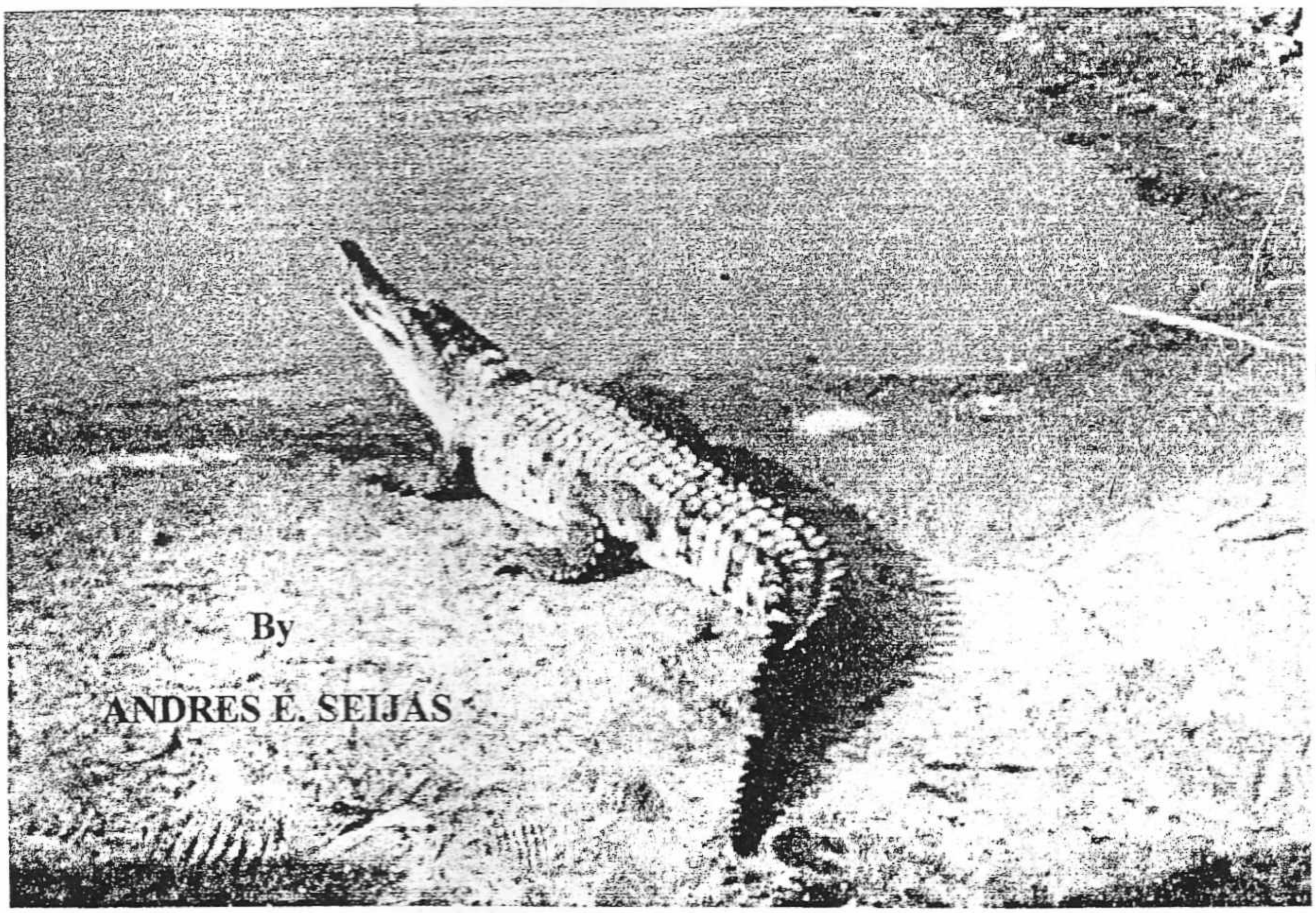
THE ORINOCO CROCODILE (Crocodylus intermedius) IN THE COJEDES RIVER SYSTEM, VENEZUELA: POPULATION STATUS AND ECOLOGICAL CHARACTERISTICS



By

ANDRES E. SEIJAS

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE
UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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THE ORINOCO CROCODILE (*Crocodylus intermedius*) IN THE COJEDES RIVER SYSTEM, VENEZUELA: POPULATION STATUS AND ECOLOGICAL CHARACTERISTICS

By

Andres E. Seijas

May, 1998

Chairperson: F. Wayne King
Major Department: Wildlife Ecology and Conservation

The Orinoco crocodile is one of the most critically endangered crocodilian species of the world. Commercial overexploitation, from 1930 through late the 1950s, decimated its populations from most of its range. The most important Orinoco crocodile population known to date is found in the Cojedes River System (CRS), Venezuela. In the last 30 years the CRS has been heavily impacted by channelization, dredging, damming, deforestation, and contamination. River reaches in the upstream (north) part of the CRS are close to urban, agricultural, and industrial centers. Compared to river reaches located farther (downstream) from human activities, these northern river sections showed low levels of dissolved oxygen (DO) and relative high values of carbon dioxide, hardness, nitrates, phosphates, biochemical oxygen demand (BOD), pesticides, and other parameters indicative of pollution and eutrophication.

Based on spotlight surveys, a minimum population of 540 non-hatchling crocodiles was estimated for the study area. Middle sections of the CRS, particularly near the downstream-end of Caño de Agua, showed the highest population indices (7.3 ind/km). Intermediate PI were observed in Cojedes Norte and Caño de Agua Norte (2.2 and 4.4 ind/km, respectively), river sections relatively close to important human settlements and with comparatively higher levels of habitat alteration and contamination. The lowest PIs (<1.0 ind/km) were observed in river reaches the farthest from main urban centers. Crocodile populations in northern sections of the CRS were dominated by juveniles, whereas sub-adults and adults composed an important fraction of the population in river reaches with relatively high crocodile densities.

Geographic Information System analysis did not show a strong relationship between relative crocodile abundance and proximity to urban centers. Navigability of river reaches and crocodile abundance are negatively correlated, suggesting that accidental or intentional killing by people may be responsible for the low population indices in southern river reaches. Habitat quality may be another factor explaining the current distribution of the species in the CRS. Most adults were observed in river reaches with the best quality beaches. These sections may be population sources whereas southern river reaches are population sinks. To ensure the long-term survival of the species some 100 km of river should be set aside from human development.

CHAPTER 1
INTRODUCTION

There is probably no place on earth surface where human presence can not be detected. The powerful technologies developed by modern societies have allowed us to alter our environment in an unprecedented fashion. Some changes are consequences of deliberate human actions, such as those resulting from the creation of dams or from deforestation to develop new agricultural lands. Other changes, such as water pollution and invasion by exotic species, are by-products of our activities. Human population growth, and its associated increasing demand for goods and services, is going to continue for the foreseeable future, and wildlife conservation programs must take into account that reality.

This study deals with the ecology and conservation of the Orinoco crocodile (*Crocodylus intermedius*) in the Cojedes River system (CRS) in the Venezuelan states of Portuguesa and Cojedes. This region is currently characterized by two main types of landscapes. In the north, where the greatest human population is concentrated, the landscape is a mosaic of intensive agriculture, cattle ranching operations, and large and medium size urban centers. In the south, natural savannas and pasture lands, dedicated to extensive cattle ranching, form the matrix of the landscape, which are intermixed with forest relicts, scattered agricultural lands, and other less extensive land-cover categories. The underlaying rationale of the present investigation is that the design of any program for the conservation of the Orinoco crocodile in the CRS, must be based on an understanding of the ecology of this species over a broad spatial (and temporal) scale in which man is a key element.

The central hypothesis of this study is that the current pattern of human activities and distribution in CRS should affect the distribution, abundance and general well-being of the Orinoco crocodile in that region. The effect of humans on the crocodiles may be direct, by means of killings, egg predation or habitat destruction; or indirect, due to degradation of the quality of its habitat, the discharge of contaminants with long term effects on its reproductive success, or the introduction of predators, competitors and diseases.

In this introductory chapter, I describe the general characteristics of the Orinoco crocodile, and its past distribution and abundance. Later on, I discuss the historical reasons that may explain why a species that was almost exterminated by commercial exploitation from most of its original range, survived in the CRS.

Chapter 2 delimits the study area and describes the major transformation that it has experienced since the middle 1950s. Chapter 3 characterizes the water quality of the study. In That Chapter I show the effects of contamination on the biological integrity of the river, and discuss the long-term effect that pesticides may have on the reproductive success of the Orinoco crocodile.

The population status of the Orinoco crocodile and spectacled caiman (*Caiman crocodilus*) in the CRS, and the distinctive patterns of abundance and distribution of these species, are the subject of Chapter 4. The spectacled caiman has been regarded as a competitor-predator of the American crocodile, *Crocodylus acutus*, along the Venezuelan coast (Seijas 1988, 1996), and of the Orinoco crocodile itself (Thorbjarnarson and Hernández 1992). My findings are discussed in relation to the competition-predation and other alternative hypotheses.

The focus of Chapter 5 is the reproductive ecology of the Orinoco crocodile in the CRS. There I answer some basic questions in regard to quality of nesting habitat, nesting chronology, hatching success, and distribution of the adults along the river. Recent loss of nesting habitat is documented, and the impact of damming and channelization on nesting is discussed.

In Chapter 6 I examine whether or not the general well-being of crocodiles in CRS related to the pattern of human occupation of the space. The physical condition and growth of juvenile crocodiles, indicators of how well the species is coping with its environment, are examined, and differences in body condition, frequency of injuries, and parasite infestation rates are compared between localities.

Chapter 7 deals with the diet of juvenile crocodiles in areas of the CRS with varying levels of anthropogenic impacts. The results are discussed in relation to food resources availability in these areas.

In Chapter 8, I test the hypothesis that the pattern of human settlement in the CRS, has directly or indirectly affected the current distribution of the Orinoco crocodile. A geographic information system (GIS) is used to model human population pressure over the entire CRS, and I examine how this influences the probability of finding crocodiles in any particular area.

The conclusion of this study, and management recommendations for the conservation of the Orinoco crocodile in the CRS, are presented in Chapter 9. An important recommendation is that a protected area must be declared in the region to ensure the long-term survival of the species. The general characteristics of the proposed protected area are presented.

The Orinoco Crocodile

The Orinoco crocodile (*Crocodylus intermedius)* is one of the most critically endangered crocodilian species of the world (Thorbjarnarson 1992). Commercial overexploitation from 1930 through the 1960s, decimated its populations from most of its distribution ~~area~~ (Medem 1983). *C. intermedius* is listed as critically endangered in the Venezuelan Red Data Book (Rodriguez and Rojas 1995), which also includes in this same category other "fresh water giants" such as the manatee, the giant river otter (*Pteronura brasiliensis*), and the river turtle *Podocnemis expansa*. The Orinoco crocodile has been legally protected both in Colombia and Venezuela for almost 30 years, and international trade has been prohibited by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since the middle 1970s (King 1989). However, despite these legal efforts, little recovery of wild crocodile populations has occurred.

The Orinoco crocodile is a large, longirostrine freshwater crocodile that historically could reach sizes close to 7 m in total length (Humboldt 1975, Medem 1981), making it one of the largest crocodilian species of the world. According to anecdotal information (Medem 1981, 1983; Whitney 1912) the largest, probably dominant males, averaged around 4-5 m in total length (TL). Animals these sizes may no longer exist, or are very rare, as a consequence of the overexploitation it suffered in the recent past. Information gathered on captive animals indicates that the TL at sexual maturity is 2.4-2.5 m for females and around 2.8 m for males (Thorbjarnarson and Hernández 1993a).

In the past, this crocodile was found in a wide variety of habitats, including rivers in tropical evergreen forests and piedmont streams and temporary and permanent savanna lagoons. But this species reached its greatest numbers in the seasonal rivers of the Llanos of Venezuela and Colombia. Today, the species is also found in very low densities in reservoirs (Thorbjarnarson and Hernández 1992; Seijas and Meza 1994).

The Orinoco crocodile is a hole nesting species, laying its eggs in seasonally exposed sandbars early in the annual dry season (January-February). Clutch size is typically in the range of 40-70 eggs, and the young hatch out during the seasonal rise in river level associated with the wet season (Medem 1981, 1983; Thorbjarnarson 1992). Only recently have detailed ecological and behavioral studies been generated (Thorbjarnarson and Hernández 1992, 1993a, 1993b).

Historical Distribution

The Orinoco crocodile is the only species of crocodile in the world whose distribution is restricted to only one hydrographic basin, the Orinoco River basin (Medem 1981, 1983; Thorbjarnarson and Franz 1987; Thorbjarnarson and Hernández 1992). This basin, however, covers an extensive territory (1,123,000 km^2; Taphorn 1992), that represents almost three quarters of Venezuela and, roughly, 35% of the Colombian territory (Fig. 1-1). Historical accounts indicate that the primary habitat of this species was the major river systems of the Llanos region of these countries (Humboldt 1975; Codazzi 1940; Páez 1980; Medem 1981, 1983), particularly the Arauca, Meta, and the Guayavero-Vichada Rivers in Colombia, and the Apure, Portuguesa, Arauca, and Orinoco River itself in Venezuela, to mention just the most important. More recent findings indicate that the species extended well up many Llanos rivers and into surrounding piedmont areas in the foothills of the Andes (Ramo and Busto 1986; Thorbjarnarson and Hernández 1992), and most of the southern bank tributaries of the Orinoco including heavily forested regions (Hitchcock 1948; Franz et al. 1985; Arteaga et al. 1994).

The Orinoco crocodile is now only found in a minute fraction of its former range. Commercial hunting in the recent past extirpated the species from most of the major river systems mentioned above. In Venezuela, scattered individuals and isolated small populations have been reported in the last 20 years (Godshalk 1978; Franz et al. 1985; Ramo and Busto 1986; Thorbjarnarson and Hernández 1992; Seijas 1992). The largest, and probably only viable, populations of the species are found in the Capanaparo River (Thorbjarnarson and Hernández 1992) and Cojedes-Sarare River system (Ayarzagüena 1987, 1990; Seijas 1992).

The Exploitation of Crocodiles in Venezuela

Crocodilians in general, and the Orinoco crocodile in particular, were traditionally hunted by both aboriginal and rural people in Venezuela as a food resource or for the putative medicinal or magic properties of their teeth and fat (Gumilla 1963; Codazzi 1940;

Figure 1-1. The cross-hatched area within the Orinoco river basin represents the presumed former range of *Crocodylus intermedius* in Venezuela and Colombia.

Petrullo 1939; Roze 1964; Tablante-Garrido 1961; Arcand 1976). Nevertheless, commercial exploitation for their hides only started toward the end of the last century.

The first attempt at commercialization of crocodile skins in Venezuela was initiated in 1894-1895 by an American company that established its headquarters in El Yagual, in Apure state (Verstraeten 1939; cited by Medem 1983; Calzadilla 1948). Crocodiles were hunted with firearms during the day, a highly inefficient method in which many dead and injured animals could not be recovered from the river. André (1904) reports that two Norwegian brothers, named Christiansen, were engaged in collecting Orinoco crocodiles skins in 1897. They, or they employees, hunted at night with the aid of reflectors adapted to lanterns. As many as 60 or 70 animals, shot with firearms, were obtained in a single night. The salted skins, which were later processed to manufacture "durable and dainty bags and dressing-cases," were sold for $1.00 apiece. These early attempts failed to prosper. The expenses of preparing and transporting the hides proved to be so great that the work had to be abandoned (Mozans 1910; Calzadilla 1948).

Despite this early commercial exploitation, during the first quarter of this century the Orinoco crocodile was probably as abundant as it was when Humboldt (1975) and other 19th century naturalists (Appun 1961; Páez 1980) were amazed by its numbers. Whitney (1912) and Calzadilla (1948) gave picturesque accounts of the abundance of crocodiles in rivers such as the Apure and the Matiyure. A new phase of commercial exploitation started at the end of the 1920s (Medem 1983). New hunting methods (flashlights and harpooning) and an international demand for crocodilians hides, combined to bring to the brink of extinction in less than three decades a species that originally could be counted by the millions.

Medem (1981, 1983) provides a detailed account of the exploitation of *C. intermedius* in Venezuela (and Colombia). Only the main points will be repeated here. The peak of the exploitation occurred from 1930-1931, when between 3,000 and 4,000 skins were traded daily in San Fernando de Apure. From 1933 to 1935, Venezuela exported 900,000 crocodile hides. The large scale exploitation ended in 1947-1948, due mostly to the scarcity of the resource by that time. Independent hunters persisted in this activity for several years, but the export of *C. intermedius* hides from 1950 to 1963 was minimal.

It is logical to presume that when the crocodile became scarce in the areas where it was historically abundant, more distant populations, in the periphery of its distribution were then hunted. Hitchcock (1948), for example, pointed out that a party of hunters killed 58 crocodiles during the dry season of 1947 in the Ventuari River, one of the southern tips of the distribution of the species. In the early 1960s, the incorporation of a sympatric species into the trade (Medem 1981, 1983), the less valuable but relatively more abundant spectacled caiman (*Caiman crocodilus*), surely contributed to the complete extirpation of the Orinoco crocodile from many areas. As was stated by King (1978), the less desirable species permitted hunters and international consumers to continue operations when the preferred species (in this case the Orinoco crocodile) was too scarce to sustain an industry. In their pursuit for caiman, the hunters surely killed the few remaining crocodiles that they encountered.

All previously mentioned activities were conducted legally. In the late 1940s, concern arose regarding the extreme scarcity of Orinoco crocodiles as a consequence of the intensive hide hunting (Blohm 1948; Mondolfi 1957; Medina 1960). The extremely depleted state of the species was further emphasized in later publications (Mondolfi 1965; Donoso-Barros 1966a, 1966b; Rivero-Blanco 1968; King 1973; Blohm 1973). Ironically, the first legal instrument to protect the species were issued in 1968-1970 in Colombia (Donadio 1981) and 1970-1971 in Venezuela (Venezuela 1970), when there were few left to be protected.

Why Are There Crocodiles Left in the Cojedes River?

The first evaluation of the status of the Orinoco crocodile in Venezuela was conducted by Godshalk (1978, 1982), through the sponsorship of the *Fundación Venezolana para la Defensa de la Naturaleza* (FUDENA). Only 273 crocodiles were located (based primarily on a tally of crocodiles known to fishermen and riverside dwelling peasants) in an extensive survey throughout the Llanos region. In Godshalk's study, two areas were highlighted as the ones with the most important populations remaining: the Capanaparo River in Apure state, and the Cojedes River in Cojedes state. The importance of these populations was later confirmed by other investigators (Thorbjarnarson and Hernández 1992, 1993a, 1993b; Ayarzagüena 1987, 1990).

The existence of a relatively large population of *C. intermedius* in a river like the Capanaparo is relatively unsurprising. This is a river with a prime habitat for the species, with ample sandy beaches, and far from most urban and industrial centers. The

Capanaparo is also in the center of the species' range, where it reached its historically higher densities. However, survival of a crocodile population in the Cojedes River is intriguing. As can be seen in the following chapters, the Cojedes is a very narrow river, near the periphery of the Orinoco crocodile distribution and very close (or even in some case under the influence) to some of the most important agricultural, urban and industrial centers in the country.

Why then are there crocodiles left in the Cojedes River? Ayarzagüena (1987) addressed this question in the following ways: (1) During the time of the commercial exploitation, communication and trade were almost exclusively conducted through the rivers, particularly the Orinoco and Apure. Communication and trade in the Cojedes River were limited up to El Baúl. Upstream from El Baúl, large scale communication and trade were almost impossible. (2) After every annual flooding season, part of the river changed its course through an intricate system of meanders and oxbows, which complicated navigation. (3) The abundance of crocodiles in other river systems distracted hunters from the Cojedes population. (4) Later, the enactment of protecting laws and the construction of roads (which diminished the use of the rivers for transportation) kept people away from the crocodiles of the Cojedes River.

Another important factor, not mentioned by Ayarzagüena (1987), is that Cojedes state was, and still is, one of the states least densely populated by people in the entire country. Cojedes is also the smallest in area among the western Llanos states (which includes Apure, Barinas, and Portuguesa). The area, human population, and human population density of the Cojedes and its surrounding states are shown in Figure 1-2.

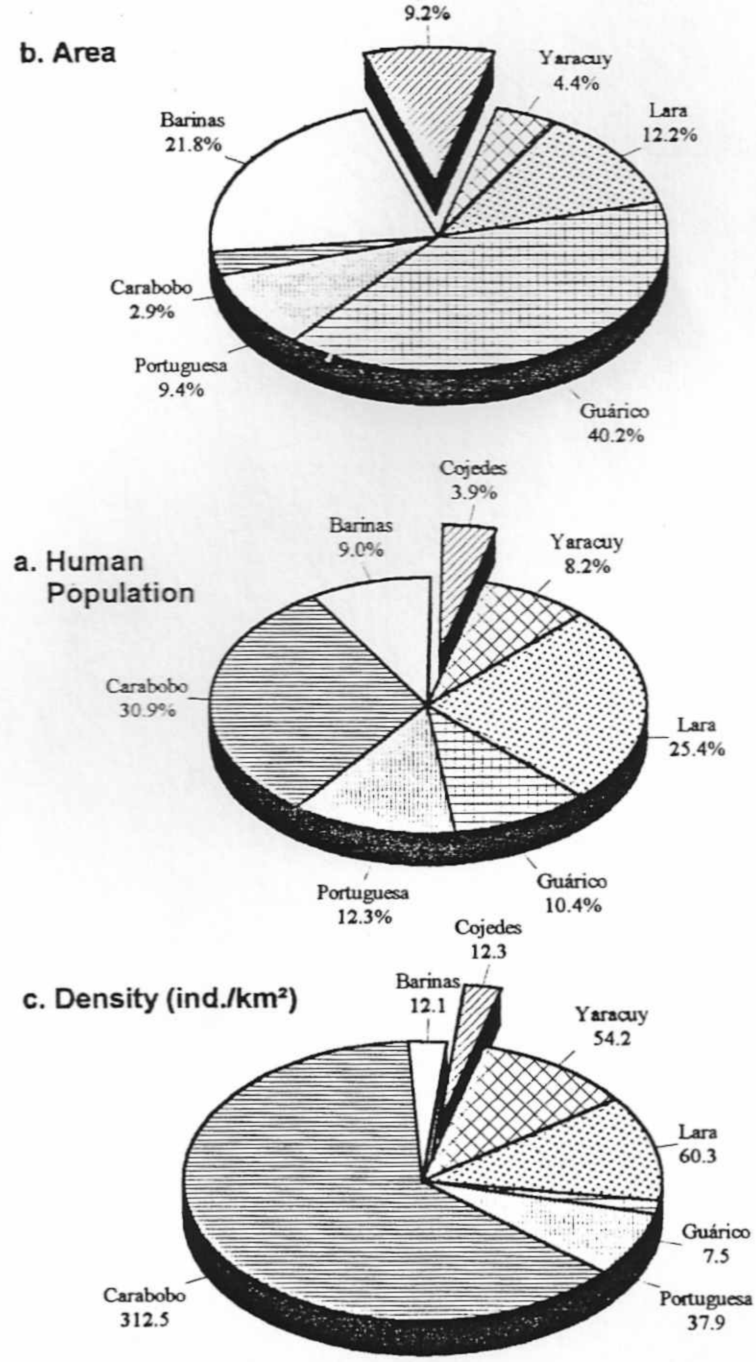

Figure 1-2. Comparison of the human population (a), and surface area (b), and human population density (c) of Cojedes with its neighboring states, Venezuela.

Low human population densities are characteristic of all the Llanos states. This factor by itself may not explain why there are crocodiles in the Cojedes River, but the pattern of human population growth may contribute to explain that issue. Since 1887, the first year for which information is available, the human population growth of Cojedes state has been relatively slow, in comparison to other Llanos states. In fact, from 1887 to 1926, the Cojedes' human population remained stable, slightly above 80,000 people. From 1926 to 1950, there was a decline in its human population (OCEI 1993; Fig. 1-3). That reduction was probably due to migration toward the industrial, commercial and oil producing centers of the country and to the high human mortality rate that characterized that period (Vila 1956; MARNR 1995). This decline in human population size in Cojedes state coincides with the peak of crocodile exploitation in Venezuela (Medem 1983). Even under these particular circumstances, the Orinoco crocodile was intensively hunted in Cojedes state. According to Vila (1956), by the early 1950s the species was restricted to those reaches of the Cojedes River farther from human settlements.

The current status of the Orinoco crocodile in the CRS is probably a consequence of the historical factors already explained, and of the interactions of the species with new factors directly or indirectly related to human presence and human activities. That is the core subject of this research.

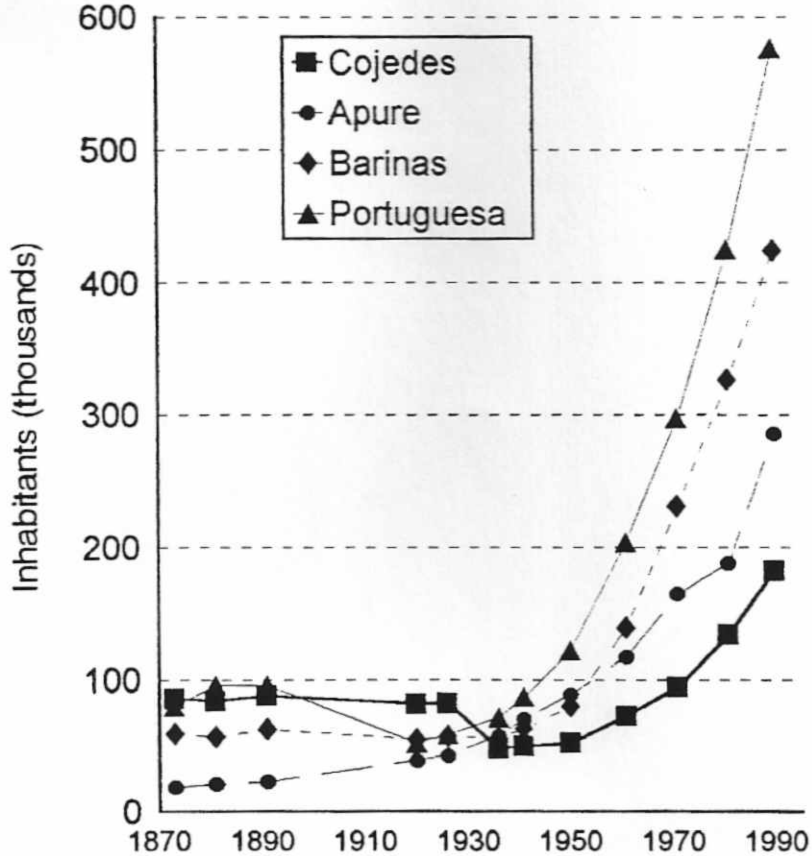

Figure 1-3. Human population growth in Cojedes state, Venezuela, as compared to other states in the Llanos region.

CHAPTER 2
STUDY AREA

The Turbio-Cojedes River basin of north-central Venezuela extends over an area of 4,325 km^2 (Contreras 1989). This river basin includes several types of regions that vary in relief, macroclimate, land-cover types, and main human activities. Here I define the Cojedes River System (CRS) as the lowlands of the Turbio-Cojedes River basin. That is the part of the Turbio-Cojedes basin that historically may have been occupied by the Orinoco crocodile.

The study area covered a wide fringe along the Cojedes and Sarare River that encompassed the cities of Acarigua (to the northwest) and San Carlos (to the northeast) and that extended south to the confluence of the main course of the Cojedes River with Caño Culebra, one of its own branches, near the town of El Baúl (Fig. 2-1).

For the purposes of this study, the CRS is considered as a region, i.e., an area with a common macroclimate and sphere of human activity and interest (Forman 1995). In the north part of this region, where most human population is concentrated, agricultural lands are the dominant landscape which is interspersed by large and medium size urban centers and cattle ranching operations. In the southern part of the region (south to the Lagunitas-Santa Cruz road), is a matrix of forested savannas and cattle pastures intermixed with forest relicts, scattered agricultural lands, wetlands, and other less extensive land-cover categories.

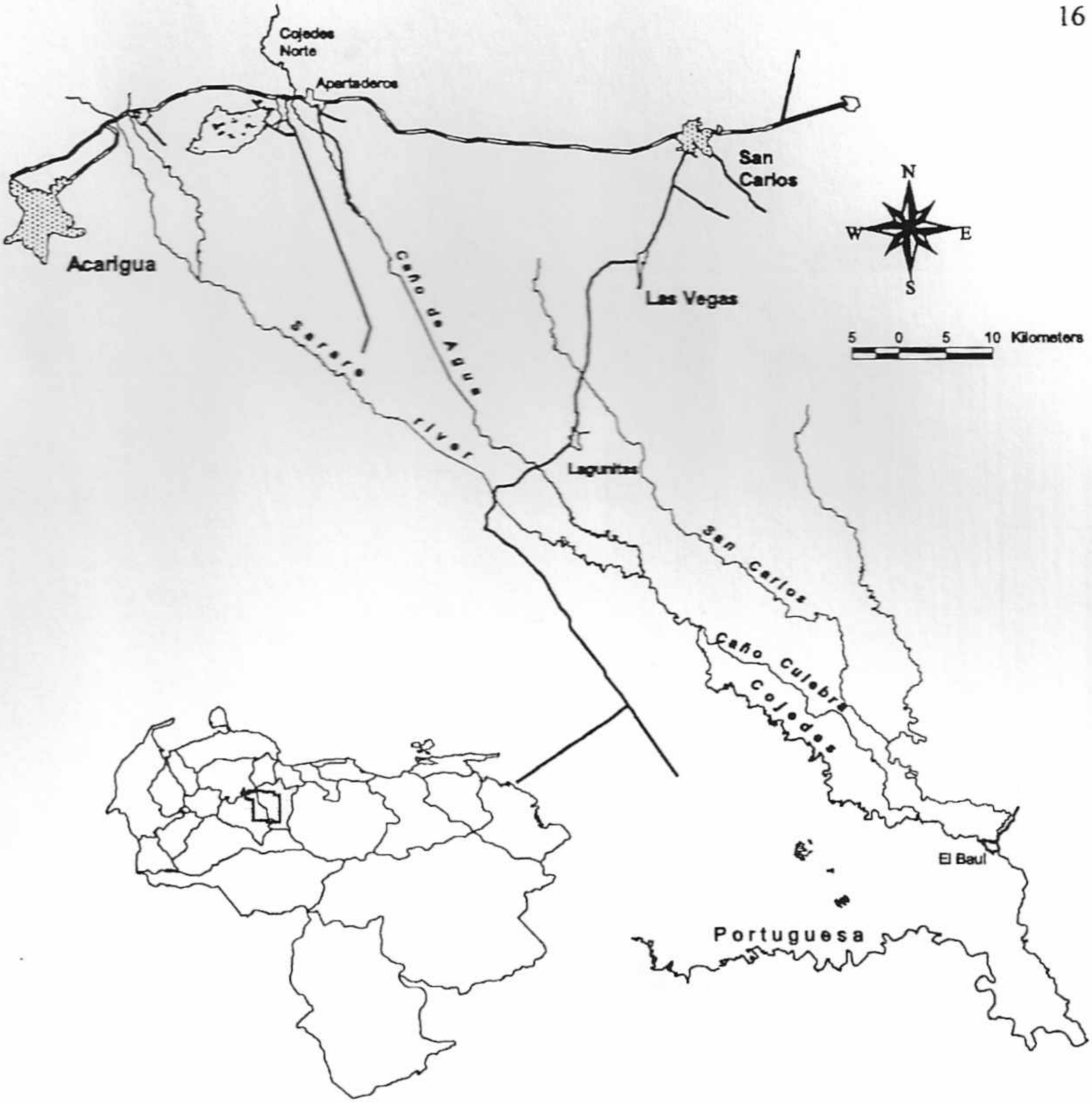

Figure 2-1. Relative position of the study area within Venezuela. States Cojedes (right) and Portuguesa (left) are shown in gray in the Venezuela map at the bottom.

The selected study area met the essential requirements to accomplish the main objective of my research. It shows zones of relatively high human population densities in the north, where the rivers have been highly impacted and modified, and zones of low human population densities where the river is closer to its pristine conditions. There are more than 200 km of rivers with diverse and contrasting characteristics, and finally, according to previous studies (Godshalk 1978, 1982; Ayarzagüena 1987, 1990), the relative abundance and reproductive status of the species vary among different river reaches of the system. Most of the sampling in this study was conducted along the Cojedes River itself and one of its main branches, Caño de Agua. Sections of the Sarare River, the larger tributary the Cojedes River on its west bank, were also studied.

The headwaters of the Cojedes River are in Cerro Rojo, in the Sanare belt of the Andes range at approximately 1,200 m above sea level, and some 50 km to the southeast of Barquisimeto (Vila 1956; Mogollon et al. 1987; Contreras 1989). Along its first 98 km the river is named Turbio. The name changes to Cojedes River below the confluence with the Buría or Nirgua River. The largest tributaries on the east bank of the Turbio and upper Cojedes, the Buría and Claro Rivers, come from the southern slopes of the Coastal Range in Yaracuy state. Originally, before the modifications over the last 40 years, the Turbio-Cojedes had a length of 316 km (Contreras 1989) from its headwater to the Portuguesa River, into which it drains.

Formerly, the Cojedes River was the border between the states of Cojedes and Portuguesa (Vila 1956). More recently, due to man caused diversions along its course, it flows mostly inside Cojedes state. In the last 40 years, the river and its surrounding areas have been heavily impacted by human development, channelization, dredging, damming, deforestation, and contamination.

Most of the Cojedes River flows through an area defined as Tropical Dry Forest, according to the classification system of Holdridge (Ewel and Madríz 1968). There are two clearly defined seasons in the study area as is typical of whole Llanos region in Venezuela. The rainy season extends from May to October, and the dry season from December to March. April and November are transitional months. The annual mean precipitation (1975-1996) is 1323 mm in the middle part of the study area and a little higher (1514 mm) toward the south (Fig. 2-2). During the rainy season the river discharge increases and frequently overflows its banks and inundates the floodplain, particularly in the southern portion of the study site.

In El Baúl, near the southern part of the study area, there is a difference of 2.9°C between the mean temperature of the coldest month (25.7°C) and the hottest month (28.6°C). The annual range between the absolute minimum and maximum temperatures is 11.6°C (21.7°-33.3°C). In the country, the coldest months of the year are usually December and January, but due to high precipitation the lowest temperatures in the Llanos could be experienced during July-September (MARNR 1995).

There are no historical records documenting how much of the Cojedes River basin was covered by forest before European colonization. Forest, however, may have been the predominant vegetation cover type in the study area. Most of the original forest has been lost due to logging, and deforestation to create pastures and agricultural lands (Ayarzagüena 1987). By 1975, 33% of Cojedes state was covered by forest. That

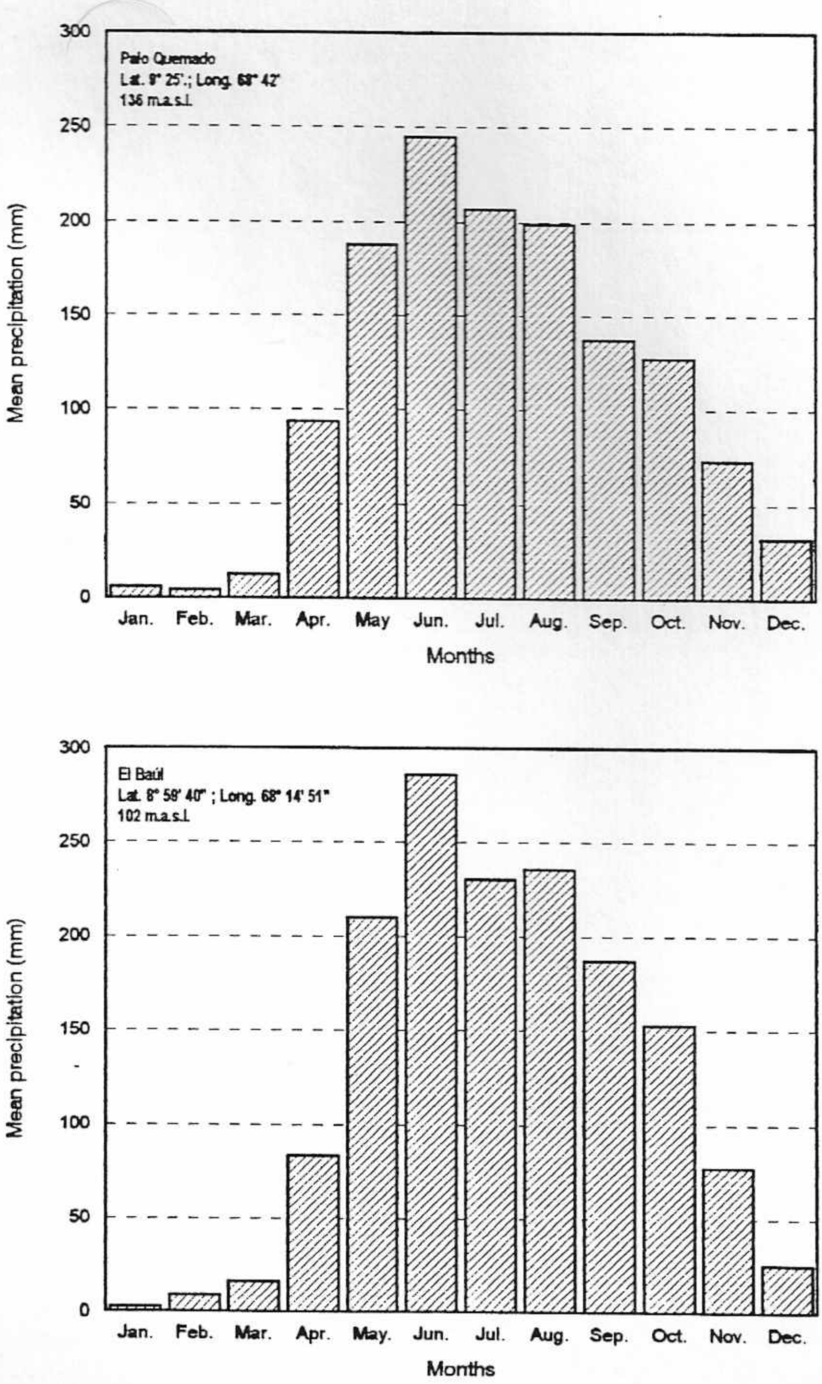

Figure 2-2. Annual patterns of precipitation in two areas of Cojedes state, Venezuela. The station El Baúl is just south of the study area.

percentage dropped to less than 16% in 1988. The annual deforestation rate in Cojedes state (3.81%) is the second highest in the country, after Portuguesa state, its neighbor, with 4.08% per year (MARNR 1995). No protected area or conservation reserve of any type exists within the Cojedes River basin.

From a socioeconomic point of view, the CRS could be characterized as an area with a low population density, high migration rate, high proportion of people making a living from agriculture, high illiteracy rates, high level of unemployment, high poverty level, and land ownership mostly concentrated in a few hands (OCEI 1993). The most important towns and cities are located in the north, near the piedmont of the Central Coastal Range. San Rafael the Onoto (Portuguesa state), Apartaderos and Cojeditos (Cojedes state) are located very close to the river (Fig. 2-1). Other relatively important human settlements in the study area are Lagunitas (or Libertad), El Amparo (Cojedes state), and Santa Cruz (Portuguesa state). The small villages of Retajao, and Sucre are the only ones directly located on the river banks. The closest large cities to the study area are San Carlos (69,217 people), and Acarigua-Araure (171,850 people), some 23.5 and 42.5 km, respectively, from their nearest point to the Cojedes River.

CHAPTER 3
WATER QUALITY IN THE COJEDES RIVER SYSTEM

Introduction

One of the many factors that may affect the survival of the Orinoco crocodile in Venezuela is habitat deterioration. The identification and quantitative evaluation of the many minor and large alterations in the physical, biological, and ecological attributes of the CRS and the analysis of the impact that these changes might have on some components of the river fauna, and in particular on the survival of the Orinoco crocodile, are essential steps to modify the status quo.

Changes in land use, irrigation practices, and the use of the water resources by an ever increasing human population and by industrial plants have altered the quantity and quality of the water in many rivers around the world (Wetzel and Likens 1979; Becker and Neitzel 1992; Petts and Calow 1996), and Venezuela is no exception. Although insufficiently studied, the Cojedes River system (CRS) is a clear example of these influences.

The headwaters and upper portion of the Cojedes River, where it is known as Turbio River, are close to Barquisimeto, one of the largest Venezuelan cities (circa one million people). There, sewage and other contaminants of agricultural and industrial origin enter the river. As the Cojedes River flows toward the Llanos region, it passes by many smaller towns and industrial plants. Later, part of its waters is diverted to a reservoir

(Las Majaguas) and a multiplicity of channels delivers its water to agricultural fields, which subsequently drain back to the main course with, presumably, a different chemical composition.

In his study on the population status of the Orinoco crocodile in the Cojedes River, Ayarzagüena (1987) described the many sources of contaminants that contribute to alter the water quality in the CRS and speculated on the impact that contamination might have on the reproductive success of the species. A proper evaluation of this problem, however, has not been accomplished. In this chapter, I summarize and update what is known about the water quality in the CRS. A case of fish kills is documented and discussed. This study, however, must be considered only as a preliminary diagnosis that could facilitate the planning and implementation of more detailed investigations.

Methods

During the dry season and early rainy season of 1997, water quality was assessed using a Water Pollution Field Detection Kit (LaMOTTE, Model AM-22). Samples were taken 10-15 cm below the surface. The parameters measured were temperature, dissolved oxygen (Winkler titration method, resolution 0.2 ppm), carbon dioxide (phenolphthalein titration method), hardness, nitrate-nitrogen (diazotization slide method, resolution 1-2 ppm), ammonia-nitrogen (salicylate method, resolution 0.5-2 ppm), and pH (colorimeter comparator, resolution 0.5 pH). Samples from different parts of the study area (Fig. 3-1) were taken at irregular intervals and at different times, although most frequently early in the morning and late in the afternoon. Samples from other rivers in the Llanos region

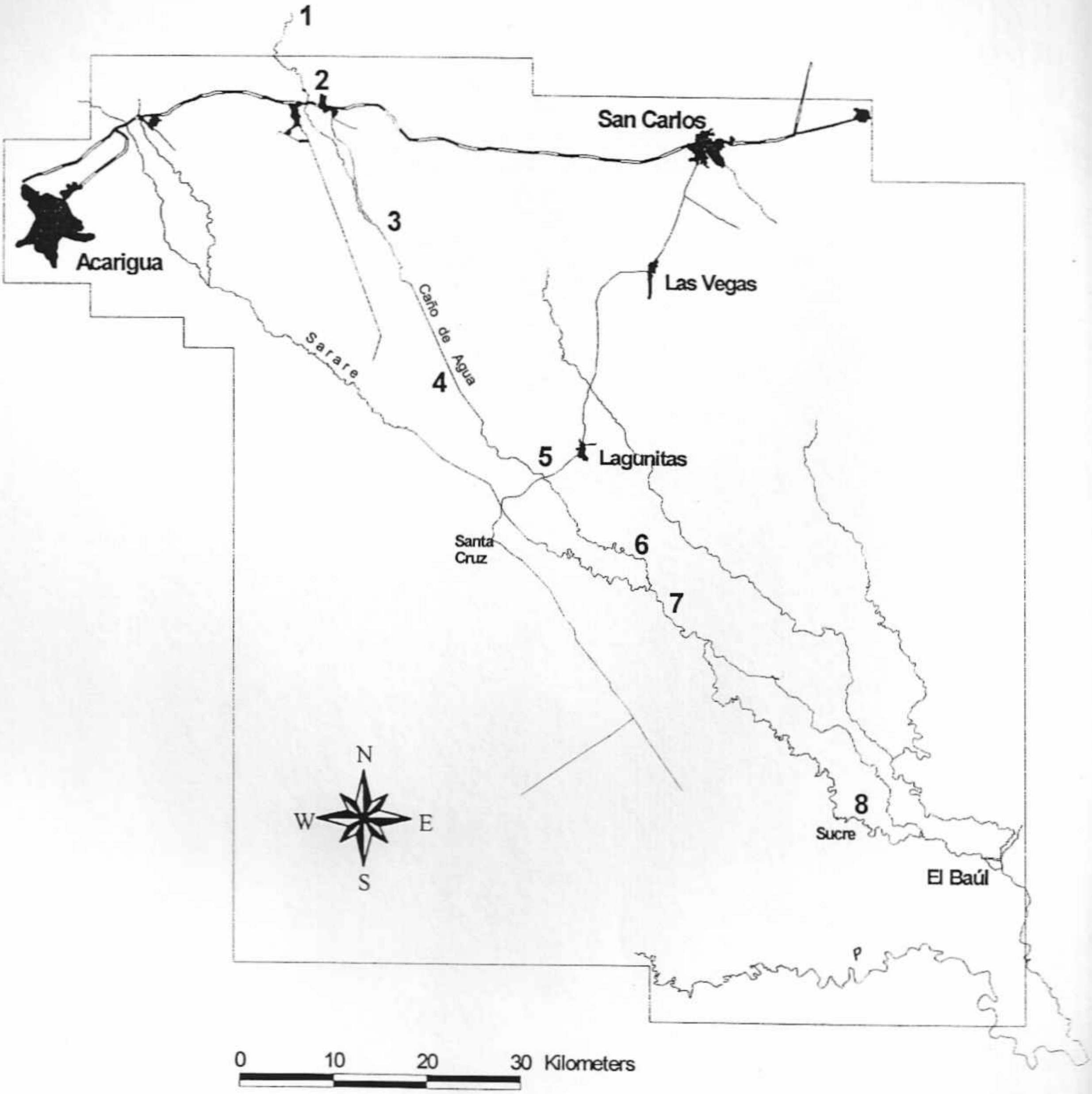

Figure 3-1. Map of the study area in the Cojedes river system (Venezuela) showing the stations where the water samples were collected. 1 Claro river, 2 Toma Cojedes, 3 Retajao, 4 La Doncella, 5 Puente Nuevo, 6 La Batea, 7 Merecure, 8 Sucre.

(Portuguesa and Guanare) and from the Claro River, which after joining the Turbio River forms the Cojedes River, just north outside of my study area, were also analyzed for comparisons.

My data were compared with data reported by Campo and Rodríguez (1995) for the Cojedes River system. The correlations among the different variables, and the pattern of changes in the water quality parameters as we move downstream, from north to south, along the Cojedes River, were obtained through the analysis of my data pooled with the Campo and Rodríguez (1995) data. Pooling these data increased the sample size and allowed a more comprehensive examination. Data from localities in close proximity were grouped, and the highest average value for a particular parameter among groups was taken as 100%. The average value of that parameter in other groups of localities was expressed as a percentage of that maximum value.

On two occasions, the sampling coincided with a massive die-off of fish. The sequence of events that occurred during these incidents is described. Samples of the dead fish and other organisms were taken and preserved for their later identification. No analyses of pesticides were conducted during my study; however, the Campo and Rodríguez data are presented and discussed.

Results

Water Quality

From 21 January to 1 May 1997, thirty-four water samples were analyzed (Table 3-1). Water temperature of the samples fluctuated from 23.8° to 30.8°C. Water

Table 3-1. Water quality analysis of the Cojedes River System (1997). The pH values were always between 7 and 8. In all case in which the phosphate level was analyzed the results were less than 0.2.

Place	Date	Time (h)	Temperature Water/Air (°C)	Ammonia-Nitrogen mg/l	Carbon Dioxide mg/l	Oxygen		Total Hardness mg/l	Nitrate NO_3-N mg/l
						mg/l	%S		
Guanare river	21 Jan.	0830	----	ND	1	7.6	--	128	<0.2
Portuguesa river	24 Jan.	0800	----	ND	4	5.8	--	72	<0.2
Claro river	3 Mar.	1700	27.7/----	ND	3	8.4	133.1	130	<0.2
Cojedes Norte	3 Mar.	1755	27.1/----	0.25	17	4.0	63.0	308	0.6
Toma Cojedes	23 Jan.	0900	----	0.5-1	10	4.0	–	268	0.6
Toma Cojedes	15 Feb.	2100	26.0/----	--	-	2.2	33.3	--	---
Toma Cojedes	16 Feb.	2100	24.6/----	0.25	17	3.0	42.9	268	---
Toma Cojedes	16 Feb.	2110	24.5/----	ND	16	3.4	48.4	284	---
Toma Cojedes	16 Feb.	2045	25.0/----	0-0.25	17	2.2	32.0	–	0.2
Toma Cojedes	21 Feb.	1205	26.0/----	0-0.25	-	4.2	63.2	276	---
Toma Cojedes	3 Mar.	2110	26.0/24.4	ND	16	3.8	57.3	300	0.6
Toma Cojedes	4 Mar.	0700	23.9/20.4	ND	14	4.2	58.4	284	0.6-1
Toma Cojedes	22 Mar.	1155	27.3/31.4	0-0.25	12	4.0	63.5	292	0.6-1
Toma Cojedes	20 Apr.	1428	27.5/----	0.25	-	0.4	6.4	--	<0.2
Toma Cojedes	1 May	1330	30.0/34.1	ND	14	4.4	78.6	300	0.4-0.6
Retajao	17 Feb.	1924	25.4/----	0.25-0.5	16	5.0	73.3	332	---
Retajao	4 Mar.	0845	24.9/24.9	ND	11	5.8	83.2	304	>1
La Doncella	28 Apr.	1730	----	--	-	4.4	--	--	--
Puente Nuevo	5 Mar.	1733	31.7/35.8	ND	13	6.4	123.1	310	1.0
Puente Nuevo	6 Mar.	0840	23.8/25.8	ND	7	5.8	79.9	300	0.4-0.6
Puente Nuevo	12 Mar.	0830	27.1/26.1	ND	7	5.8	90.8	308	1.0
Puente Nuevo	17 Apr	1316	30.5/38.0	ND	18	4.4	80.5	340	>1
Puente Nuevo	25 Apr.	1800	30.8/33.9	--	-	4.9	90.8	--	---
La Batea	13 Feb.	0700	27.3/----	ND	8	5.4	85.3	264	1.0
La Batea	15 Feb.	---	27.0/----	ND	10	6.0	93.4	248	0.2
La Batea	15 Feb.	---	27.0/----	ND	9	6.0	93.4	244	0.3
La Batea	16 Apr.	2207	29.3/23.2	ND	15	2.0	34.8	360	0.2-0.4
Merecure	10 Mar.	---	28.5/28.1	--	--	5.4	89.8	268	0.2
Merecure	26 Apr.	1130	29.1/33.8	ND	9	5.6	95.6	260	0.2-0.4
Merecure	30 Apr.	---	30.3/36.1	ND	7	6.0	108.0	284	0.2-0.4
Sucre	18 Apr.	1050	29.5/----	ND	-	1.0	17.6	280	<0.2
Sucre	18 Apr.	1410	----	ND	-	0.6	--	--	---
Sucre	19 Apr.	1045	28.8/28.5	ND	10	5.2	87.6	292	0.2
Sucre	20 Apr.	0820	----	ND	-	6.8	--	--	---

ND: Non-detectable

temperature was largely a function of time of the day (Fig. 3-2). Temperatures in the stations located in the southern part of the study area were 2-4°C higher than temperatures in the northern locations. Only seven samples were analyzed for phosphates and always were less than 0.2 mg/l. Tests for phosphates depend strongly on temperature, with the best results obtained at 23°C. Temperature, however, was not controlled in the field. Much higher concentrations of phosphates (PO_4-P) were detected by Campo and Rodríguez (1995), as will be discussed later.

The pH was always close to neutrality, between 7 and 8. The more precise measurements taken by Campo and Rodriguez (1995) showed a fluctuation of pH between 6.6 and 8.5.

Dissolved oxygen (DO) was the only parameter that was measured for every sample. Because the concentration of oxygen in water is affected by temperature, Table 3-1 also shows the levels of DO as a percentage of saturation values. The highest values of DO were found outside the study area, in the Guanare (7.6 mg/l) and Claro (8.8 mg/l) rivers. Even the DO level for a third river outside the study area (Portuguesa River, 5.8 mg/l) was higher than most of the samples taken within the Cojedes River system.

Dissolved oxygen was low and highly variable in the northernmost part of the study area: Cojedes Norte and Toma Cojedes. The DO in these sections never exceeded 4.4 mg/l, and frequently was far below its saturation levels (Table 3-1, Fig. 3-3). The lowest values in this area were obtained from several hours to two or three days after it rained in the upper part of the basin. Oxygen depletion in some rivers after rains is a well known phenomenon (Horne and Golman 1994). In contrast to the situation in the north,

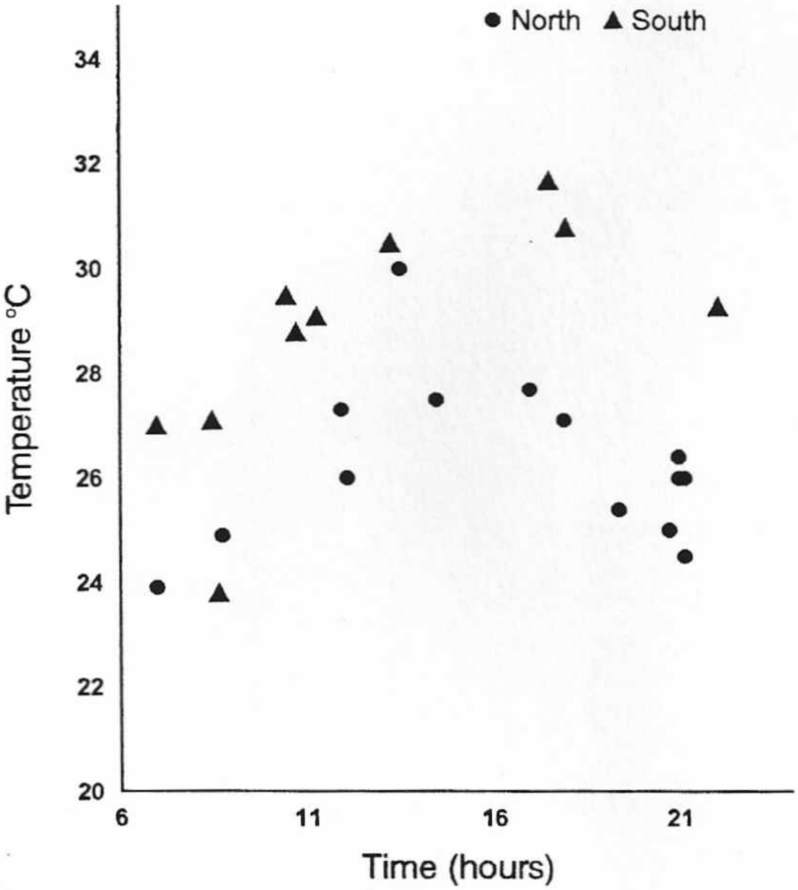

Figure 3-2. Daily water temperature fluctuations in the study area (Cojedes river system, Venezuela) during the water sampling. North sites include Claro river, Toma Cojedes and Retajao. South sites are those from Puente Nuevo (Lagunitas-El Amparo) to Sucre (see Figure 3-1).

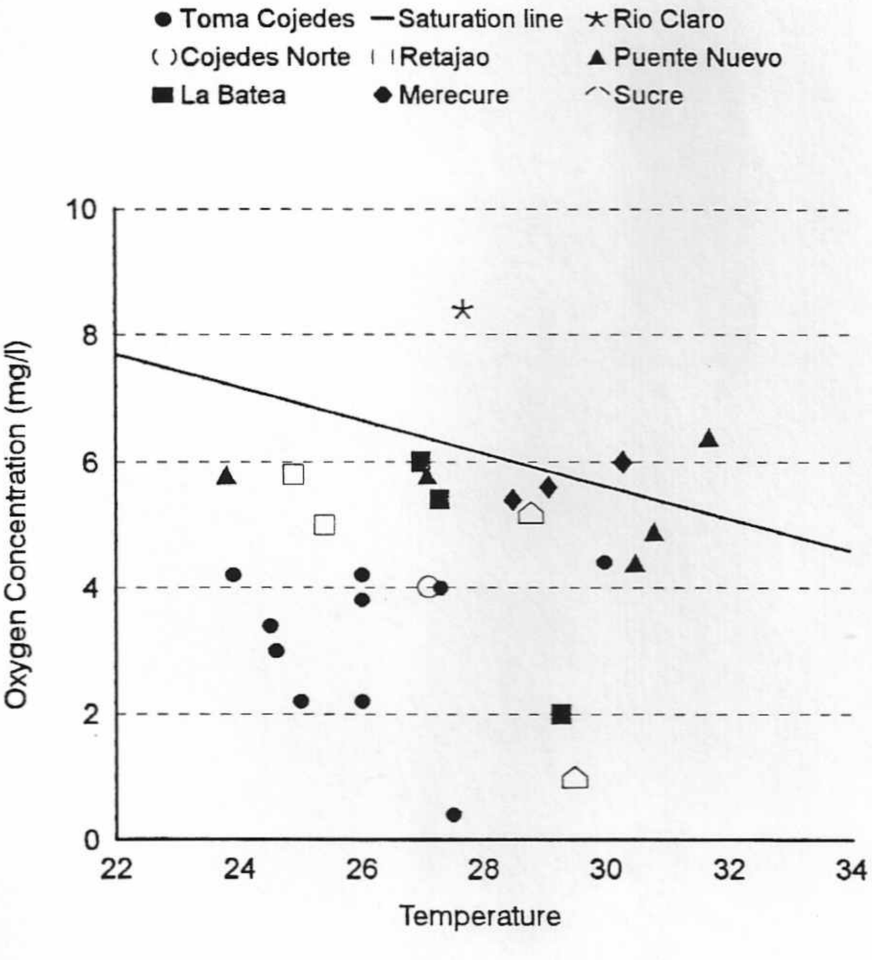

Figure 3-3. Dissolved Oxygen (DO) concentrations in water samples from the Cojedes River System, Venezuela. In most of the samples the DO was below the saturation level of pure water, represented by the line. Rio Claro (*) is a clean water river.

DO south of Toma Cojedes was generally above 4.4 mg/l. The only instance in which lower levels were measured, was on 16 April in La Batea (2.0 mg/l) and 18 April in Sucre (1 and 0.6 mg/l). The drop in the oxygen levels on these occasions was the probable caused of a massive fish mortality, which will be described in more detail below. The analyses of DO given by Campo and Rodriguez (1995) agree in general terms with those found in this study.

Hardness, which is a measure of the concentration of cations in the water, particularly calcium and magnesium, had its lowest values in the rivers outside the study area. Once again, these results are similar to the ones found by Campo and Rodriguez (1995).

Detectable levels of ammonia-nitrogen were only obtained in the upper sections of the study area. The highest value (in the range of 0.5-1.0 mg/L) was found on 23 January in Toma Cojedes. The other relatively high level (0.25-0.5 mg/L) was measured in Retajao on 17 February. Carbon dioxide (CO_2) was measured in higher concentrations in the northern part of the study area (Cojedes Norte, Toma Cojedes and Retajao). The levels of CO_2 were the lowest in the Guanare, Portuguesa and Claro rivers (less than 4 mg/l). Neither ammonia-nitrogen nor CO_2 were measured by Campo and Rodriguez (1995).

The analyses of my data, pooled with those reported by Campo and Rodriguez (1995), indicate that there are correlations (positive and negative) among many of the water quality parameters measured (Table 3-2). Some of these correlations may not have any ecological meaning. However, detailed physicochemical explanations of them are beyond the scope of this study. Suffice it to say that they help us to understand and

Table 3-2. Correlation analysis of water quality parameters. Upper value is Pearson correlation coefficient. Lower value is the probability Prob > |R| under Ho: Rho=0. The number of observations for each parameter are within parentheses. Data from Campo and Rodríguez (1995), and this study.

	Temp (71)	TDS (43)	DO (74)	Hardness (64)	NO_2 (43)	NO_3 (43)	PO_4 (41)	BOD (31)
pH	-0.356	-0.068	0.246	-0.049	0.022	-0.103	0.062	0.038
	0.031	0.693	0.161	0.792	0.899	0.545	0.726	0.858
Temp.		0.587	-0.180	0.421	-0.103	0.040	0.325	0.363
		0.001	0.161	0.001	0.548	0.765	0.061	0.074
Total Diss. Solids (TDS)			-0.531	0.786	0.375	0.605	0.735	0.602
			0.002	0.001	0.024	0.001	0.001	0.002
Dissolved Oxygen (DO)				-0.570	-0.344	-0.144	-0.555	-0.382
				0.001	0.050	0.277	0.001	0.066
Hardness					0.312	0.316	0.481	0.362
					0.082	0.018	0.005	0.090
Nitrites						0.723	0.640	0.286
						0.001	0.001	0.176

Table 3-2 (continued).

	COD (32)	TColif (34)	TS (37)	Deterg. (36)	CO_2 (25)
pH	-0.295	0.103	0.041	0.098	-
	0.144	0.609	0.834	0.612	-
Temperature	0.143	0.120	0.065	-0.015	-0.128
	0.486	0.551	0.738	0.937	0.569
TDS	-0.008	0.501	0.518	0.185	-
	0.968	0.008	0.004	0.347	-
DO	-0.232	-0.351	-0.170	-0.315	-0.806
	0.265	0.079	0.387	0.102	0.001
Hardness	-0.143	0.304	0.424	0.185	0.743
	0.506	0.140	0.028	0.357	0.001
Nitrites	0.175	0.359	0.751	0.715	-
	0.403	0.072	0.001	0.001	-
Nitrates	0.127	0.200	0.433	0.681	0.401
	0.536	0.318	0.019	0.001	0.064
Phosphates	0.219	0.679	0.660	0.728	-
	0.281	0.001	0.001	0.001	-
Bioch. Oxygen. Demand (BOD)	0.389	0.973	0.540	0.433	-
	0.055	0.000	0.005	0.035	-
Chem. Oxygen. Demand (COD)		0.256	0.059	0.147	-
		0.217	0.790	0.483	-
Total coliforms			0.780	0.522	-
			0.001	0.006	-
Total Solids (TS)				0.642	-
				0.001	-

interpret the pattern of changes among localities. Non-polluted or non-euthrophic waters tend to show relatively high DO levels (near or above the saturation levels), and low measurements or concentrations of CO_2, nitrites, nitrates, phosphates, hardness and coliforms, biochemical oxygen demand (BOD), and chemical oxygen demand (COD). The correlations of DO with hardness, TDS, nitrites, phosphates and carbon dioxide (all of them statistically significant) are shown graphically in Figure 3-4 (a, b, and c). The correlation between hardness and carbon dioxide (Fig. 3-4d) was highly significant ($r=0.743$, $P<0.001$). There was also a highly significant positive correlation between phosphates and total coliforms ($r=0.679$, $P=0.001$) and between BOD and total coliforms ($r=0.973$, $P<0.001$) (Fig. 3-4 e and f).

Water quality parameters changed as we move from north to south in the Cojedes River (Fig. 3-5). 'Outside rivers' include samples from Guanare, Portuguesa and Claro Rivers, which are relatively clean-water rivers outside the study area. The Turbio River, which is in fact the headwaters of the Cojedes River, was the most polluted, with the lowest level of DO and the highest relative values of all the other parameters. The concentration of phosphates determined by Campo and Rodríguez (1995) in the Turbio River was close to the levels considered typical of secondary treated sewage effluents (5 to 8 mg/l; Horne and Goldman 1994). Similarly, the BOD of the Turbio River measured by these authors were close, in some instances above, the typical values of raw sewage (200 mg/l; Laws 1993). The quality of the water improved somewhat in Cojedes Norte, although it was mainly sampled just below the confluence with the Claro River, one of the clean-water rivers mentioned above. The water quality deteriorates again in Retajao,

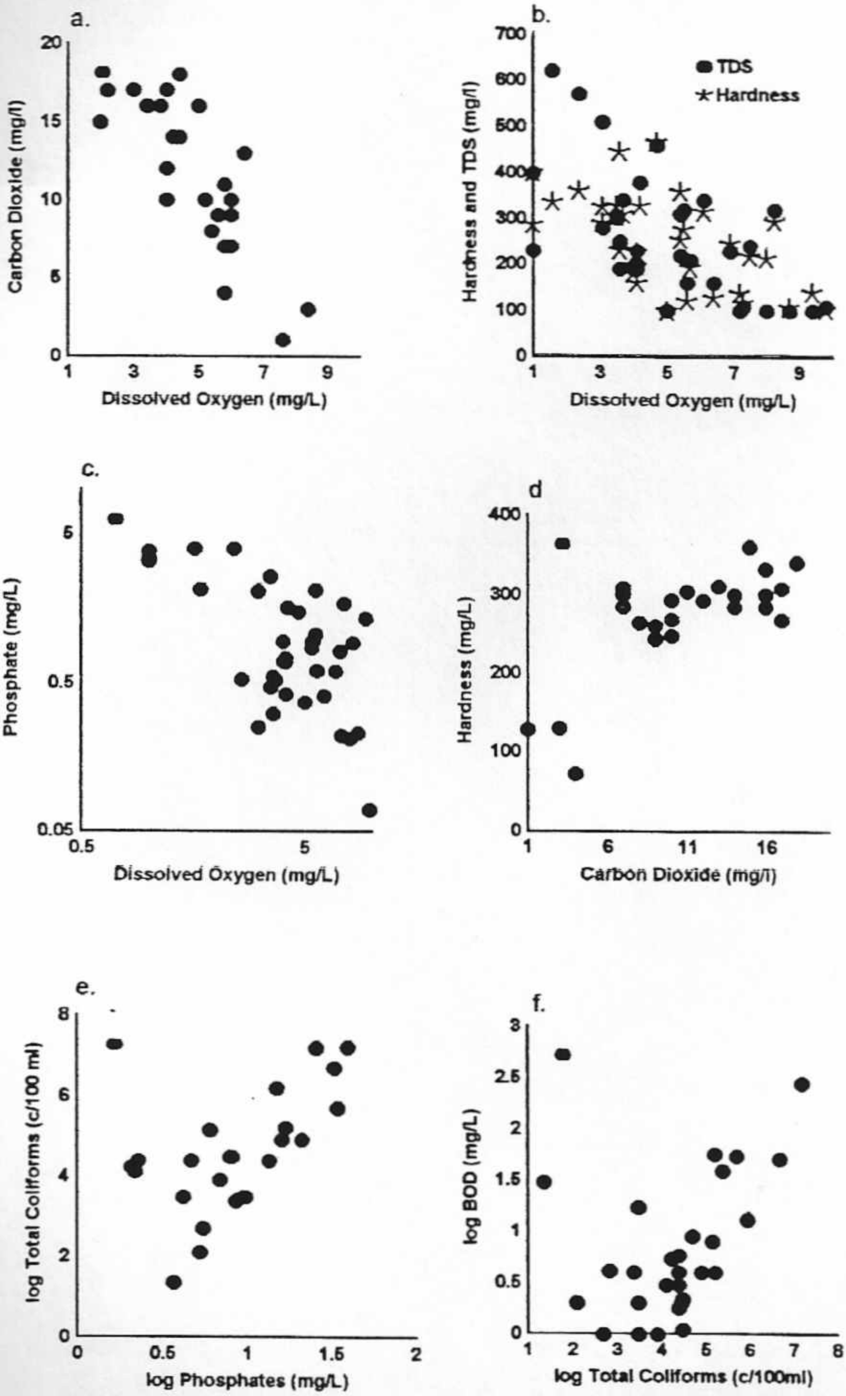

Figure 3-4. Relationship among different water quality parameters in the Cojedes River System, Venezuela. Details in the text

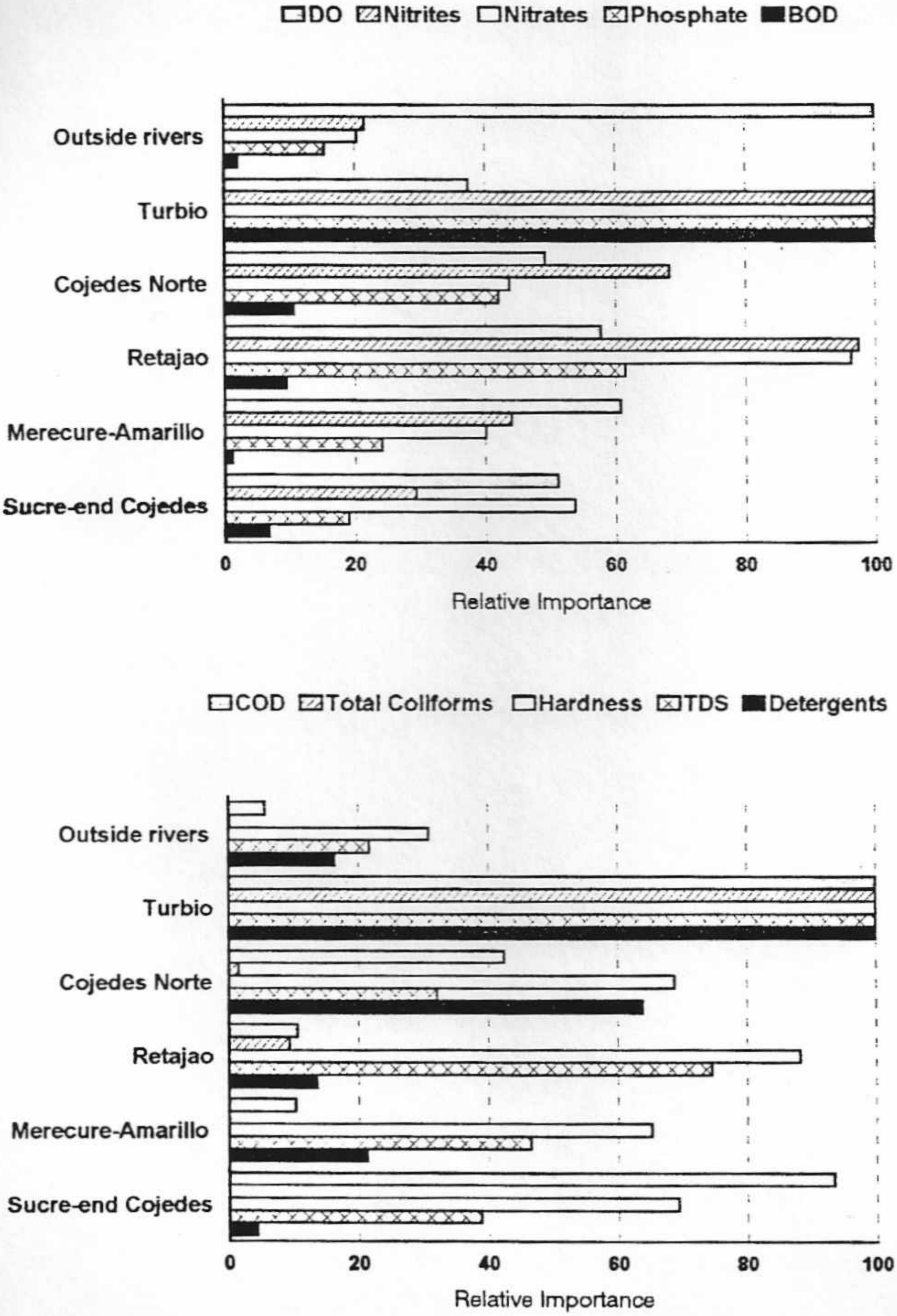

Figure 3-5. Variation of water quality parameters in some rivers of the Venezuelan Llanos. 'Outside rivers' refers to rivers outside the study area, which include Guanare, Portuguesa, and Claro rivers. Other localities are ordered from north to south. DO, dissolved oxygen; BOD, biochemical oxygen demand; COD, chemical oxygen demand; TDS, total dissolved solids.

downstream from the towns of Cojeditos and Apartaderos, and it shows some signs of recovery in Merecure-Caño Amarillo (i.e., relatively high DO and lower values of nitrites, nitrates and phosphates). In the southernmost locations the river again showed some signs of deterioration (high COD and hardness), which may be the consequence of wastewater discharges from the towns of Sucre and El Baul.

Most of the samples (88.2%) taken by Campo and Rodríguez (1995) in the Cojedes River basin exceeded the maximum values of total coliforms and fecal coliforms allowed for uses for recreational purposes, 1,000 and 200 c/100ml, respectively (Parra-Pardi 1974; COPLANARH 1976). Even the requirements for less restrictive uses (5,000 and 1,000 c/100 ml) such as irrigation and fish culture, were exceeded in 76.5% of the samples.

The concentration of some parameters decreased with an increase in river discharge (Fig. 3-6). This phenomenon is probably due to a dilution effect, which is typical of many rivers (Parra-Pardi 1974; Depretis and Paolini 1991; Martins and Probst 1991; Trihadiningrum et al. 1996). The scarcity of data did not allow to make refined analyses in this regard.

Fish Mortality

On 16 April 1997 (Tuesday), I observed a massive fish die-off in Caño de Agua Sur, sector La Batea. All the fish were in an advanced stage of decomposition, suggesting that mortality occurred from 24 to 48 hours earlier. DO level was very low (2 mg/l), which indicates anoxia as the proximate cause of mortality. The following day

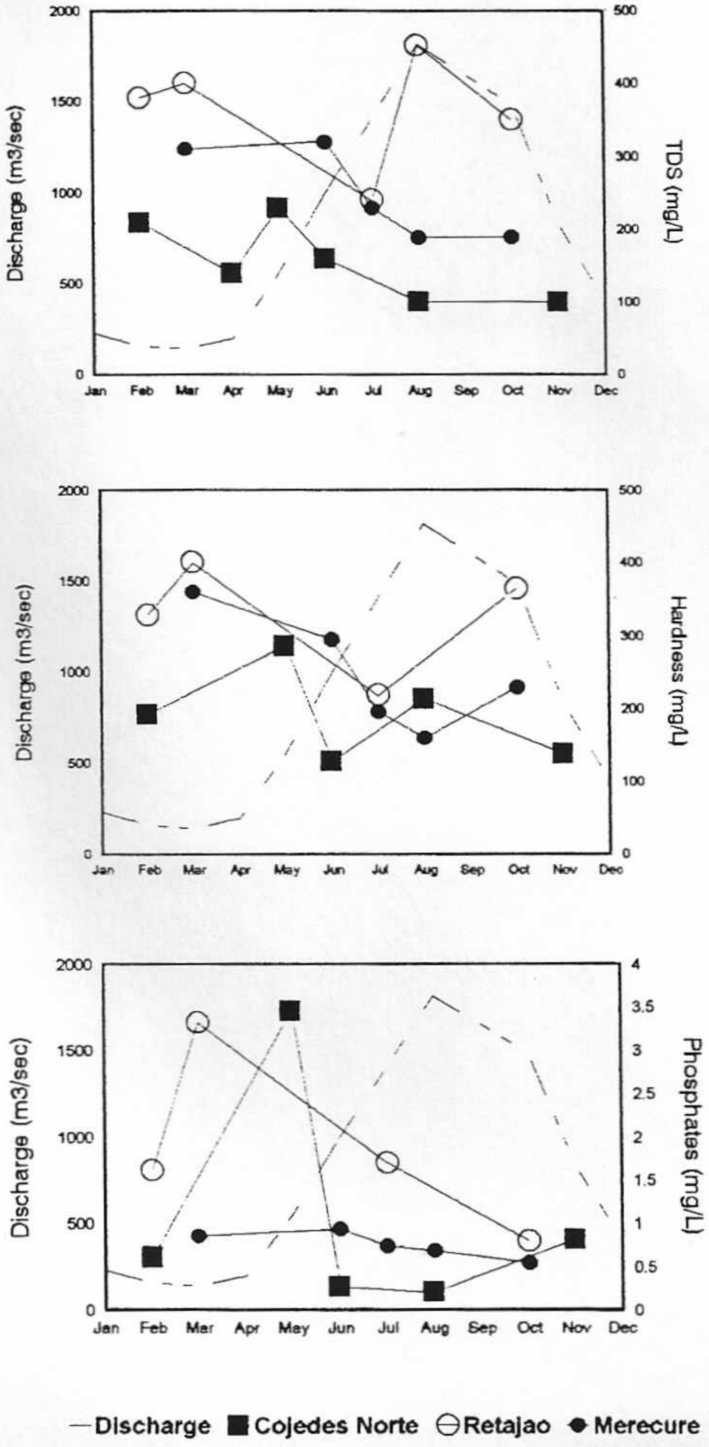

Figure 3-6. Variation of total dissolved solids (TDS), total hardness, and phosphates in relation to river discharge in some river reaches of the study area, Cojedes river system, Venezuela.

dnesday, 17 April) a sample taken some 20 km upstream, in Caño de Agua Norte nte Nuevo) showed a DO concentration of 4.4 mg/l, the lowest ever measured at that There was no indication that a fish mortality had occurred there. On Thursday (18 l), while working some 40 km downstream from La Batea (sector Sucre) a fish kill n. I immediately took a sample (1030 h), which showed a DO of 1 mg/l. A few hours (1410 h), the level of DO dropped to only 0.6 mg/l.

With the exception of a few piranhas, all of the dying fish species collected in e, belonged to the families Loricaridae, Pimelodidae, Potamotrigonidae and nphichthyidae (Table 3-3). Moribund shrimp and crabs also were found. People from own of Sucre collected many of the dying fish, particularly the big catfish *doplatystoma*. Tens (maybe hundreds) of these fish were salted to be later sold in the ket.

Moving upstream, we found fish in a more advanced state of putrefaction. Several l Characidae species were also found (*Mylossoma duriventris*, *Leporinus sp*, and *ortheus angulatus*). The following day (Friday, 19 April), we travel 3 km downstream n Sucre, and up 12 km ~~in~~ To Caño Culebra. There were also dead fish in Caño Culebra, the degree of putrefaction of the fish suggested massive mortality occurred there er than in the Sucre sector.

On 20 April (Saturday) I moved to the north and took a sample in Toma Cojedes. DO levels there were 0.4 mg/l, the lowest ever measured in this study. According to of the workers that operates the dams in Toma Cojedes (Pedro Rojas, com. pers.), the er in that place started to change its appearance (darker color and foul odor) a week

Table 3-3 Organisms killed due to oxygen depletion on April 18 1997 in the Cojedes river, Venezuela.

Taxonomic group	Family	Species
Fish: Characiformes	Characidae	*Pygocentrus caribe*
		Triporteus angulatus
		Mylossoma duriventris
		Cynopotamus bipunctatus
	Anastomidae	*Leporinus sp*
Siluriformes	Doradidae	*Agamyxis albomaculatus*
		Orinococoras eigenmanni
	Loricaridae	*Loricaria cataphractus*
		Lasiancistrus sp
		Panaque maccus
		Hypostomus sp
	Pimelodidae	*Paraucheripterus galeatus*
		Pimelodela spp
		Pimelodus blochii
		Platysilurus barbatus
		Pseudoplatistoma tigrinum
		Zungaro zungaro
Gymnotiformes	Rhamphichthyidae	*Rhamphicthys marmoratus*
Rajiformes	Potamotrigonidae	*Potamotrygon orbingy*
Crustacea		
Macrobrachium sp (shrimp)		
Poppiana dentata (crab)		

earlier. At that time they decided to close the dam that controls the water that going to Las Majaguas reservoir and diverted all the water toward Cojedes-Caño de Agua. The changes in the condition of the river were triggered by heavy rains upstream in the river basin.

These instances of fish mortality are common in the Cojedes River and occur irregularly through the year (Ayarzagüena 1987; Coromoto Ramírez and Pedro Rojas, pers. comm.) and have been reported as early as the late 1970s (Godshalk 1978). They seem to occur more frequently at the beginning of the rainy season. One of the people that does maintenance work in the river for the Venezuelan Government informed us of four such events, from 26 April to 12 June1990 (Coromoto Ramirez, comm. pers.). González-Fernandez (1995) also witnessed a massive fish kill at La Batea on 29 May 1994, just after the first heavy rains of that year.

Pesticides

I did not conduct analyses of pesticides in the study area. Campo and Rodríguez (1995), reported their results on this aspect, which are summarized here. From 1991 to 1993, they analyzed 36 water samples. Twenty-five of them (69.4%) showed detectable levels of at least one pesticide. The most frequently found compound was DDT or its metabolites (particularly p,p'-DDE), but also heptachlor, hectachlor epoxide, lindane, aldrin, and dieldrin were found. The levels of aldrin (three times) dieldrin and heptachlor (one time each) reached the critical levels established by the U.S. Environmental Protection Agency (EPA).

Only p,p'-DDE was found in at least one of the samples taken in all of the field stations considered by Campo and Rodríguez (1995). Figure 3-7 shows the average concentrations (in µg/L) of these pollutants. The higher values were found in the Turbio River, close to the city of Barquisimeto (more than one million people) and Retajao. The lowest values were from the Claro River, a tributary of the Cojedes River and considered a clean river, without any important urban or industrial center within its basin. The samples in the Cojedes Norte, were taken some 100 m downstream from the confluence with the Claro River, which may explain the relative low levels of pesticides. The pesticides levels of the other localities were relatively low Campo and Rodríguez 1995).

Discussion

Water Quality

In terms of its water quality, the Cojedes River system contrasts sharply with some rivers in the same region with similar origin and characteristics. These differences are caused by the discharge of sewage and other contaminants from point sources in cities and towns along the Cojedes River course, combined with a widespread and diffuse discharge of water loaded with agrochemicals from the extensive agriculture around the river.

The headwaters of the Cojedes River are near Barquisimeto (where it is called Turbio River), one of the largest cities in the country. All the water quality parameters measured by Campo and Rodriguez (1995) in the Turbio River (see also Mogollón et al. 1987) indicate a high degree of contamination, with low level of DO and the highest levels of all the parameters indicative of pollution and eutrophication. Downstream, the Cojedes

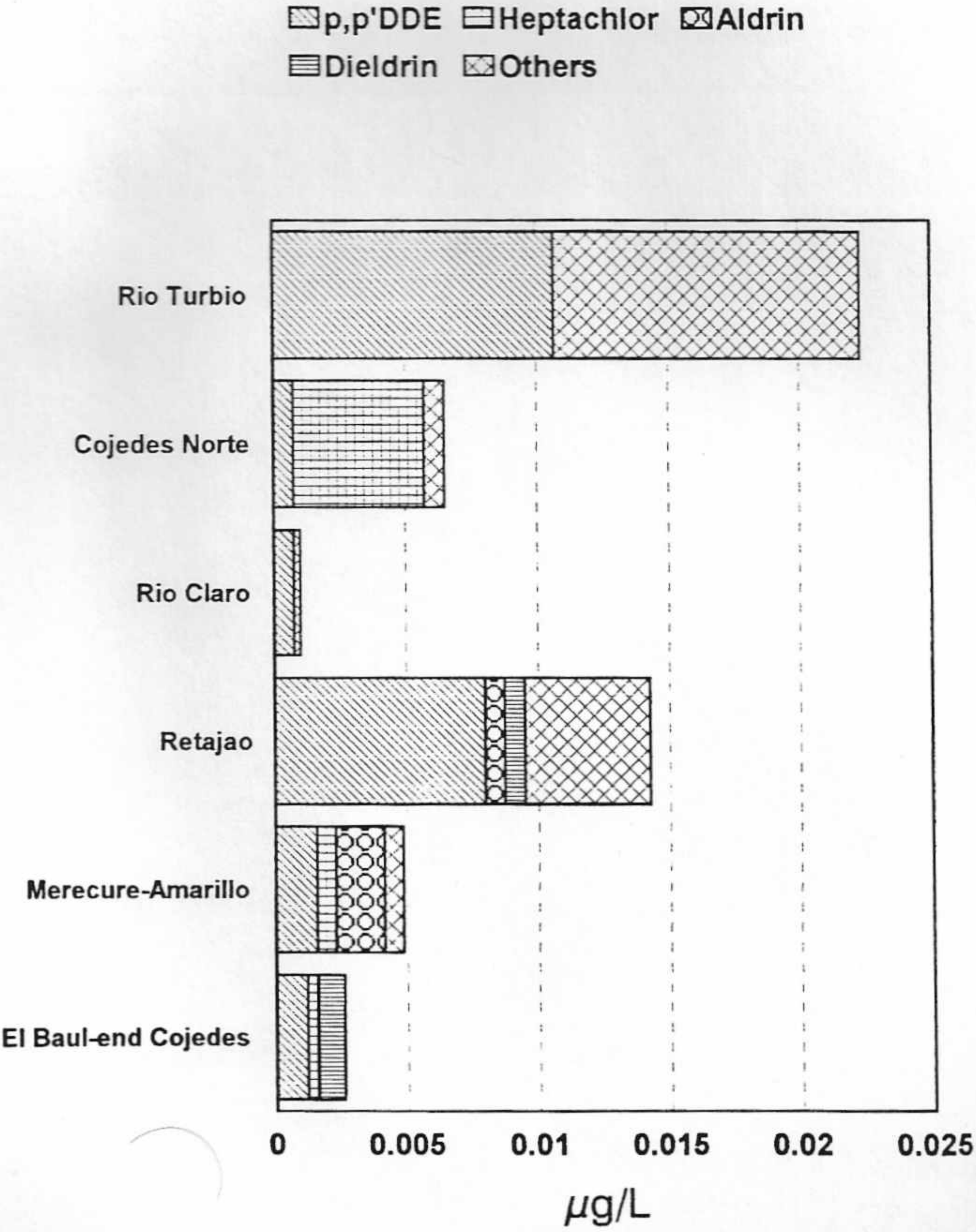

Figure 3-7. Mean pesticides levels in different river sections of the Cojedes river system, Venezuela. Drawn from data in Campo and Rodríguez (1995).

River shows some sign of recovery, but frequent point and diffuse discharges of contaminants, interrupts the recovery.

Oxygen is probably the most frequently measured parameter in studies of water quality. This is because of the important role this element plays in the metabolism of most aquatic organisms (Wetzel 1975; Cole 1983). The concentration of dissolved oxygen (DO) in the water depends on many factors, including temperature, dissolved salts and biological activity. Although temperature changes may partially explain the differences in DO measured from north to south along the Cojedes River system, most of the variation should be attributed to biological activity, which is triggered by the input of nutrients (Kadlec and Knight 1996), particularly nitrogen compounds. According to the Campo and Rodríguez's (1995) data, BOD, a measure of the amount of oxygen required by aerobic bacteria to stabilize decomposable organic matter contained in wastewater, frequently exceeded the quality standards of clean water (4 mg/l) or even water usable for sport fishing (6 mg/L) of European countries (Maitland 1990; Trihadiningrum et al. 1996). Oxygen depletion may negatively impact the river causing massive fish kills (as was found in this study), allowing accumulation of noxious anaerobic decomposition end products, and increase solubility of some metal ions, such as Fe^{+2} and Mn^{+2} (Laws 1993; Mitsch and Gosselink 1993)

The concentrations of oxygen and carbon dioxide in water are usually inversely related because of the photosynthetic and respiratory activities of the biota (Hynes 1970). Photosynthetic activity in the Cojedes River system, however, should be very limited due to the lack of aquatic macrophytes, the turbidity of the water, and in the southern part of the study area, the shading of the river by trees.

Phosphorus is a nutrient required by organisms for growth. The most rapid uptake of phosphorus is by microbiota (bacteria, fungi, algae, microinvertebrates, etc; Kadlec and Knight 1996). Phosphorus is frequently a limiting factor for vegetative productivity (Mitsch and Gosselink 1993; Kadlec and Knight 1996), but due to the turbidity of the water and the apparent lack of submerged macrophytes and presumably other autotrophic organisms in the Cojedes River, photosynthesis should have a little impact on replenishing DO in the water.

The negative correlation of DO with total dissolved solids (TDS) and hardness can be also explained by the decrease in solubility of oxygen in the presence of salts and by the fact that these parameters (TDS and hardness) occur in relative high concentration in waste-waters, simultaneously with nutrients that enhance growth of microorganisms. Water hardness in rivers is variable, depending on the soil and rock concentration of calcium and magnesium and on the degree of contact with rocks, soils, and pollution (Kadlec and Knight 1996). In most rivers, hardness appears to increase downstream (Hynes 1970; Becker and Neitzel 1992). This pattern is partially reversed in the Cojedes River because human activities in its basin are mostly concentrated near the headwaters (Mogollón et al. 1987).

The relationship of BOD and total coliforms is obvious, because BOD is a measure of the oxygen consumption of microorganisms in the oxidation of organic matter. Some of the other correlations (for example phosphates and total coliforms, Fig. 3-4e and f) may be partially explained by the fact that a common process, for example, rainwater runoff, control their concentrations.

Fish Mortality

The proximal factor that seems to explains the massive fish kills in the Cojedes River is oxygen depletion. DO levels below 3 mg/l are generally considered distressful or even lethal to most aquatic vertebrates, particularly in temperate waters, although the threshold may be lower for tropical fish (Lind 1974, Val and Almeida-Val 1995). The ultimate cause, however, is the discharge of untreated wastewater from urban, industrial and agricultural areas. As stated by Laws (1993), large-scale fish kills are probably the most dramatic results of oxygen depletion problems associated with eutrophication. Those reaches of the river that are closer to point sources of contamination, must be under permanent stress, as is indicated by the low DO concentrations. The effects of those discharges can be experienced well away from point sources, as exemplified by the fish mortality described in this study. Sucre, the site of one of the fish kills, is 60 km downstream from Cojeditos, the closest known point source of wastewater in the study area.

Most of the fish that were found dying in Sucre, on 18 April 1997, were slow-swimming species that belong to the group described by Machado-Allison (1987) as bottom-dwellers. This is an indication that oxygen depletion in the bottom of the river should be more severe than near the surface (where the samples were taken).

It is probable that crocodiles feed upon the dying or recently dead fish. In that sense fish kills may represent a sudden source of superabundant food. But is unlikely that these event represent a benefit to the species in the long term. In the areas where the river is regularly under stress, as in Cojedes Norte, many fish species may have disappeared due to chronic low-oxygen levels. This aspect will be discussed in more detail in Chapter 7.

Pesticides

All the pesticides that were found by Campo and Rodriguez (1995) in the Cojedes River, have been reported to have reproductive and endocrine-disrupting effects on wildlife and humans (Colborn et al. 1993). Exposure to pesticides, particularly to the so-called endocrine-disrupting contaminant (EDCs) has been associated with decreased fertility, decreased hatching success, demasculinization and feminization of males, and alteration of immune function in a variety of organisms (Blus et al. 1974; Colborn et al. 1993; Mason 1995). The most frequently found EDC was p,p'-DDE, which has been linked to development anomalies and low recruitment rate in *Alligator mississippiensis* in a Florida lake (Heinz et al, 1991; Guillete 1995; Guillete et al 1994; Guillete et al. 1996). To what extent the relatively high concentrations of EDC in the Cojedes River affects the survival of the Orinoco crocodile is unknown.

Although the concentration of pesticides in different parts of the Cojedes River system varies (Fig. 3-7), the long persistence of most of them, the fact that they are stored in the fatty tissues of organisms, and that they might become greatly concentrated at higher trophic levels in the food chain (Laws 1993; Hendriks 1995) make crocodiles particularly vulnerable to their effects. On the other hand, the long-term effects of toxic compounds on wild populations are usually more difficult to distinguish from other factors that have a short-term impact (Hendriks 1995), as for example oxygen depletion.

The available data indicate that water quality in the Cojedes River system is highly impacted by human activities. Contrary to what happens to many river systems, the Cojedes is more affected close to the headwaters than near its mouth. Some sections of the river, particularly those close to important human settlements, are under permanent stress. The effects of occasional stronger spills, however, can be felt for many kilometers below the point of discharge. The impact that the eutrophication and contamination of the Cojedes River has had on its wildlife, and especially on animals at the top of the food chain such as crocodiles, has not been assessed. Among the direct or indirect effects that the deterioration of the water quality in the Cojedes River may have on crocodiles are (a) changes in the quantity or quality of available food, (b) increased risk of infectious diseases, and (c) low reproductive success. Some of these will be discussed in the chapters that follow. Ironically, probably the most important population of *Crocodylus intermedius* in the world is found in the Cojedes River, whereas the species is absent from many rivers in the Llanos farther from human intervention and presumably with intact habitats.

CHAPTER 4
CROCODILES AND CAIMAN: POPULATION STATUS AND SPATIAL DISTRIBUTION

Introduction

The principal hypothesis of this dissertation is that the current pattern of human activities in the CRS affects the distribution, abundance and general well-being of the Orinoco crocodile in that region. Consequently, a preliminary step to any further investigation is to have a reliable estimation of the distribution and numbers of the species in the study area. That information is also crucial for the conservation and management of the species.

Estimation of crocodile abundance is generally based on spotlight counts. This methodology, however, is subject to problems of interpretation when comparing densities observed at times or habitats with different visibility conditions (Hutton and Woolhouse 1989; Da Silveira et al. 1997). The environmental factor that most affect spotlight counts is water level (Woodward and Marion 1979; Montague 1983; Messel et al. 1981; Seijas 1988). The first question addressed in this chapter is how water level affects the survey results in the CRS.

Information on the population structure of crocodiles is another important element for the design and implementation of the conservation program of the species. In the context of this study, however, population structure may reflect the effect of environmental variables as well as the effect of direct human pressure. Adult crocodiles are large and conspicuous and they are considered as vermin, and occasionally killed, by people living in rural areas of the region. If killing of adult crocodiles by human is an important factor, that would be reflected in the population structure of the species in areas with distinct human pressures. This hypothesis is examined, although not properly tested, in this chapter.

The CRS is also inhabited by the spectacled caiman (*Caiman crocodilus*), a smaller crocodilian which has been regarded as a potential predator-competitor of the Orinoco crocodile. The negative interactions with the spectacled caiman could be one of the factors inhibiting the recovery of the crocodile (Thorbjarnarson 1992; Thorbjarnarson and Hernández 1992). A similar situation occurs with the American crocodile (*Crocodylus acutus*), and Seijas (1988, 1996) showed that spectacled caiman prey on hatchlings of *C. acutus* in sites along the Venezuelan coast where the two species coexist.

Throughout the Venezuelan Llanos, populations of *Caiman* have greatly expanded over the last 50 years. The species have seemingly benefitted from the extirpation or severe reduction of crocodile numbers, but also by an increase in its habitat due to the creation of temporary or permanent water bodies resulting from the damming effect of road construction, or deliberate construction of ponds, levees or dikes to maintain water for cattle during the dry season (Gorzula and Seijas 1989; Seijas et al. 1989; Thorbjarnarson and Hernández 1992). The negative impact of numerous populations of spectacled caiman on the recovery of the Orinoco crocodile, if significant, could be hypothesis it would be expected that (1) the relative abundance of caiman and crocodiles would be inversely correlated, and (2) there would be a trend toward the separation of individuals of different species. These issues are also addressed in this chapter.

Methods

From 1991 to 1997, nocturnal spotlight surveys were carried out from a 3.7m open boat powered by 10 or 15 hp outboard engine. Surveys were started between the 1930 h and 2000 h. The direction of the surveys was clockwise in Las Majaguas reservoir and downstream in the rivers, except for the Cojedes River segment between the opening of Caño Amarillo and Merecure, and the lower Sarare, which were always surveyed upstream. The positions of landmarks and locations used as reference during the surveys are shown in Figure 4-1. The geographical coordinates of these locations are shown in Appendix A.

All sighted crocodilians were approached as close as possible to make a positive identification of the species (*C. intermedius* or *C. crocodilus*) and to estimate their size. In the field 30 cm size-class intervals were used, but for the analyses of the size class distribution, the following broader size categories, were used:

Size 1	TL= <0.6 m
Size 2	TL= 0.6 to <1.2 m
Size 3	TL= 1.2 to <1.8 m
Size 4	TL= 1.8 to <2.4 m
Size 5	TL= >2.4 m

Hatchling (individuals less than 6 months old) were counted but not incorporated into these size categories. Non-hatchling crocodiles less than 1.8 m in total length were

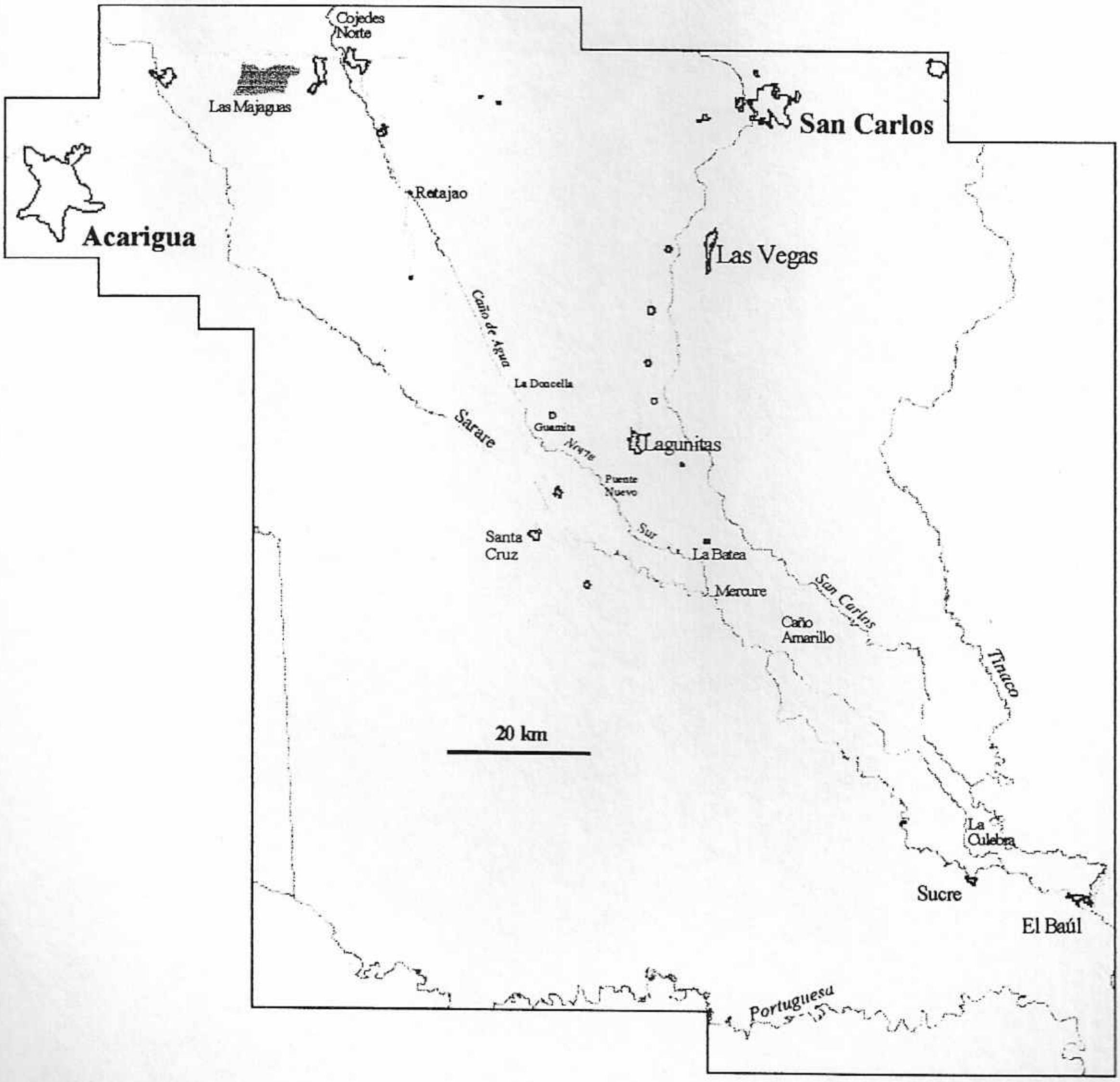

Figure 4-1. Map of the study area (Cojedes river system) Venezuela, indicating the position of landmarks, reference points, and main river reaches surveyed.

regarded as juveniles. Crocodiles in the size category 4 ($1.8\text{m} \leq TL < 2.4\text{m}$) were considered sub-adults, and those 2.4 m or larger were classified as adults. When an observed crocodilian could not be identified as crocodile or spectacled caiman, it was placed in a 'Non-Identified' (NI) category. These individuals were not used in the analysis.

The length of river surveyed was recorded with the odometer of a Global Positioning System (GPS, Magellan 4000 and Magellan 4000XL). The length of surveys in the Majaguas reservoirs and in other sections of rivers that were only visited before 1996 were estimated using a wheeled map measurer on a 1:25,000 map. Maps of the study area, particularly of the most important river courses, were based on a Landsat TM image taken on January 1990. The index of relative abundance of crocodilians in the locations surveyed was expressed as number of individuals observed per kilometer.

The adult population size in the study area was estimated based on records of nesting females and social organization (Chapter 5). The number of dominant males was calculated using a relationship of 1♂:3♀♀, which is a conservative figure compared to the 1♂:2.2♀♀ reported by Thorbjarnarson and Hernández (1992) for the Capanaparo River.

To establish if there were changes in the fraction of crocodilians (both crocodiles and spectacled caiman) sighted as the dry season progress, the population index (PI, ind/km) obtained in every survey was expressed as a percentage of the maximum PI ever calculated for April (taken as 100%) in the same river part. April is usually the last month of the dry season, when the river reach its lowest level. April also was the only month for which surveys were conducted in every river section. This method allowed comparison of the results of localities with different PI. In the case of the crocodiles, a correlation analysis was used to describe the relationship between these percentages and days after 1 January, an indirect measurement of water level. Surveys conducted in November and December (early dry season) were assigned day zero. A similar procedure was used to determine whether the probability of seeing a crocodile, as the dry season progressed, was related to its size.

The sequence in which the crocodilians were observed during the surveys was recorded. That information was used to establish if caiman and crocodiles were spatially separated along the river. The procedure consisted in determining, for every non-hatchling crocodilian sighted along the route (focal individual), to what species belonged the previously observed one (nearest neighbor). The data were later tabulated and analyzed as a contingency table (Herron 1985, Seijas 1996).

Population indices for crocodiles between river sections were compared by means of analysis of covariance (PROC GLM, SAS Institute Inc. 1987) using days after 1 January as the covariate. This approach removes the bias introduced by differences in how far into the dry season the surveys were conducted.

To calculate the minimum population size of *C. intermedius* in the entire study area, I estimated the density of crocodiles in unsurveyed reaches of the river as a value intermediate between the PI of its immediate upper and lower reaches for which information was available. The population structure of those localities with two or more surveys per year, was calculated using the maximum number of individuals in a particular size category, regardless of the survey in which they were observed, as the best estimate for that particular size class for that year. This method is referred to by Messel et al.

(1981) as the maximum-minimum (MM) method. Comparisons of population structure among localities were made using contingency tables.

Results

From 1991 to 1997, 56 nocturnal spotlight surveys were conducted in the study area. Some places were visited only once (Las Majaguas reservoir and Sarare River, for example), but several others were visited between two and 12 times. A detailed account of all these surveys is presented in Appendix B.

Surveys were carried out during different periods of the year, but most of them (71%) were conducted during the advanced dry season (February-April). The study area was not surveyed from August to October. During those months the plains surrounding the rivers are flooded and access to many places is difficult. To facilitate the interpretation of the data, the results for crocodiles and caiman are presented separately.

Crocodiles

Only the data from Caño de Agua Norte (CAN), Caño de Agua Sur (CAS) and Caño Amarillo-Merecure (CAM) were used for the analysis. These are the river sections with the largest number of surveys. Surveys for segments of the river less than 5 kilometers in length also were excluded. The fraction of the crocodile population that was seen during the surveys diminished as the dry season advanced, from November to April, and continued to decline during the early rainy season (May-July)(Fig. 4-2). A correlation analysis indicated that this negative relationship was statistically significant ($r=-0.639$, $P <$

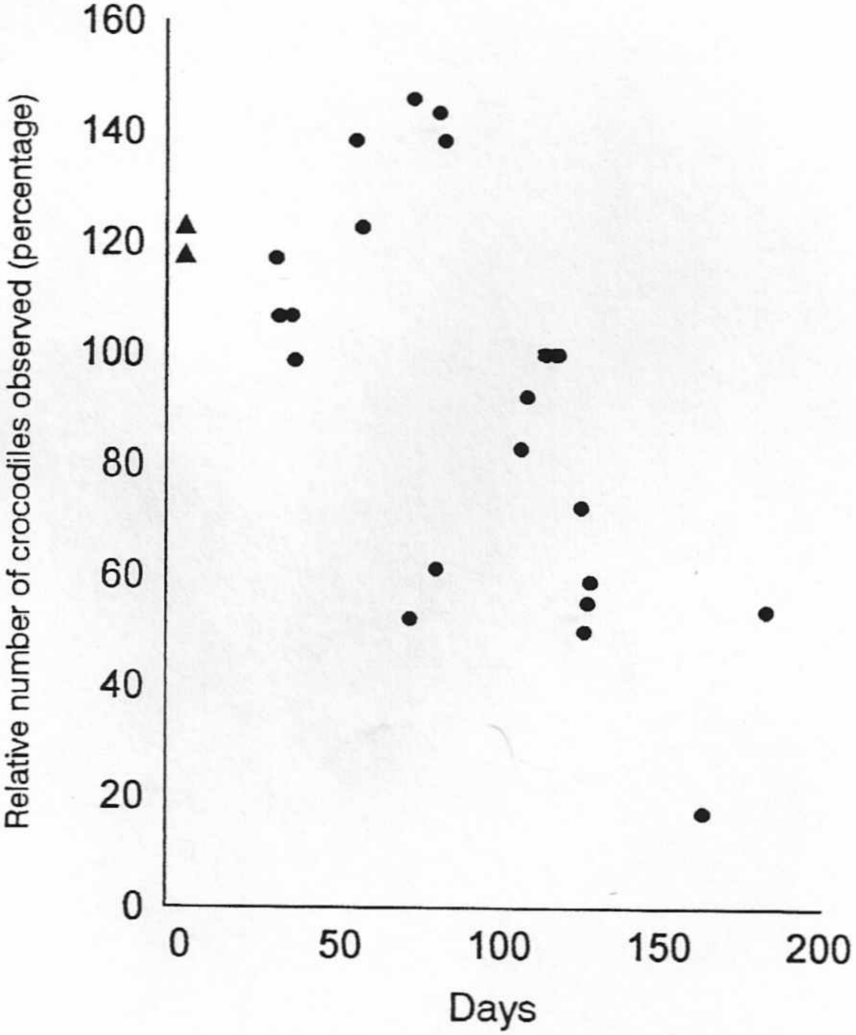

Figure 4-2. Decline in the observed fraction of the crocodile population in the Cojedes river system, Venezuela, with time. 1 January was taken as day zero. Triangles represent surveys conducted in November and December. For every

0.001). The described pattern of decline was in fact due to a decrease in the sighting fraction of juvenile crocodiles less than 1.80 m in TL ($r=-0.58$, $P < 0.01$)(Fig. 4-3a).

Crocodiles larger than 1.80 m in TL (sub-adult and adult) showed a more complicated pattern (Fig. 4-3b). These crocodiles tended to be seen in relatively higher numbers from November to January, the beginning of the dry season, when the water level in the river was still relatively high. They were seen in lower numbers during February and March (advanced dry season), and reappeared at the beginning of the rainy season in late April-early May (Fig. 4-3b). An analysis of the data grouped by month, indicated that the monthly differences in the sighting proportion of crocodiles ≥ 1.80 m in TL were significant (Kruskal-Wallis test, $H=12.3$, $P=0.031$). For this analysis, November, December and January (one survey each) were grouped as early dry season months. June and July (one survey each) were also grouped. The lowest proportion of large crocodiles are seen in March, in the middle of the incubation period (see Chapter 5).

A flaw of the analysis made with the percentages is that it has an underlying assumption that the population has remained stable through the years (from 1991 to 1997). That assumption may not be true. The data, however, do not allow an analysis of trend, because some years, particularly 1991 and 1992, are poorly represented.

With the exception of Las Majaguas reservoir, crocodiles were seen in all the surveyed sections. Ayarzagüena (1987) did not observe crocodiles in Las Majaguas reservoir either, although anecdotal information indicates that a few individuals are there. Localities where crocodiles were seen but were not included in most analysis are a 2 km

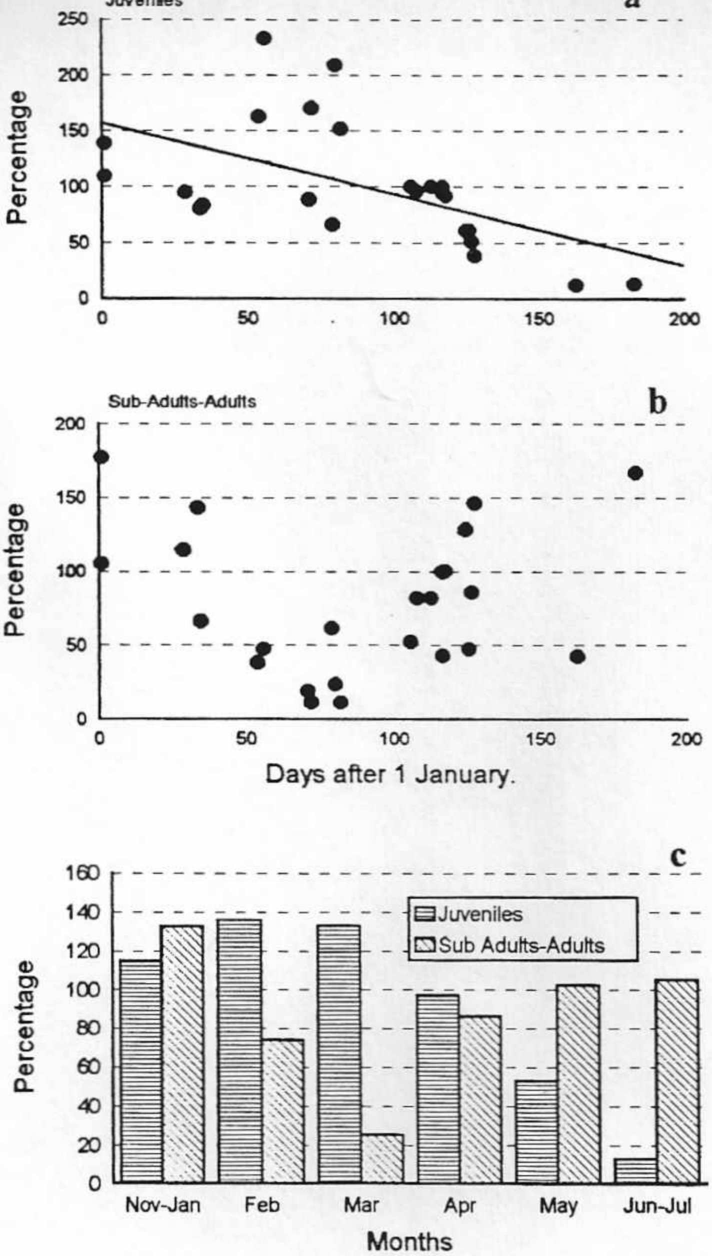

Figure 4-3. Decline in the observed fraction of juvenile (a) and, subadult-adult (b) crocodiles in the Cojedes river system, Venezuela, with time. 1 January was taken as day zero. For every river section , the number of crocodiles (juveniles or adults, respectively) observed in a particular survey was expressed as a percentage of the nur of crocodiles of that size-class seen in April, which was taken as 100%. The differenc visibility of these two groups of crocodiles is shown in c.

the lower Sarare, downstream from El Amparo bridge (visited twice, PI 4.9 and 3.3 ind/km)(Appendix B).

Caño de Agua Sur was the segment with the highest mean PI (Table 4-1). The survey with the highest PI also was obtained in this section in February 1997 (12.7 ind/km), although due to the short distance surveyed (3 km) it was not used in the analysis (see Appendix B). The lowest PI were found in the surveyed section of the river closest to the town of Sucre, with a maximum of 0.3 ind/km.

Table 4-1. Comparisons of population indices (PI) for crocodiles in different river stretches in the Cojedes River System. The Least Squares Means (LSMEANS) are estimators of the class marginal means (in this case river stretches) that would be expected had the structure of the data been balanced (SAS Institute, Inc. 1987). LSMEANS with the same letter are not statistically different at the 0.05 alpha level.

River section	Number of Surveys	Densities (ind/km) Range	Densities (ind/km) LSMEANS (±SE)	Grouping
Caño de Agua Sur (CAS)	8	4.4-10.8	7.3±0.46	A
Caño Amarillo-Merecure (CAM)	6	1.0-6.8	4.9±0.53	B
Caño de Agua Norte (CAN)	12	2.1-5.7	4.4±0.37	B
Cojedes Norte (CON)	4	2.5-3.8	2.0±0.70	C
Caño Culebra	3	0.8-0.9	1.4±0.76	C
Cojedes Sur (Sucre)	5	0.1-0.3	0.6±0.58	C

A simple model that only takes into account the location (river stretches) explains 71% of the variation of PIs ($F_{5,32}=15.68$, $P<0.001$). An analysis of covariance, which considers days after 1 January as the covariate, explains a higher proportion of that variability ($r^2=0.82$) ($F_{6,31}=23.1$, $P<0.0001$). Many other factors that were not under control, may explain the remaining variability as has been shown in other crocodilian population studies (Woodward and Marion 1978; Wood et al. 1985; Hutton and Woolhouse 1989; Da Silveira et al. 1997). Differences in visibility among localities, might introduce some bias in the results. In Caño de Agua Norte the river banks are covered by grasses and shrubs which allows many crocodiles to hide and escape detection during the nocturnal surveys. In contrast, Caño de Agua Sur and other river sections downstream, are almost devoid of that type of vegetation.

The minimum population size of non-hatchling crocodiles in the entire study area was estimated as 540 individuals (Table 4-2). This is a very conservative estimate as it is based on population indices that were below the maximum obtained for every river section. If the maximum PIs had been used, the estimated population would be 664, a 23% increase. In the river section Toma Cojedes-Retajao, for example, six crocodiles were seen in the upper extreme in 19 January 1993, and in 1996 a female nested close to the lower extreme. However, that stretch of the river is close to the small towns of San Rafael de Onoto, Apartaderos, and Retajao. Crocodiles there are presumably under high human pressure. Anecdotal information about crocodile killings (Aniello Barbarino, and Freddy Rodriguez, pers. com.) support this presumption.

Furthermore, indices of relative abundance usually underestimate the true population size (Hutton and Woolhouse 1989). A fraction of the population usually remains undetected and the relationship between the PI and the true population density is difficult to establish. Studies conducted with marked crocodiles in Zimbabwe, for example, indicated that even under the most favorable conditions more than 37% of the population

Table 4-2. Estimated number of non-hatchling Orinoco crocodiles in river reaches in the Cojedes River system, Venezuela.

River section	Length (km)	Density (ind/km)	Estimated Number
Cojedes Norte	7.0	1.96	14
Toma Cojedes-Retajao	14.5	0.59[1]	9
Retajao-La Doncella	16.0	2.20[2]	35
La Doncella-Puente Nuevo	16.0	4.39	70
El Amparo-Camoruco[3]	13.0	---	--
Camoruco-La Batea	6.7	6.40	43
La Batea-Merecure	5.2	7.26	38
Merecure-Caño Amarillo	8.4	4.88	41
Caño Amarillo-Sucre	39.5	2.74[2]	111
Sucre	11.6	0.59	7
Caño Amarillo	20.7	3.16[2]	65
Caño Culebra	12.8	1.43	18
Sarare	8.4	3.10	26
Lower Sarare	15.8	4.00[2]	63
Totals	195.6		540

[1] Not surveyed. Assigned the lowest density for any surveyed section (Sucre 0.59 ind/km).

[2] Not surveyed. Assigned the averaged density of the upper and lower continuous stretch.

[3] This river section is almost all lost due to diversion into smaller branches after 1996 flood.

remain undetected, and the proportion of the total population seen during spotlight counts ranged from 0.1 to 0.63. (Hutton and Woolhouse 1989).

Population Structure

The structure of the crocodile population in Cojedes Norte is shown in Figure 4-4a,b. The differences between 1993 and 1997 are not statistically significant (Fisher's exact test, $P=1$). Due to the small sample size only two size categories were used in this analysis. The population in this locality is composed mostly of juveniles.

The population structure of Caño de Agua Norte (Guamita-Puente Nuevo) was estimated for 1996 and 1997 (Fig. 4-4c,d). The differences between years is not statistically significant ($X^2=3.2$, $P=0.363$, 3 d.f.). As in Cojedes Norte, here the population is dominated by small juveniles, but adults represent an important fraction of the population.

The size structure for three continuous segments of the river in Caño de Agua Sur (Camoruco-Batea and Batea-Merecure) and the proper Cojedes (Caño Amarillo-Merecure) are shown in Figure 4-5. The Camoruco-La Batea section was only surveyed in 1992 and is shown in the Figure 4-5a for comparison. Statistical analyses were made only for the same segments surveyed in different years, or for different segments surveyed the same year.

The size classes were more evenly distributed in Caño de Agua Sur than in Caño de Agua Norte and Cojedes Norte, especially as indicated by the 1996 surveys. The

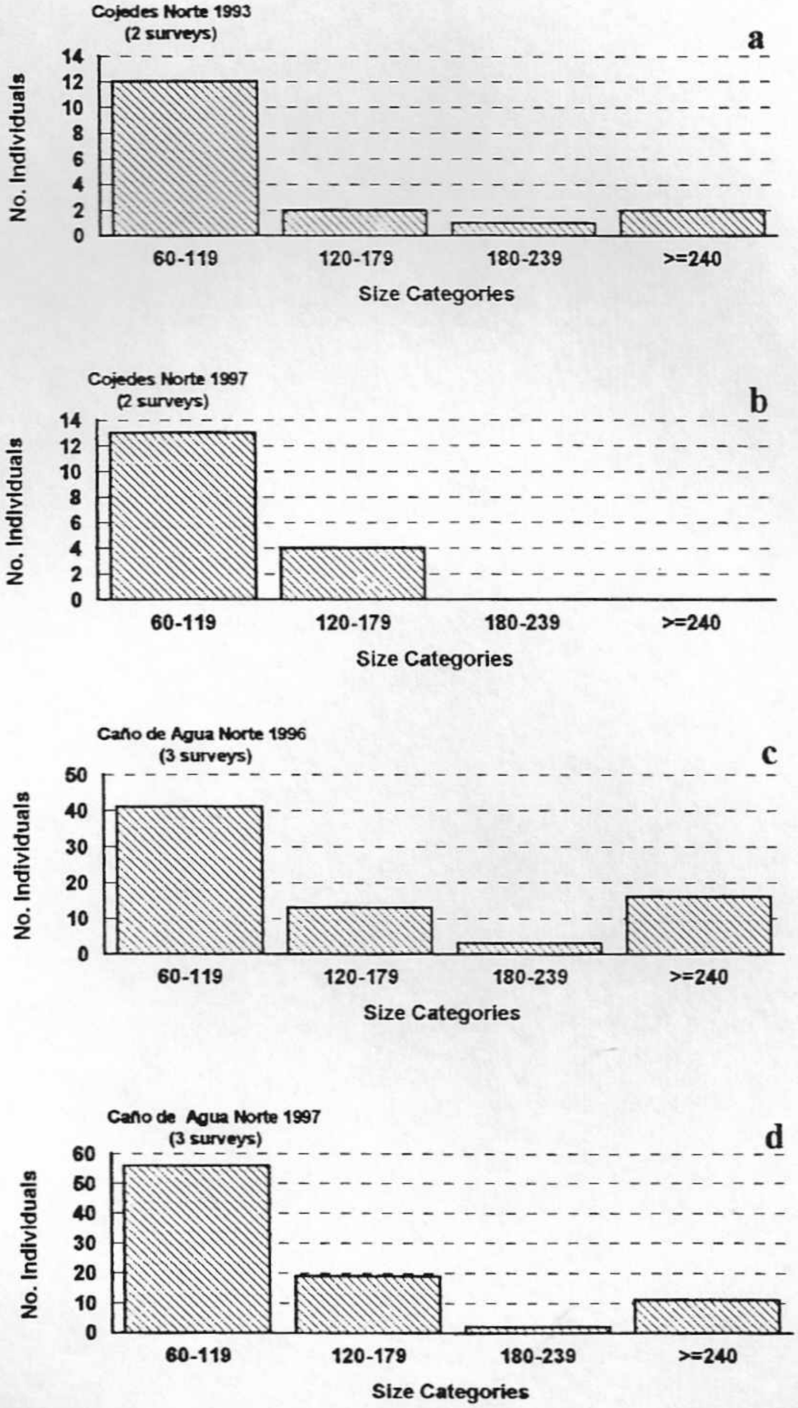

Figure 4-4. Population structure of Orinoco crocodiles in river sections of the Cojedes river system, Venezuela. Size categories in cm of total length.

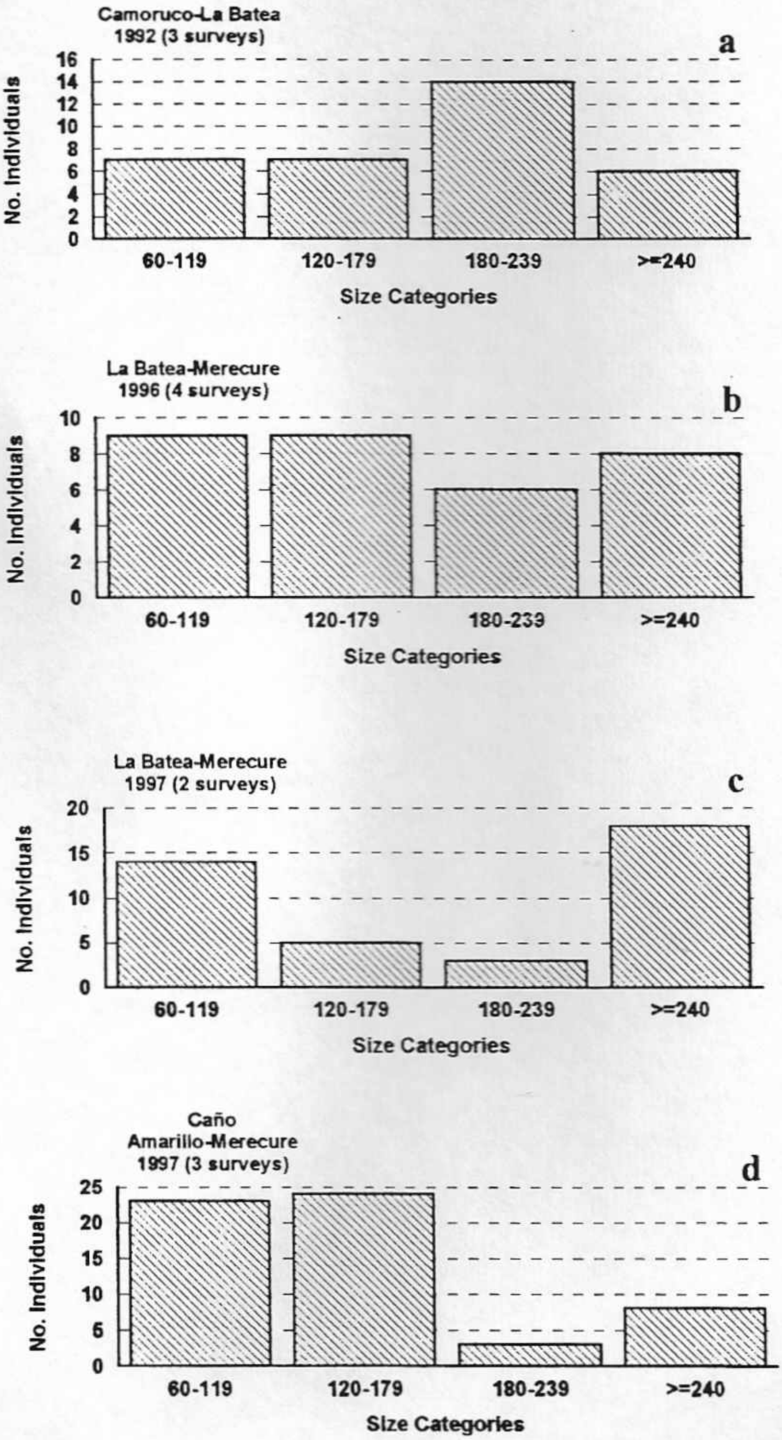

Figure 4-5. Population structure of Orinoco crocodiles in three continuous sections of the Cojedes river system, Venezuela. Camoruco-La Batea, and La Batea-Merecure are almost entirely within Caño de Agua Sur. Size categories in cm of total length.

differences between Batea-Merecure for 1996 and 1997 are not statistically significant (X^2=6.264, *P*=0.099, 3 d.f.).

The crocodile population in Caño Amarillo-Merecure in 1997 was dominated by individuals less than 1.8 m in total length (Fig. 4-5d). Comparison of the population structure in this river stretch with the one for La Batea-Merecure obtained the same year, indicated a highly significant difference (X^2= 15.7, *P*=0.001, 3 d.f.).

The population size for the Sucre section and for Caño La Culebra was too small to attempt an analysis of its structure. Neither adults nor hatchlings were seen in these river reaches, which seems to indicate that reproduction does not occur there (see Chapter 5).

Caiman

Contrary to the situation with crocodiles, the number of caiman seen in the river increased as the dry season progressed, reaching a peak during March. Caiman numbers declined after that, almost disappearing from the river during the wet season (Fig. 4-6). Due to the temporal presence of caiman in the river, only data from the dry season (January-April) were used in the comparisons.

There were differences in the abundance of caiman between localities. A model that included the main effect of river location explains only 40.7% of the variability of the PIs of caiman ($F_{5,24}$=3.3, *P*=0.021). An improved model, which incorporated the interaction between river stretches (locations) and the days after 1 January, explained 83.3% of that variability ($F_{11,18}$ = 8.15, $P < 0.001$). There was a trend of increased caiman

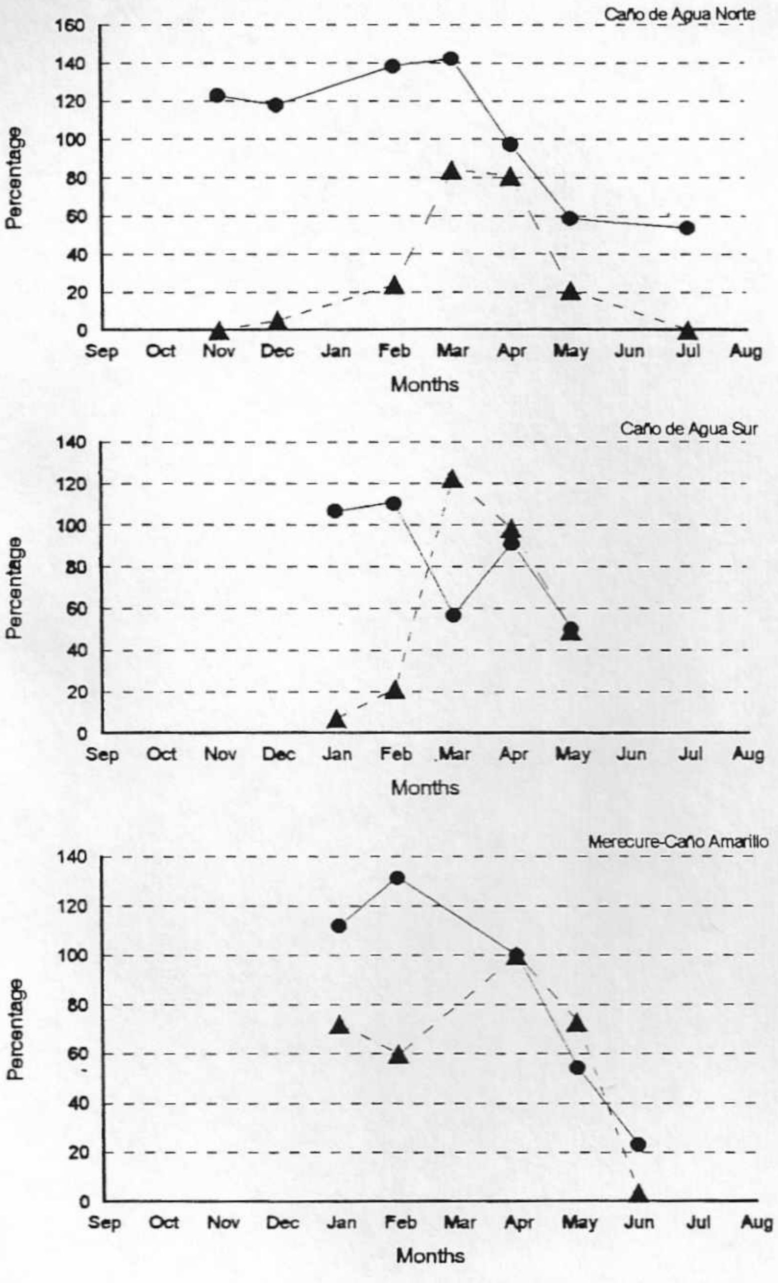

Figure 4-6. Relative proportion of caiman and crocodiles that were seen in different river reaches of the Cojedes river system, Venezuela. The average number of each species of crocodilian seen during each month was compared with the average number seen in April (taken as 100%). The highest numbers of caiman were observed during March and April, whereas crocodiles tend to be seen in larger numbers in January and February.

abundance from north to south (Table 4-3). The highest index ever recorded was for the Cojedes Sur (Sucre) in March 1994, with 69.2 ind/km.

Downstream from Caño de Agua Sur there was a decline in abundance of crocodiles whereas the population of caiman tended to increase (Fig. 4-7). Upstream from Caño de Agua Sur the relative abundance of both species decline. In all locations surveyed, caiman outnumbered crocodiles during the late dry season. A negative correlation between the PIs of caiman and crocodiles would be expected if competition or predation were playing an important role in determining the population status of these species in the Cojedes River system. A negative correlation exists but it is weak (Kendall Tau b = -0.2, *P*=0.573).

Table 4-3. Comparisons of population indices (PI) for spectacled caiman in different river stretches in the Cojedes River System. The Least Squares Means (LSMEANS) are estimators of the class marginal means (in this case river stretches) that would be expected had the structure of the data been balanced (SAS Institute, Inc. 1987). LSMEANS with the same letter are not statistically different at the 0.05 alpha level.

River section	Number of Surveys	Densities (ind/km) Range	LSMEAN	Grouping
Cojedes Norte (CON)	4	5.5-6.9	5.7	AB
Caño de Agua Norte (CAN)	8	2.9-14.2	7.3	B
Caño de Agua Sur (CAS)	7	1.5-26.7	16.8	ACD
Caño Amarillo-Merecure (CAM)	3	10.5-17.5	14.8	BC
Caño Culebra	3	16.9-21.8	19.3	DE
Cojedes Sur (Sucre)	5	17.2-69.2	58.7	E

The distribution of crocodiles and caiman along the river is not random. The probability of finding individuals of the same species in a sequence during the surveys was

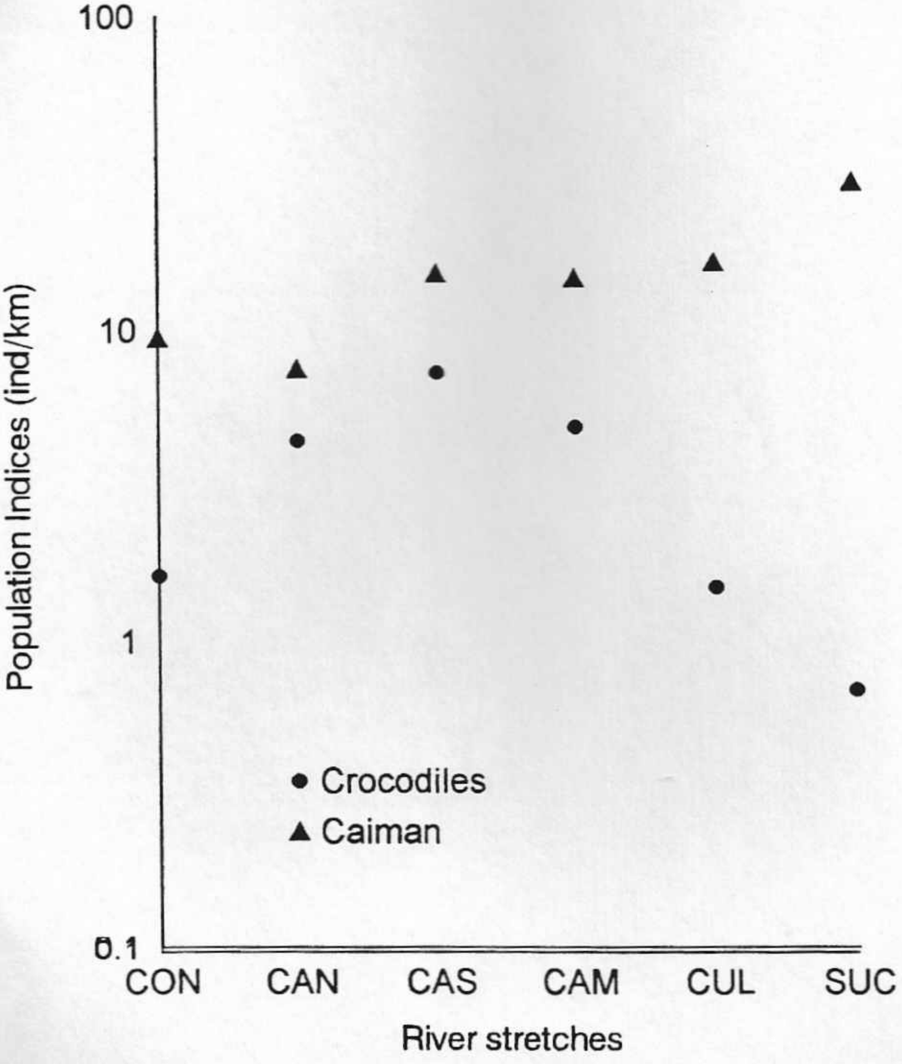

Figure 4-7. Changes in relative abundance of caiman and crocodiles in sections of the Cojedes river system, Venezuela. River reaches are shown from upstream to downstream (left to right). CON, Cojedes Norte; CAN, Caño de Agua Norte; CAS, Caño de Agua Sur; CUL, Caño Culebra; and SUC, Sucre. The y-axis is in logarithmic scale.

higher that the expected by chance (Table 4-4). This mean that caiman and crocodiles tend to segregate along the river. This finding support the competition-predation hypothesis. However, there is an alternative explanation: these results are probably consequence of the fact that caiman are only temporarily in the river, during the late dry season, and most of them remain in those river sections closest to the borrow pits and lagoons where they concentrate as the dry season progress (pers. observ.).

Discussion

In the study conducted by Godshalk (1978, 1982), the Cojedes River was highlighted as the area with the most important population of the Orinoco crocodile (*Crocodylus intermedius*) in Venezuela. This early report was confirmed by Ayarzagüena (1987), who concluded that there were some 350 crocodiles more than 1 m in total length in the Cojedes River System (CRS), most of them in the river section known as Caño de Agua, and in the Sarare River, the largest tributary of the Cojedes River. The CRS has been highly modified in the last 40 years. Many of the numerous new channels or river courses that have been created to satisfy human needs or have appeared "naturally" during the yearly flooding seasons, are not shown in the available cartography. This situation was recognized by Ayarzagüena (1987), which makes his valuable data difficult to compare and to be used as baseline for future studies of population trends.

In this study, river reaches not previously surveyed were incorporated and, thanks to the use of satellite imagery and Global Positioning Systems (GPS), more accurate locations and length of the river reaches studied are given.

Table 4-4. Analysis of the distribution of crocodiles and caiman along surveyed river sections. The nearest species refers to the crocodilian that was sighted immediately before the focal animal.

Surveyed section	Focal Species	Nearest neighbor Caiman	Nearest neighbor Crocodile	X^2	P
Caño de Agua (Pte. Nuevo-La Batea) 4-5 March 1992	Caiman	269	29	40.01	<0.001
	Crocodile	26	21		
Caño de Agua Batea-Merecure 25-26 February 1993	Caiman	10	10	4.93	0.026
	Crocodile	12	40		
Cojedes-Sarare Downstream from bridge Amparo-Sta Cruz 4 May 1993	Caiman	14	5	15.09	<0.001
	Crocodile	6	26		
Cojedes Merecure-Caño Amarillo 5 May 1994	Caiman	123	23	2.72	0.099
	Crocodile	23	9		

The true population size in the Cojedes River system is difficult to determine. The methodology used in this study relies on the assumption that the population was stable from 1991 to 1997. This presumption could not be tested with the current data available. This report indicates that a minimum of 540 non-hatchling Orinoco crocodiles may be found in the study area. This figure includes animals found in river sections not previously surveyed by Ayarzagüena (1987). However, part of the CRS, particularly most of the Sarare River, was insufficiently surveyed. Ayarzagüena (1987) estimated a population of 150 individuals (more than 1.5 m in TL) in that river. The differences in methodologies and the imprecision about the boundaries of the sections surveyed by Ayarzagüena, preclude reliable comparisons. However, the population seems to be more widespread than it was suggested by him, when he indicated that most crocodiles were concentrated in a 10-km stretch of Caño de Agua Sur.

Another important methodological consideration to take into account is that there are many factors that affect the visibility of crocodiles during nocturnal surveys. Water level is the most important of those factors. The decrease in the of number of juvenile crocodiles observed as the dry season advance may indicate that many of these animals refuge in borrows along the river bank where they cannot be detected, particularly during late dry season surveys. Some of them, particularly the smallest ones, may die during the advanced dry season, when the risk of predation and cannibalism should be higher.

As was indicated for the juveniles, most adult crocodiles may be hidden in burrows during the dry season. They may be out again, particularly the females, at the beginning of the hatching period in mid-April, as is indicated by Figure 4-3. When the water level is high, which occurs during the rainy season and early dry season, these burrows might be flooded, and the crocodiles should be out of them.

The differences in visibility of crocodiles depending on the water levels have important implications for the monitoring of its status. The best period to conduct the surveys to determine population size should be from November to January. Not only is a higher fraction of crocodiles seen during these months, but also the number of spectacled caiman is relatively low, which reduces survey time and avoids observer fatigue (Thorbjarnarson and Hernández 1992). During these months most areas can be accessed by car, and the high water level of the river should facilitate navigation.

The Orinoco crocodile population in the CRS is not uniformly distributed. Both differences in size and structure were observed among the several river reaches that were surveyed from 1991 to 1997. The highest densities were found in Caño de Agua Sur, a stretch of the CRS that maintains its meandering condition and is still surrounded by forest. This result is in general agreement with the data reported by Ayarzagüena (1987) for the same location. The densities of crocodiles decrease upstream in Caño de Agua Norte and Cojedes Norte, areas that are highly impacted by deforestation, channelization and contamination (see Chapter 3).

The results for the Sucre and Caño Culebra sections represent the first data on the population status of the species in those localities. In these river stretches, the Orinoco crocodile population is extremely low, particularly near Sucre.

If the Sucre and Caño Culebra localities are not taken into consideration, the densities of crocodiles in the CRS are very high (from 3.08 to 7.43 ind/km) compared to the ones reported by Thorbjarnarson and Hernández (1992) for the Tucupido (before it was dammed) and the Capanaparo Rivers (1.94 and 1.64 ind/km, respectively). These contrasting figures are paradoxical, because compared to the CRS, the Capanaparo River is relatively isolated from important human settlements and is regarded as good crocodile habitat by Thorbjarnarson and Hernández (1992). However, egg predation and hatchling collection by human is a fundamental negative element in the Capanaparo River (Thorbjarnarson and Hernández 1992), a factor of marginal importance in the CRS (Chapter 5).

In reference to the population structure, there were important differences among river sections. Cojedes Norte and Caño de Agua Norte were mostly dominated by small crocodiles (less than 1.2 m in TL), which accounted for no less than 56.2% of the crocodiles seen. In contrast, the crocodile population in Caño de Agua Sur was composed largely of sub-adults and adults (>1.8 m in TL). The Merecure-Amarillo stretch showed an intermediate population structure. These dissimilarities may be partially explained by differences in habitat quality between sections. The principal nesting beaches, for example, were found in Caño de Agua Sur (see Chapter 5). Differences in mortality rate (see Chapter 6) may also play a role in structuring these populations.

There is another possible explanation of the differences in population structure among localities. Those composed predominantly of juveniles (Cojedes Norte and Caño de Agua Norte) may be recovering from overexploitation as has been suggested for other crocodilians (Webb and Messel 1978; Rebelo and Magnusson 1983). In the case of Caño de Agua Norte it is more plausible to think that the Orinoco crocodile is simply colonizing that river stretch. Most of Caño de Agua Norte is an artificial channel which has been receiving the water of the Cojedes River only after the 1960s (Pedrañez 1980; Campo and Rodríguez 1995).

The most plausible explanation is that the population structures reflect human impact. Large crocodiles are easily detected and more frequently killed by people in Cojedes Norte and Caño de Agua Norte. These areas are more developed and human-crocodiles encounters may occur relatively frequently. Fewer adults could remain in the river under these circumstances, and the less conspicuous juveniles may escape detection and survive, although in lower densities than juvenile in Caño de Agua Sur. In river sections less accessible to humans, as in Caño de Agua Sur, large crocodiles may have greater chances to survive and became established to constitute a high fraction of the population.

The hypothesis of competition-predation is not completely satisfactory to explain the pattern of relative abundances and spatial distribution of crocodile and caiman in the CRS. The negative (although weak) correlation of densities and apparent spatial segregation of caiman and crocodiles could be the result of the combination of two factors: (1) through predation and competition, crocodiles keep the population size of caiman in check in areas where the crocodiles are relatively abundant, which may explain the reduction in caiman numbers in the middle sections of the rivers, and (2) because *C. crocodilus* use the river mostly during the dry season, moving to temporary lagoons, borrow pits and flooded areas during the rainy season, the abundance of caiman in a particular river stretch would depend on the quality and quantity of habitat for caiman that surrounds that river stretch. That habitat might be relatively scarce in the upper part of the CRS, less frequently flooded areas, and also areas more affected by human activities (agriculture and urbanization). In the southern part of the study area, the river is mostly surrounded by cattle ranches, with presumably more temporary and permanent water bodies for caiman, which would explain the high densities of caiman in those river reaches. Furthermore, toward the south, intentional or accidental killings of crocodiles by people maybe an important factor to explain the low crocodile densities. Some of these aspects will be analyzed again in the following chapters.

The presumed negative interaction between caiman and crocodiles should be formally investigated with a removal experiment. Caiman can be legally harvested in Venezuela. A controlled removal of caiman could be implemented in some river reaches with high crocodile densities in such a way that we could have sites with very low caiman population and places with high densities of this species. The effect of this removal on survival and growth of hatchling and juveniles crocodiles could be later measured. A project like this can only be accomplished with the collaborative effort of the government and landowners.

Regardless of their imprecisions, the procedures reported here and the population indices derived from them, represent the first attempt to standardize the methodology for the study of the Orinoco crocodile population in the Cojedes River system, the most important population of this endangered species. These results can serve as a baseline for future investigation of the species in the area.

CHAPTER 5
REPRODUCTIVE STATUS AND ECOLOGY

Introduction

Until recently very little was known about the reproductive ecology of the Orinoco crocodile, one of the less studied crocodilian species in the world. Ayarzagüena (1987) and González-Fernández (1995) reported important data on the reproductive ecology of the Orinoco crocodile in the Cojedes River system (CRS), but their information was too general or restricted to a small part of the CRS. The landmark study by Thorbjarnarson and Hernández (1993a,b) in the Capanaparo River, state Apure, shed some light on several aspects of the reproductive ecology of *C. intermedius*. However, the particular characteristics of that river make extrapolation to other waterways, particularly one severely stressed by human activities like the CRS, inappropriate.

In the last 40 years, human activities have changed the characteristics of the Orinoco crocodile habitat in the CRS. Some changes have modified the water quality of the river (Chapter 3). Others have altered the physical characteristics of the river through damming, dredging, and channelization (Chapter 2). To what extent have these alterations affected reproduction of the Orinoco crocodile? It has been suggested (Ayarzagüena 1987) that dredging and channelization, for example, have a negative impact on crocodiles because it destroys nesting beaches. This should translate into a reduced nest density in modified sections in comparisons to sections where the river maintains its meanders. The main objectives of this chapter are (1) to answer basic questions on the reproductive ecology of *C. intermedius* in the CRS in reference to nesting chronology, nesting habitat, reproductive success, reproductive status, parental care, and (2) discuss the reproductive ecology of the species in the context of the anthropogenic modifications of the river course.

Methods

During nocturnal spotlight surveys and daylight reconnaissance, I collected information on aspects of reproductive ecology of the Orinoco crocodile in the CRS, such as nest location, soil texture of nesting beaches, nesting and hatching chronology, and clutch size. A part of the river shore was subjectively considered as potential nesting place for *C. intermedius* if it had one or more of the following characteristics: (1) It consisted mostly of lightly compacted material and generally had excavations made by other reptilians such as iguanas (*Iguana iguana*) or turtles (*Podocnemis unifilis*), species with similar nesting requirements in terms of soil texture; (2) The shore was bare or sparsely covered by vegetation; (3) it was 1.5 m or more above the water level, and (4) there was a record of previous utilization of the place by nesting females. The number of beaches adequate for nesting of Orinoco crocodile was counted in sections of Caño de Agua Norte, Caño de Agua Sur, and the section between Merecure and Caño Amarillo.

The soil composition of the substrate from nesting beaches was determined, as was the substrate from the river bank in sections where nesting beaches (according to the proceedings criteria) were not present. The proportion of silt, clay and sand in those samples was determined following the hydrometer method of Bouyoucos (Foth 1978) at the *Universidad Nacional Experimental de los Llanos Occidentales* 'Ezequiel Zamora' (UNELLEZ) in Guanare, Venezuela.

After hatching from the nest, neonates remained in well defined groups or "pods" for several weeks. During the nocturnal surveys, the location and number of pods, and the number of hatchlings in each pod was recorded. When a particular pod was counted more than once, the maximum number of hatchlings recorded was taken as the pod size. The location and number of pods were used to estimate the number of nesting females in the surveyed sections. A preliminary measure of hatching success was obtained by comparing the average number of hatchlings per pod against the average number of eggs per clutch. The average clutch size was calculated combining my own data with information found in the literature. Due to predation and dispersion of hatchlings, pod size decreases with time and only those pods found in April or early May were considered in the analyses.

The presence or absence of an adult crocodile in the proximity of the pod was recorded and taken as an indication of parental care. A contingency table analysis was used to establish if parental care of hatchling pods differed between river sections under different human pressure.

The nesting chronology of the species was determined based on reports of Ayarzagüena (1987) and González-Fernández (1995) and my own observations on dates of nest construction, banding of eggs, hatching period, sizes of the hatchlings, and size of the umbilicus of the hatchlings.

During 1996 and 1997, the position of each nest (or pod of hatchlings) was recorded with a Global Positioning System (Magellan 4000 and 4000xl). I assumed that females tend to nest in the same spot year after year, a behavior that is well documented for many crocodilian species (Garrick and Lang 1977; Ogden 1978; Thorbjarnarson and Hernández 1993a). The minimum number of nesting females in the survey area was determined by comparing the relative position of nests and pods from 1996 and 1997.

The size of the reproductive population was estimated based on the number of nesting females. In non-surveyed sections of the CRS the number of nesting females was subjectively estimated based on the characteristics of the section and the known nest densities in contiguous upper and/or lower reaches of the river. The number of dominant males was calculated as one per female for relative isolated females, and up to one male for every four females for localities with several females, depending on the relative proximity of the nests. The last estimate is conservative if we take into account that the sex ratio reported by Thorbjarnarson and Hernández (1993b) is 1♂:2.2♀♀

Results

Nesting Habitat.

Three river segments were examined for the presence of potential nesting habitat (Table 5-1). Only the section of the Caño de Agua Norte downstream from Puente Nuevo, was surveyed for potential nesting beaches (Puente Nuevo-Carama). There, the river was very narrow (8-12 m) and has numerous meanders despite it has been dredged an unknown number of times in the past. Both margins of the river have been deforested and grasses and bushes cover the banks down to the water's edge. Most of this part of the river (60%) was lost during the rainy season of 1996 when the river changed its course and diverted into smaller branches toward Caño Camoruco. Caño de Agua Norte, upstream from Puente Nuevo, has been dredged and partially channelized over the last 20 years but in some parts it has recovered its meandering condition. In those latter reaches the characteristics of the river were the same as downstream from the bridge, but in the river segments that remained channelized, banks were very steep and nesting beaches were absent.

Table 5-1. Number of beaches considered as potential nesting habitat in three river reaches in the Cojedes River system.

Place	Length (km)	Number of Beaches	Beaches per kilometer
Caño de Agua Norte	4.7	16	3.40
Caño de Agua Sur	5.2	20	3.85
Merecure-Caño Amarillo	8.4	9	1.07

Caño de Agua Sur was also very narrow (in general less than 12 m) and it was the most meandering river segment of the entire study area. Most of the banks were forested and grasses were less abundant than in Caño de Agua Norte and usually did not reach the water's edge. Scattered bunches of logs and branches of fallen trees were found along the river. Dense clumps of the riparian shrub (*Coccoloba obtusifolia*) also were frequently found along the river edge.

In the part of the river referred to as Merecure-Caño Amarillo, the Cojedes River was relatively wide (15-20 m) with ample meanders and with the banks covered mostly by forest. The shrub *C. obtusifolia* was very common in this part of the river. Most of the beaches counted along this section were found approximately in the first 4 km downstream from Merecure. In the remaining downstream part of this river section proper beaches were almost nonexistent; grasses and *Heliconia* plants were abundant and reach the water's edge.

In the sections of the river that had been channelized, river banks that fulfill the criteria as potential nesting beaches were scarce or absent. In the southern part of the study area (Sucre and Caño La Culebra) adequate nesting habitat was also scarce.

In early February 1997, a smaller number of beaches (15) from Caño de Agua Sur and Merecure-Caño Amarillo were more carefully scrutinized to determine their use by iguanas and turtles. Twenty percent of the beaches had clutches of turtles' eggs (*Podocnemis unifilis*). Most of these beaches (73.3%) also had nest excavation made by iguanas. The count for turtles nest was clearly an underestimation, because it is much more difficult to find turtle clutches than iguana excavations. On the other hand, it was probably too early in the nesting season of *Podocnemis* and many turtles may have not nested yet. González-Fernandez (1995) found turtle nests in 38% of the beaches with crocodile nests. In a nocturnal survey conducted from La Batea to Merecure on 27 April 1997, the remains of eight turtle nests were found. Turtles or turtle nests have never been observed in the northern part of the study area (Caño de Agua Norte and Cojedes Norte).

In Cojedes Sur, turtles frequently were seen basking on logs or branches of fallen trees. They may nest in that area, although nesting was never observed. Iguanas were very rare in this part of the river, which had its banks profusely covered by trees. This suggests that iguanas may be limited by scarcity of nesting substrate. Adequate nesting substrate in Caño Culebra seemed to be also scarce, but the presence of iguanas cannot be used there as an indicator of quality of nesting habitat, because that part of the CRSs is almost devoid of arboreal vegetation, which may signify a more important limiting factor for iguanas.

Another criterion for evaluating the suitability of a section of the river for nesting was through the analysis of soil texture. Samples from the northern sections of the study area show a preponderance of sand in their composition (65.5-89.5%; Fig. 5-1). In two samples from Caño de Agua Sur, close to Merecure, sand accounted for 58.5% on average. A lower percentage of sand was found in La Culebra (54.8%), and the lowest percentages of sand in all the samples was obtained in Sucre (range 11.5 to 23.5%).

Although vast parts of the study area were not evaluated for their suitability for nesting, a pattern of decrease in the quality of the substrate on the banks from north to south was apparent.

Nest Density

Based on the comparisons of the positions of nests and pods from 1996 and 1997, I estimated that there were at least 48 nesting females in the surveyed sections of the study area. Those sections represent a total of 45.7 km of river with a density of 1.03 nests (or nesting females) per km (Table 5-2). Although Cojedes Norte was never surveyed during

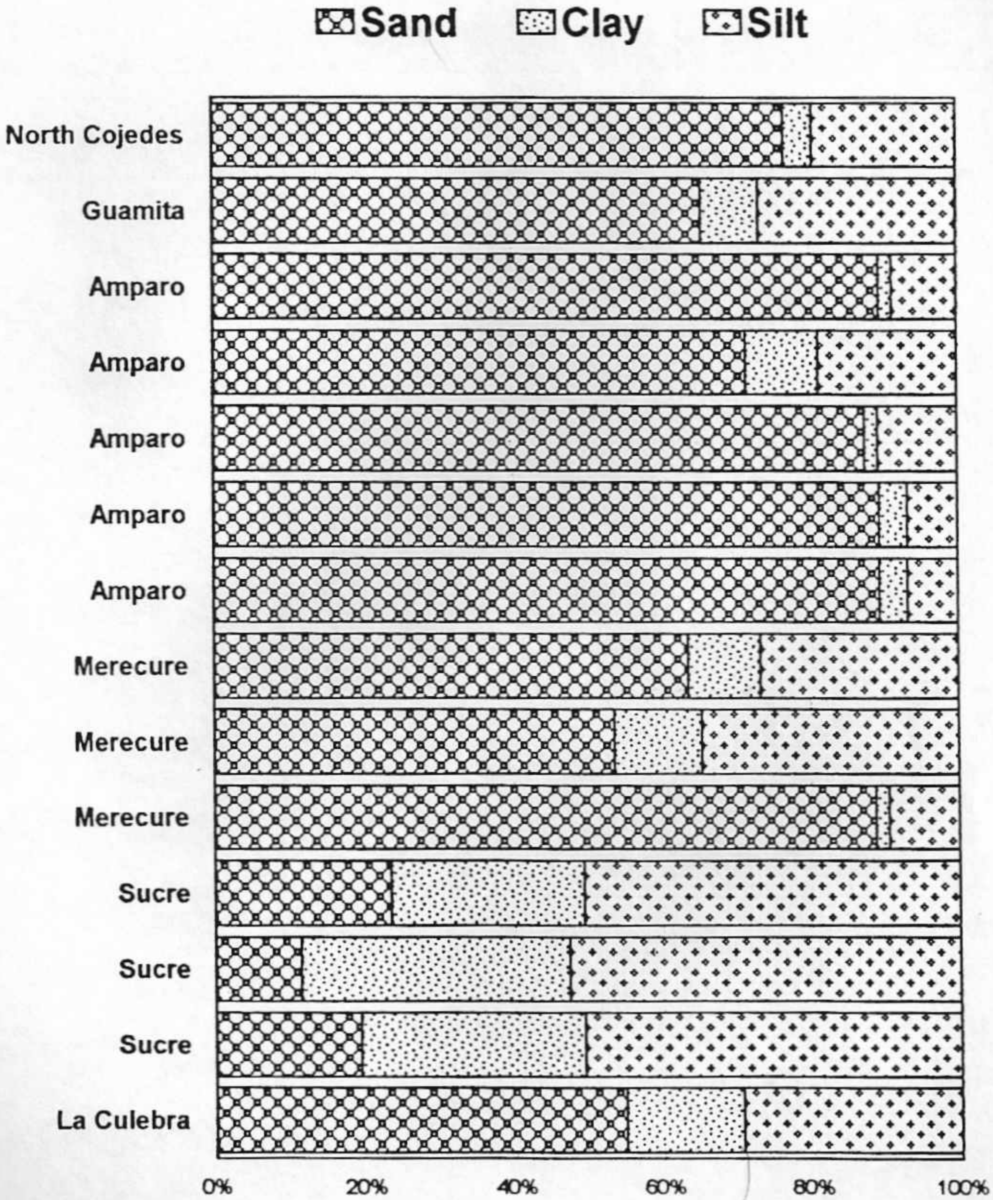

Figure 5-1. Texture of river bank soil samples collected at different locations along the the Cojedes river system, Venezuela. Locations are ordered from north to south (top to bottom)

Table 5-2. Number Orinoco crocodile females that nested in several river sections of the Cojedes river system during 1996 and 1997.

River section	Length (km)	Nesting Females	Density (female/km)
Caño de Agua Norte			
Retajao[1]	--	1	--
Doncella-Guamita	5.5	4	0.73
Guamita-Puente Nuevo	10.5	12	1.14
Caño de Agua Sur			
Puente Nuevo-Carama[2]	4.7	8	1.70
Pte Lorenzo-Confluence	7.6	12	1.58
Cojedes Medio			
Merecure-Caño Amarillo	9.0	4	0.44
Sarare	8.4	7	0.83
Totals	45.7	48	1.03

[1] The nest from Retajao was a casual observation in a non-surveyed section. It was not considered for the calculation of density.

[2] Most part of this river section disappeared during the 1996 flooding

the time when hatching occurs (late April early May), the size of many of the crocodiles seen there indicated that successful reproduction have taken place in that part of the river in previous years. Cojedes Norte is isolated from the rest of the study area by a dam. That dam constitutes a barrier that effectively blocks passage from downstream.

Nesting females were not uniformly distributed along the river. In river section Doncella-Guamita only four nest (0.73 nest/km) were observed. This river reach was completely channelized and had steep banks. Downstream from it, in the Guamita-Puente Nuevo section of Caño de Agua, the river had recovered its meandering conditions. Nest density there increased to 1.14 per km.

The highest density (1.7 nesting females/km) was found in 1996 in a 4.7-km long reach of Caño de Agua, downstream from Puente Nuevo. Most of that section of the river (approximately 60%) was lost during the rainy season of 1996 due to river diversion after a severe flooding event. The fate of the 8 nesting females from that part of the river is not known. Two nests found near Puente Nuevo in 1997, just north of the diverted river section, might have belonged to some of these females.

Four km of Caño de Agua Sur, the river stretch between Camoruco and Puente Lorenzo, were not surveyed for nest or hatchlings. Considering that the characteristics of that river section were very similar to the ones found immediately downstream, in the section Puente Lorenzo-Confluence, six additional nesting females, not listed in Table 5-2, could be expected in Caño de Agua Sur.

In the Sarare River, only a stretch of 8.4 km was surveyed for nest or pods, resulting in a density of 0.83 nest/km. The river section from downstream to the confluence with Caño de Agua has never been surveyed. No hatchling or nest was ever found in Sucre or Caño La Culebra. The size of the crocodiles seen or captured there indicate that they were older than a year, suggesting that crocodiles in these locations may have come from elsewhere, probably upstream.

A detailed examination of crocodile nest distribution revealed a pattern of clustering (Fig. 5-2). Groups of up to four females were found in close proximity, suggesting the presence of a dominant male and a group of females, as has been reported in the Capanaparo River by Thorbjarnarson and Hernández (1993b).

Nest predation by humans did not seem to be an important factor affecting the viability of the Orinoco crocodile in the CRS. One nest seemed to have been taken by people in the section Merecure-Caño Amarillo in 1997, but the evidence was equivocal. People in Retajao took at least 11 hatchling from a pod in 1996.

Adult Population

Ninety-one reproductively active crocodiles were estimated for the Cojedes River System, most of them (63.2%) in Caño de Agua (Table 5-3). This figure represents the minimum of adults as (1) some parts of the since river were poorly surveyed and, conservatively, a low density of adults was assigned to them, and (2) not all the adult females nest every year.

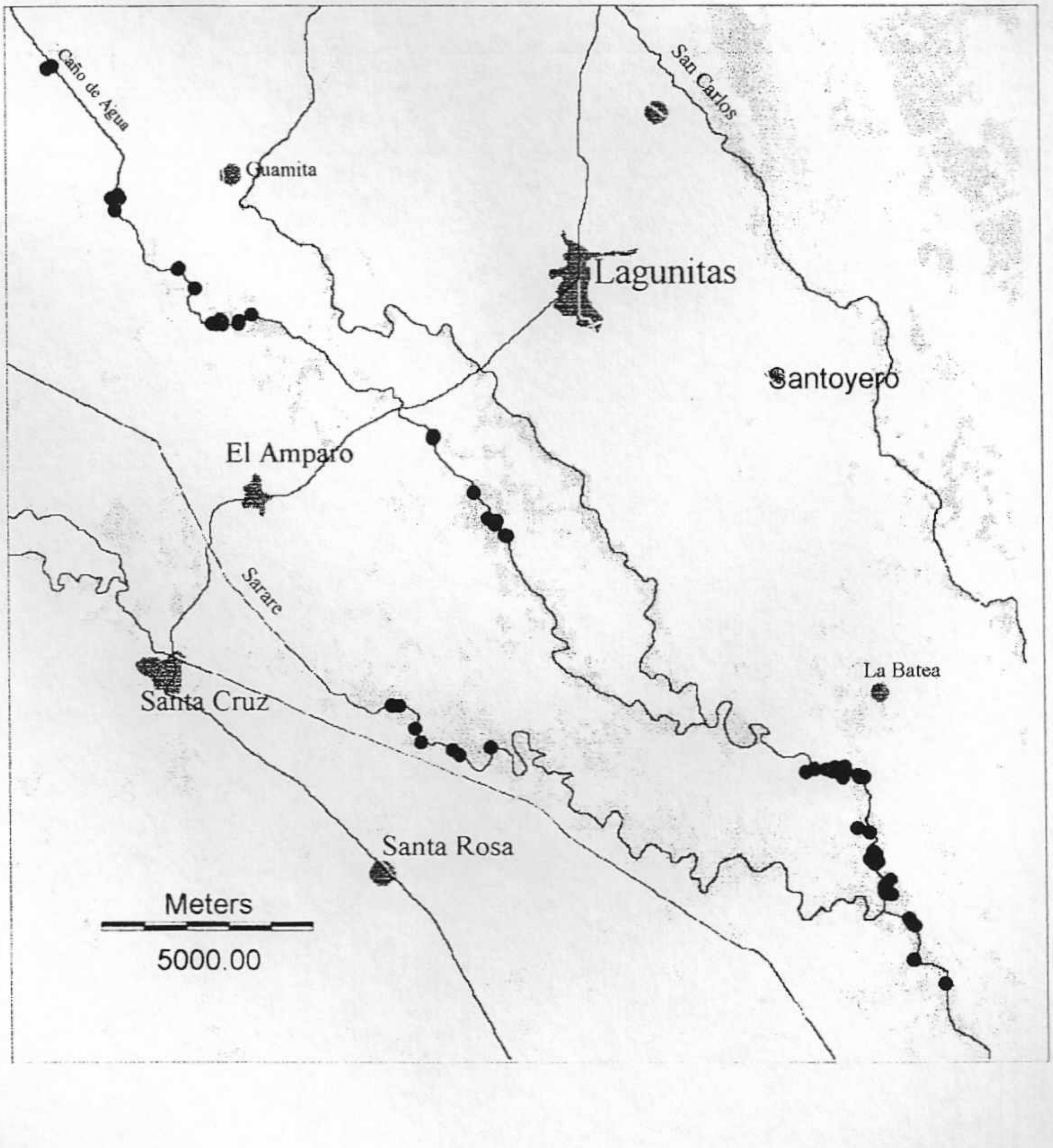

Figure 5-2. GPS positions (dots) of Orinoco crocodile nests observed during 1996 and 1997 in some river reaches of the Cojedes river system (Venezuela). Nest tend to occur in clusters, indicating the presence of a dominant male and two or more adult females.

Table 5-3. Reproductive population of Orinoco crocodiles in the Cojedes River System. The number of dominant males was calculated as one per female for relative isolated females, and one male for every three-four females for places with several females.

Place	Length (km)	Nesting Females	Dominant Males	Total
Cojedes Norte	7.0	2[1]	1	3
Caño de Agua Norte				
Toma Cojedes-La Doncella	25.5	1	1	2
Doncella-Guamita	5.5	4	1	5
Guamita-Puente Nuevo	10.5	12	4	16
Caño de Agua Sur				
Puente Nuevo-Carama[2]	4.7	8	3	11
Camoruco-Pte. Lorenzo	3.7	6[1]	2	8
Pte Lorenzo-Confluence	7.6	12	4	16
Cojedes Medio				
Confluence-Caño Amarillo	9.0	4	1	5
Caño Amarillo-Sucre	51.0	1[1]	1	2
Caño Amarillo-La Culebra	33.5	1[1]	1	2
Sarare				
Downstream Amparo bridge	8.4	7	2	9
Lower Sarare	12.0	8[1]	3	11
Totals	153.0	66	25	91

[1] Not surveyed. Figure estimated based on similarity of appearance with surveyed sections.

[2] Most of this river reach disappeared during the flooding season of 1996.

Nesting Chronology

The earliest observation of hatchlings crocodiles was 12 April, during the 1996 hatching season. Morphological characteristics (total length, presence of egg tooth and size of the umbilicus) of the hatchlings found in 72 pods observed from 1991 to 1997, suggest that most of the hatching occurred from mid-April to early-May. In captivity, under ideal conditions, the incubation period lasts some 80-85 days (Ramo et al. 1992; Thorbjarnarson and Hernández 1993a; Seijas and González 1994; Lugo 1995), so construction of nests may start as early as middle January. Most nesting, however, occurs in late January and early February. The earliest nest ever examined by me, on 5 February 1997, and those found by Ayarzagüena (1987) support this conclusion.

Hatchling Pods and Parental Care

Based on the size 44 pods observed in the first month of the hatching season (Fig. 5-3), the average number of hatchlings per pod was 26.0 ±13.9, as compared to 31 ±10 reported by González-Fernández (1995). When analyzing for the differences in pod size among localities (Caño de Agua Norte, Caño de Agua Sur + Cojedes, and Sarare), the statistical result was significant (Kruskal-Wallis Test; X=6.2, P=0.045). This result is a consequence of the higher number of individuals (35.5) in the pods from the Sarare River. Pod size in Caño de Agua Norte and Caño de Agua Sur + Cojedes were very similar (24.0 and 22.1 hatchlings/pod, respectively).

According to my own data, and on information reported by Ayarzagüena (1987) and González-Fernández (1995), the average number of eggs per clutch in the CRS is 38.2

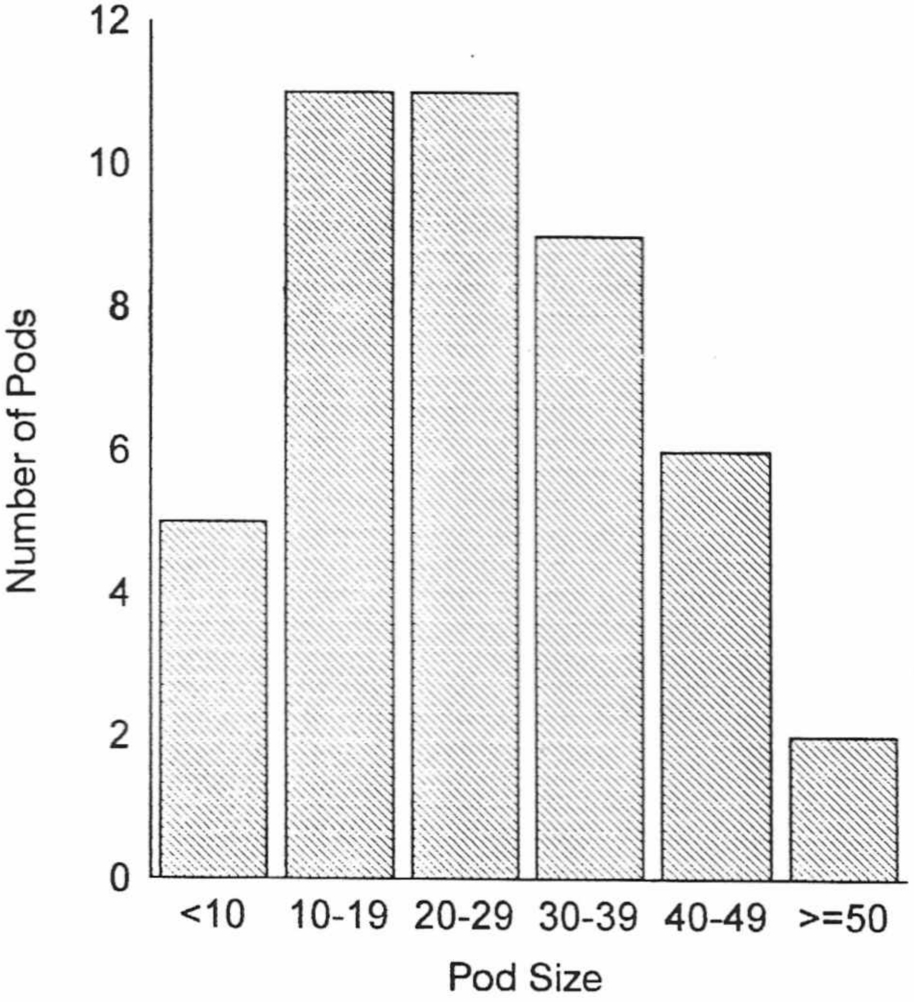

Figure 5-3. Frequency distribution of pod of Orinoco crocodile hatchlings according to their number of individuals in the Cojedes river system, Venezuela. Very large pods may result from the integration of hatchlings from more than one female.

±11.0 (n=12), which is below the typical range (40-70) mentioned for the species by Thorbjarnarson (1992). The mean pod size found in this study (26.0) represents 68% of the average clutch size, which could be taken as a preliminary measure of hatching success. A flaw in this method of calculating hatching success is that nests that fail to produce hatchling could not be detected, and so are not included in the calculations. There is no information on other wild Orinoco crocodile populations to compare these results.

There was a negative correlation ($r=-0.29$, $P<0.05$) between the size of the pod and days after the beginning of the hatching season (Fig. 5-4). The most parsimonious explanation of this relationship should be the disintegration of the pods resulting from predation and dispersion. Another contributing factor is that larger females tend to lay their eggs earlier than smaller females, as has been mentioned for captive Orinoco crocodile females) and for *Alligator mississippiensis* (Joanen and McNease 1992). It is also known for most crocodilians, including the Orinoco crocodile, that clutch size is positively correlated with female body size (Cott 1961; Greer 1975; Thorbjarnarson and Hernández 1993a, Thorbjarnarson 1996)

At 47.7% of 44 pods for which the information was recorded, an adult crocodile, presumably the mother of the hatchlings, was seen in close proximity. This figure is surely an underestimation, because the disturbance produced by the noisy approach by boat, powered by an outboard engine, might have caused many females to disappear from sight. Compared to Caño de Agua Norte, Caño de Agua Sur-Caño Amarillo is less disturbed by human activities (Chapter 4). I expected less pod attendance in Caño de Agua Norte. The statistical analysis support this hypothesis ($X^2=4.48$; $P=0.034$).

→ Perturbación humana
incide negativa
en la atención a la
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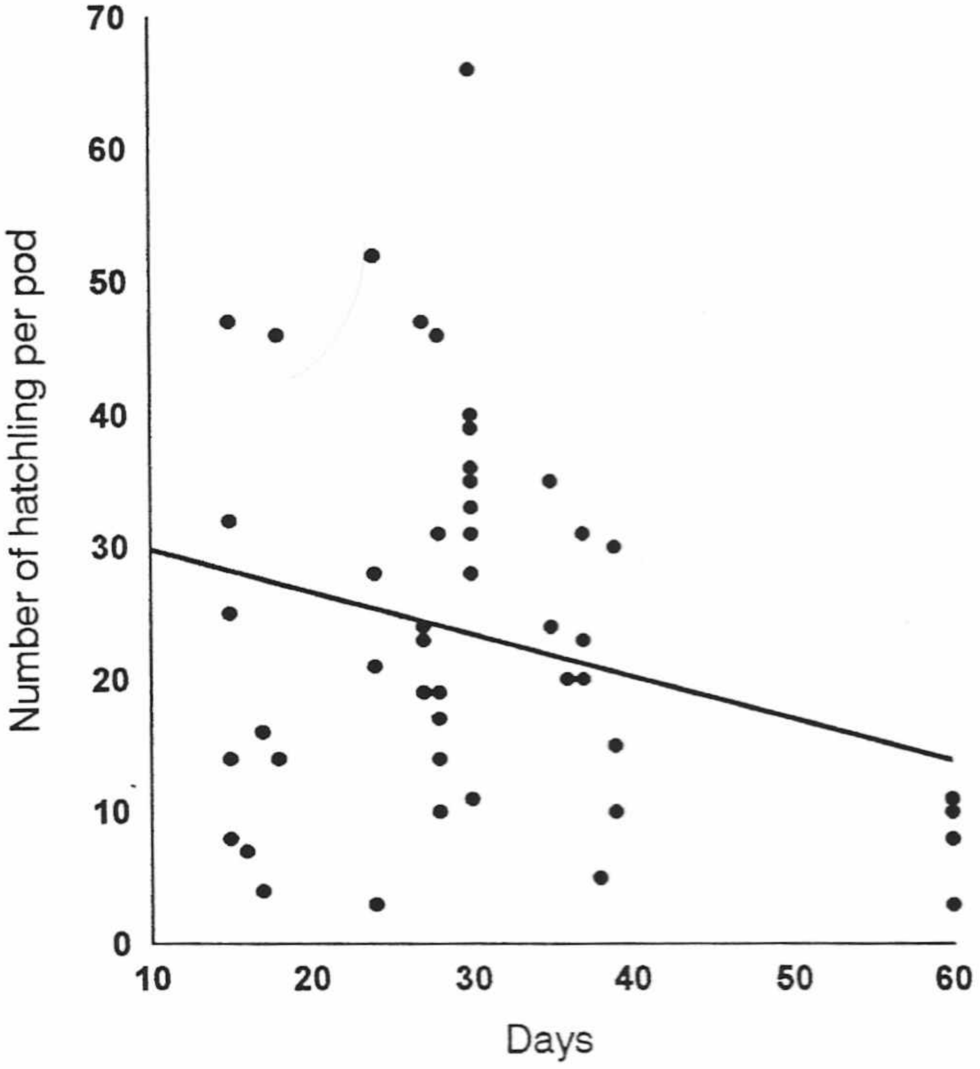


Figure 5-4. Size of Orinoco crocodile hatchling pods in relation to time after hatching. Cojedes river system, Venezuela. Day zero is 12 April, the beginning of the hatching season.

Discussion

Although depleted in most of its former range, there is high density of Orinoco crocodiles in the CRS. There were at least 48 adult females in the surveyed sections of the river, a number that is most probably an underestimation since a relatively small part of the region was properly surveyed.

Soil samples taken from active nests indicated that the most frequently selected nesting sites are composed in a high proportion of sand (generally more than 70%). Lack or scarcity of good nesting substrate seems to be an important factor determining the current distribution of the species in the CRS. The reproductive population is concentrated in the Caño de Agua and in the lower Sarare River, the areas that had the highest quality nesting habitat. There was no evidence that the species reproduces in Cojedes Sur and in Caño Culebra, areas which had lower quality nesting habitat. The abundances of crocodiles and quality of nesting sites of many sections of the CRS have not been evaluated, so this conclusion is preliminary.

Globally, the total density of nests was the same as found by González-Fernández (1995) in part of the study area (1.04 nest/km). Ayarzagüena (1987) estimated that there were some 25 nesting females in Caño de Agua Sur, which was roughly the same number found in this study for the same part of the CRS. The nest density of the *C. intermedius* population in the Capanaparo River studied by Thorbjarnarson and Hernández (1993a) ranged from 0.24 to 0.36 nests/km.

Nest density in the Merecure-Caño Amarillo sector was relatively low when compared with the 1.4 nests/km obtained in 1994 by González-Fernández (1995). The results obtained by González-Fernández may be exceptional, because that year the rainy season started late, with the lowest combined precipitation for April-May (129.7 mm) for the period 1975-1996 (MARNR 1997). Compared to other years, a lower number of nests (if any) may have been lost in 1994 due to flooding.

Some river sections that have been dredged repeatedly in the last 20 years had relatively high density of nesting. Dredging may have an immediate negative impact because they destroy beaches (González-Fernandez 1995) but the river seems to recover after several years. One of the lowest nest densities was found in La Doncella-Guamita, a stretch that has been channelized. Channelization may have a greater impact on reproduction and on the population as a whole because it reduces the habitat for the species, eliminates most beaches, and increases the flow speed of the river.

The distribution of nests or nesting females along the river indicated that in the Cojedes River the Orinoco crocodile showed the same social structure described for the species in the Capanaparo River, in which dominant males form polygynous groups with two or more females (Thorbjarnarson and Hernández 1993b). Reproductive data from this study compared to data in the literature (Ayarzagüena 1987, González-Fernandez 1995), suggest that the number of nesting females has remained stable over the last 10 years.

If pollution and other human related factors affect egg viability in the area studied, that may be reflected in the average pod size. Habitat modification and pollution (see

Chapter 4) are higher in Caño de Agua Norte than in Caño de Agua Sur. Habitat alteration in the surveyed portion of the Sarare River is comparable to that found in Caño de Agua Norte, but information on pollution was not available. There were a statistical differences in pod size among localities, due to the relatively higher average pod size in the Sarare River. However, this later site was insufficiently sampled. Since there are many factors that can affect pod size, including female size and hatching success, it is difficult to interpret the meaning of these differences in pod size. More detailed studies in this regard are necessary, particularly on the effects of contamination on crocodile reproduction.

There was a significant difference in what was interpreted as maternal care or pod attendance between Caño de Agua Norte and Caño de Agua Sur-Caño Amarillo. This may be a consequence of higher human interference in Caño de Agua Norte, as has been reported for *Caiman yacare* in Brazil (Crawshaw 1987). Another possibility is that females in Caño de Agua Norte were relatively new colonizers of the area and probably younger and less experienced than females in southern locations.

Egg or hatchling collection did not seem to be a factor that affects the survival of the Orinoco crocodile in the CRS, at least where most of the nesting occurs, although anecdotal information indicated that this kind of human intervention occurs sporadically (pers. observ; González-Fernández 1995). Human settlements are generally several kilometers away from the river banks, and in the CRS is not inhabited by people exploiting the river resources as is the case in the Capanaparo River (Thorbjarnarson and Hernández 1992). Gonzalez-Fernandez (1995) reported that 2 of 27 (7.4%) nests analyzed by him were destroyed by a dredge, but no predation by human was reported.

Nesting chronology documented in this study agrees with the general pattern described for the species (Medem 1981, 1983; Ramo et al. 1992; Thorbjarnarson and Hernández 1993a): egg-laying starts during the months of lowest precipitation (January-February) and hatching takes place at the onset of the rainy season (late April-early May). Nesting (and consequently hatching) occurs earlier in the captive breeding facilities of the Universidad Nacional Experimental de los Llanos (UNELLEZ), and later in the breeding facilities of Masaguaral ranch, in response to different precipitation regimes in those areas (Ramo et al. 1992, Thorbjarnarson and Hernández 1993). Eggs laid late during the nesting season are under a high risk of being lost due to flooding. The high nesting success reported by González-Fernández (1995) for a reach of the Cojedes River (Merecure-Caño Amarillo) in 1994 may be the result of delay of flooding events in that year. The impact that damming, channelizing and water diversion in the CRS may have on nesting and reproductive success of the Orinoco crocodile has not been properly studied. Several kilometers of good nesting habitat have been lost due to flooding and river diversion in the last 10 years. The wise management of the Las Majaguas reservoir and of the future Las Palmas reservoir, to avoid sudden rises of water levels and loses of nests, will be crucial for the survival of the species.

CHAPTER 6
PHYSICAL CONDITION

Introduction

Habitat modification and degradation due to human activities can have short, medium, or long-term effects on living organisms. For example, the incidental destruction of localized nests or nesting beaches (González-Fernández 1995) may have a minor, but immediate, short-term effect on the reproduction of the Orinoco crocodile in the Cojedes River system. On the other hand, in a long-lived, slow-growing species like the Orinoco crocodile, the widespread and constant discharge of endocrine disrupting environmental contaminants (Guillete 1995), even at sub-lethal amounts, could take several years to express its negative effects on reproduction in terms of clutch size, nesting success, and hatchling survivorship.

The combined, synergistic effect of multiple anthropogenic impacts can cause profound changes in the ecological characteristics and biological integrity of rivers (Karr 1981; Petts and Calow 1996; Winemiller et al. 1996) including the modification of the species composition, alteration of ecological processes (predation, competition, energy flow, nutrient cycles), and others (Angermeier and Karr 1996). Some of these changes may have medium-term effects in ecosystems as a whole and on its species in particular. In the case of the Cojedes River system (CRS), could the physical condition of crocodiles be used as indicator of habitat deterioration? In this chapter, I assess that question comparing the physical condition of crocodiles from river sections with varying degrees of human-induced alterations.

The response of an organism to its environment can be measured in several ways. The accumulation of fat, for example, has been considered as a measure of how well animals are coping with their environment (Taylor 1979; Johnson et al. 1985; Beintema 1994; Gerhart et al. 1996). The accumulation of fat is generally used as an indicator of the physiological condition and survival and the overall nutritional state in different groups of vertebrates. Direct measurements of fat deposition, however, are difficult to obtain under field conditions and may require organisms to be sacrificed. Indirect measurement of the fatness of organisms can be obtained by means of condition indices (Virgl and Messier 1993; Setzler-Hamilton and Cowan 1993; Gerhart et al. 1996; Spengler et al. 1997). Condition indices are derived by measuring a variable (generally weight) that is responsive to the organism's feeding environment, which is then adjusted by a starvation independent variable (e.g., body length)(Suthers et al. 1992). Although widely used in studies of many groups of vertebrates, condition indices have been rarely used with crocodilians (Taylor 1979; Hutton 1987; Brandt 1991; Ramo et al. 1992).

Another way to measure the response of an organism to its environment is through its growth rate. Growth rate in crocodilians, for example, is highly variable depending on the environmental conditions (Gorzula 1978; Webb et al 1978, 1983; Chabreck and Joanen 1979; Hutton 1987; Jacobsen and Kushlan 1989; Rootes et al. 1991, Brandt 1991). Since the quality and abundance of resources and several other environmental constraints are variable from place to place, variation in the growth rate of crocodiles in different areas is expected (Jacobsen and Kushlan 1989). For example, it is generally known, also, that captive crocodilians, fed on a high protein and well balance diet, can grow faster, and accumulate more fat, than wild animals (Coulson, Coulson, and Hernández 1973; Joanen and McNease 1979; Montague 1984).

Finally, the prevalence and seriousness of injuries and parasitic infestations can be a handicap that affects the survivorship, growth and physical condition of individuals. Animals from areas with relatively high predation pressure may have a higher incidence of injuries (Webb and Messel 1977) and, presumably, poorer physical conditions in terms of accumulation of fat (Taylor 1979). In this chapter, the growth rate and physical condition of crocodiles caught in different localities in the study area were analyzed and compared. Their relevance as indirect measures of habitat quality is discussed.

Methods

Crocodiles were captured at night by hand or with nooses. The following measurements were taken: total length (TL), from the tip of the snout to the tip of the tail; snout vent length (SVL), from the tip of the snout to the posterior edge of the vent; head length (HL), from the tip of the snout to the median posterior edge of the cranial platform; snout length (SL), from the tip of the snout to the anterior edge of the orbit; tail girth (TG), the maximum girth of the base of the tail just posterior to the cloaca. TG was taken for only a fraction of the animals captured in 1997. TL, SVL, and TG were measured to the nearest millimeter, HL and SL to the nearest 0.1 millimeters. Weights were measured to nearest 5 g for individuals less than 1 kg, to the nearest 50 g for individuals between 1 and 5 kg, and to the nearest 100 g for animals more than 5 kg. Each crocodile was tagged or/and marked by excision of unique combinations of tail scutes crests.

Animals less than 600 mm SVL were sexed by direct observation of the penis or clitoris, after slightly bending the individual ventrally while exerting a lateral pressure on the cloaca. Larger crocodiles were sexed by probing the cloaca with the small finger. These methods are considered reliable for individuals more than 350 mm in snout-vent length. Crocodiles smaller than that size were regarded as unsexed.

Injuries and Parasites

Every captured crocodile was carefully scrutinized to detect major scars or mutilations, which indicates the presence of past or current injuries. The number of rows in the single crested caudal whorl (SCCW) was counted and taken as an indirect measurement of the degree of mutilation of the tail. Although the Orinoco crocodiles may have up to 20 rows in the SCCW, for most statistical analyses individuals with 15 or more rows in the SCCW were considered as with complete tail. The presence of nematode worm trails (King and Brazaitis 1971; Ashford and Muller 1978) and ectoparasites also was recorded.

Condition Indices

To establish the relative fatness of individuals, two condition indices (CI), were developed. The first one used the relationships between the weight (W, in g) and the linear measurements (TL, SVL, HL, and SL; in mm) of captured crocodiles. The second one used the relationship of the same linear attributes versus the tail girth (TG).

In the first case, the relationship between W (dependent variable) and any of these linear measurements (LM) has the form:

$$W = a \cdot LM^{b} \quad (6.1)$$

where a is a constant whose value depend on the units of measurements, b is an exponent usually close to 3, and LM represent the linear measurement under consideration. These equations are particular cases of the general allometry equation $y=ax^{b}$ (Le Cren 1951, Jolicoeur 1963; Gould 1966; Dodson 1975), where y and x represent the body dimension being compared. The values of the parameters a and b were estimated by PROC NLIN (SAS Institute, Inc. 1987). Advantages of using nonlinear models to estimate the parameters, instead of linear regression models with the log transformed data, were discussed by Wilkinson et al. (1997). The formulas of the first set of condition indices (CI1s) have the general form:

$$CI1 = a^{-1} \cdot W \cdot LM^{-b} \quad (6.2)$$

Only individuals with a complete tail and without mutilations or serious injuries, were used for the calculation of the constants a, and b. Similar condition indexes have been used in crocodilians (Taylor 1979; Hutton 1987) as measures of individual success under prevailing environmental conditions. The condition index employed here has the advantage of being centered in 1 (Le Cren 1951). Individuals with CI<1.0 are considered relatively lean, and individuals with CI>1.0 are relatively fat.

The relative condition of each crocodile was evaluated, and the means of CIs by site and by year were compared statistically. Several studies with crocodilians have shown that growth rate or the physical condition of the individuals deteriorate during the dry season or other environmental stress (Chabreck and Joanen 1979; Webb et al. 1983; Hutton 1987). That hypothesis was tested in this study.

The second condition index (CI2), involves the relationship of the tail girth (TG) versus the measured linear attributes of crocodiles. This relationship has the same form shown for (6.1); i.e.,

$$GL = a \cdot LM^{b} \qquad (6.3)$$

The parameters were calculated following an identical procedure. This index allows determination of the relative fatness of individuals without taking into account their weight. The weight of individuals with a severe mutilation (lack of a leg or most of the tail, for example) may not be appropriate to be used in an index of relative fatness. The equations of CI2s have the general form

$$CI2 = a^{-1} \cdot TG \cdot LM^{-b} \qquad (6.4)$$

CI2 was used to determine if the presence of injuries have an effect in the relative fatness of crocodiles.

Growth rate

Growth rate was determined based on the recapture of marked crocodiles. Because many individuals were missing the tips of their tails, growth rates were based on

SVL. Only growth data for recapture intervals of 60 days or longer were used. Capture-recapture data were fitted to the von Bertalanffy growth model:

(6.5) $$x = a(1-be^{-kt})$$

where x is the predicted size at time t. The parameter a represents the asymptotic size, i.e, the maximum size attainable by the species. The parameter k is an indication of the rate of proportional growth of the animal (Fabens 1965). The Fabens modification of the von Bertalanffy growth model (Fabens 1965; Chabreck and Joanen 1979; Rootes et al. 1991) is

(6.6) $$y = x + (a - x)(1-e^{-kt})$$

where y = SVL at recapture, x = SVL at first capture, and t = time lapse between initial capture and recapture. This new equation was used to estimate the parameters a and k by the least square methods using PROC NLIN (SAS Institute Inc. 1987).

Once a and k were known, the parameter b was calculated solving equation (6.5) at t=0, i.e., for the animal size at hatching ($x_{t=0}$). According to my own data, size at hatching is 140 mm in SVL and 280 mm in TL.

To allow comparisons with published (Ramo et al. 1992; Seijas 1993) or unpublished data for the species, I also calculated growth rate based on TL. The total length of individuals missing part of the tail was estimated from a regression model using individuals with complete tails.

Results

From 1992 to 1997, one hundred ninety-one (191) different Orinoco crocodiles, greater than 250 mm in SVL, were captured at least once in the Cojedes River system (Table 6-1). Most of the sample (83.8%) was from the sectors referred here as Caño de Agua Norte (40.3%) and Caño de Agua Sur-Cojedes (43.5%, Fig. 6-1). Most of the sample (75.9%) was composed of crocodiles from 300 to 600 mm SVL (Figure 6-2). For animals measuring 400 mm SVL or larger, the sample was biased toward females, but the difference were not statistically significant (X^2=1.944, P=0.105).

Table 6-1. Number of crocodiles (*Crocodylus intermedius*) captured in the different segments of the Cojedes river.

Place	1992-93	1996	1997	Total
Cojedes Norte	11	--	12	23
Caño de Agua Norte	1	35	41	77
Caño de Agua Sur-Cojedes	18	21	44	83
Sarare	3	--	--	3
Cojedes (Sucre)	-	2	1	3
Caño Culebra	--	2	--	2
Totals	33	60	98	191

Condition Indices

Nonlinear fitting analyses for different pair combinations of variables, indicated that some values of the allometric coefficient (b) departed from the figure that represents isometric growth, which is 1 when only linear variables are related, or 3 when the

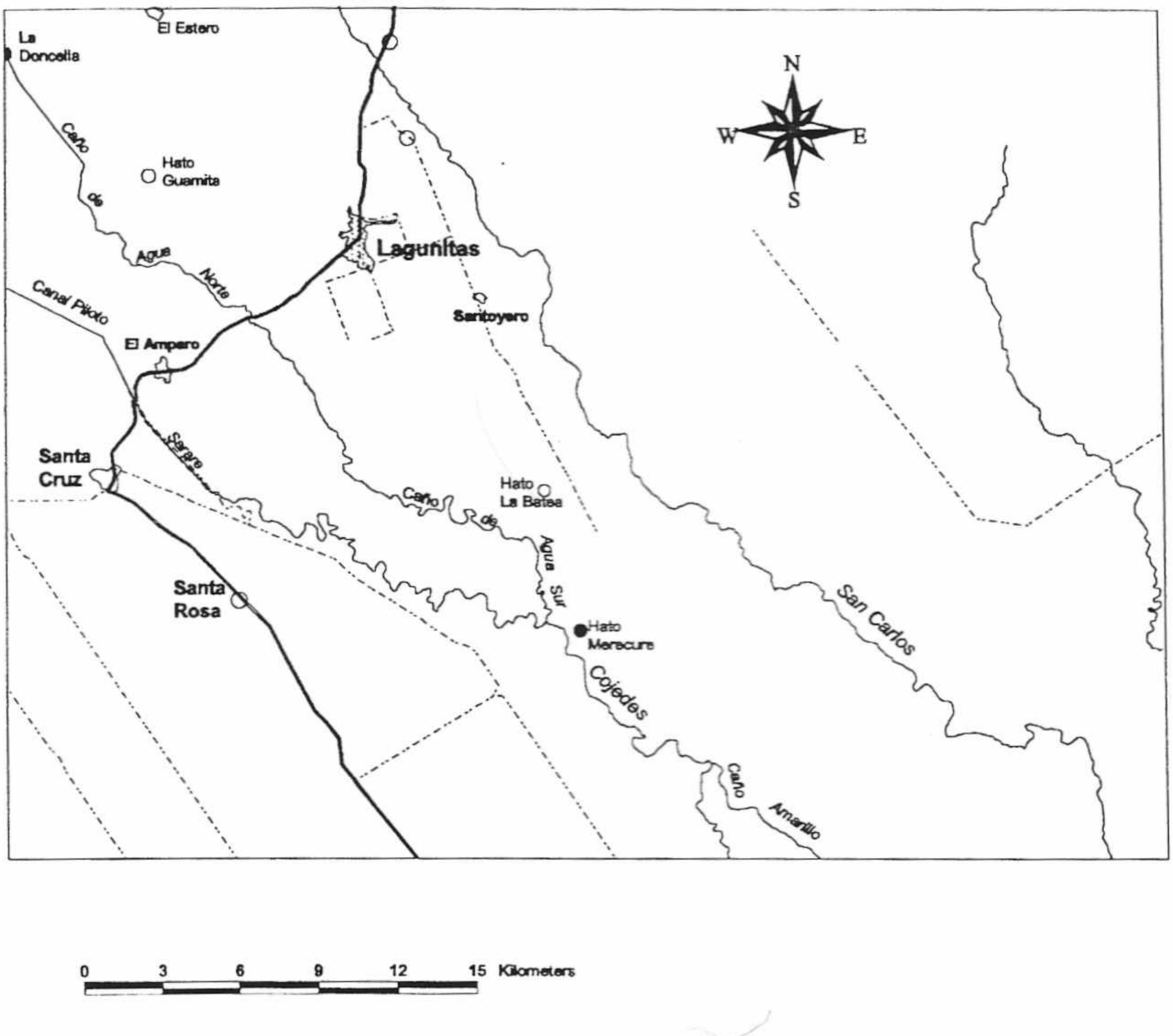


Figure 6-1. Detail of the study area in the Cojedes river system (Venezuela) showing the river sections where most of the animals were captured.

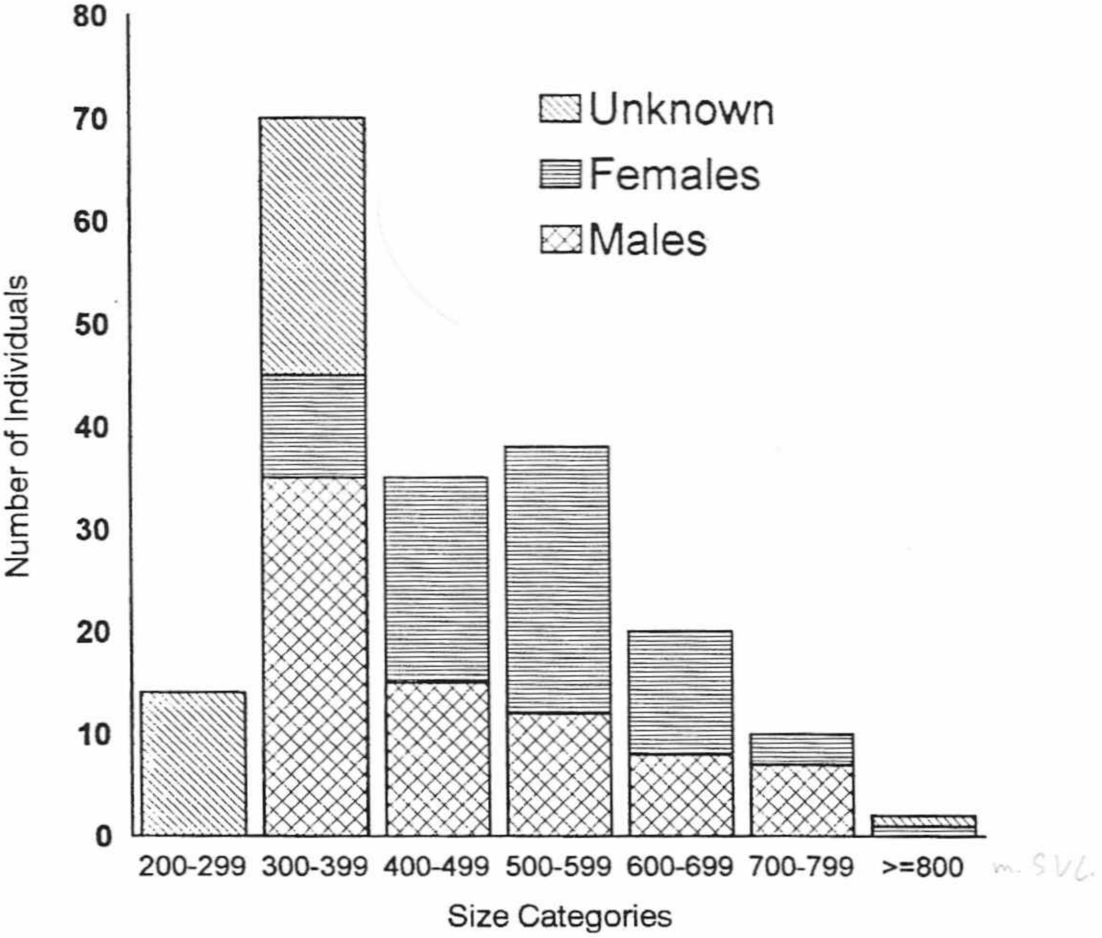


Figure 6-2. Sex and size distribution of Orinoco crocodiles captured in the Cojedes river system, Venezuela, from 1992 to 1997.

dependent variable is weight (Table 6-2). The coefficients a and b in Table 6-2 were used to generate the following CI1 equations:

$$CI1_{SVL} = 65175.9 \cdot W \cdot SVL^{-3.037} \quad (6.7)$$

$$CI1_{HL} = 6412.8 \cdot W \cdot HL^{-3.266} \quad (6.8)$$

$$CI1_{SL} = 441.3 \cdot W \cdot SL^{-2.982} \quad (6.9)$$

Table 6-2. Results of the non-linear fitting analysis. The 95% confidence interval of the parameter b are shown. Figures marked with an asterisk depart from the value expected if the relationship between the variables was isometric. X represents the independent variable and Y the dependent one.

Variables					95% Conf. Interval	
Y	X	N	a	b	Lower	Upper
W	SVL	114	$1.53 \cdot 10^{-5}$	3.037	2.954	3.119
W	HL	114	$1.56 \cdot 10^{-4}$	3.266*	3.152	3.379
W	SL	113	$2.27 \cdot 10^{-3}$	2.982	2.865	3.098
GL	SVL	60	$1.71 \cdot 10^{-1}$	1.141*	1.078	1.202
GL	HL	60	$4.51 \cdot 10^{-1}$	1.205*	1.125	1.285
GL	SL	59	1.527	1.048	0.974	1.123

As would be expected, these indices are correlated, with the highest correlation between $CI1_{HL}$ and $CI1_{SL}$ ($r=0.88$), and the lowest correlation between $CI1_{SVL}$ and $CI1_{SL}$ (0.75). A plot of the values of the CI1s versus the SVL is shown in Figure 6-3. Although any of the last three equations could be used to calculate the CIs, only the last one (6.9) was used in the analyses. It was preferred because among all body measurements, the relationship between W and SL is the closest to perfect isometry, as indicated by its coefficient b very close to 3. The meaning of an exponent equal to 3, is that the relative

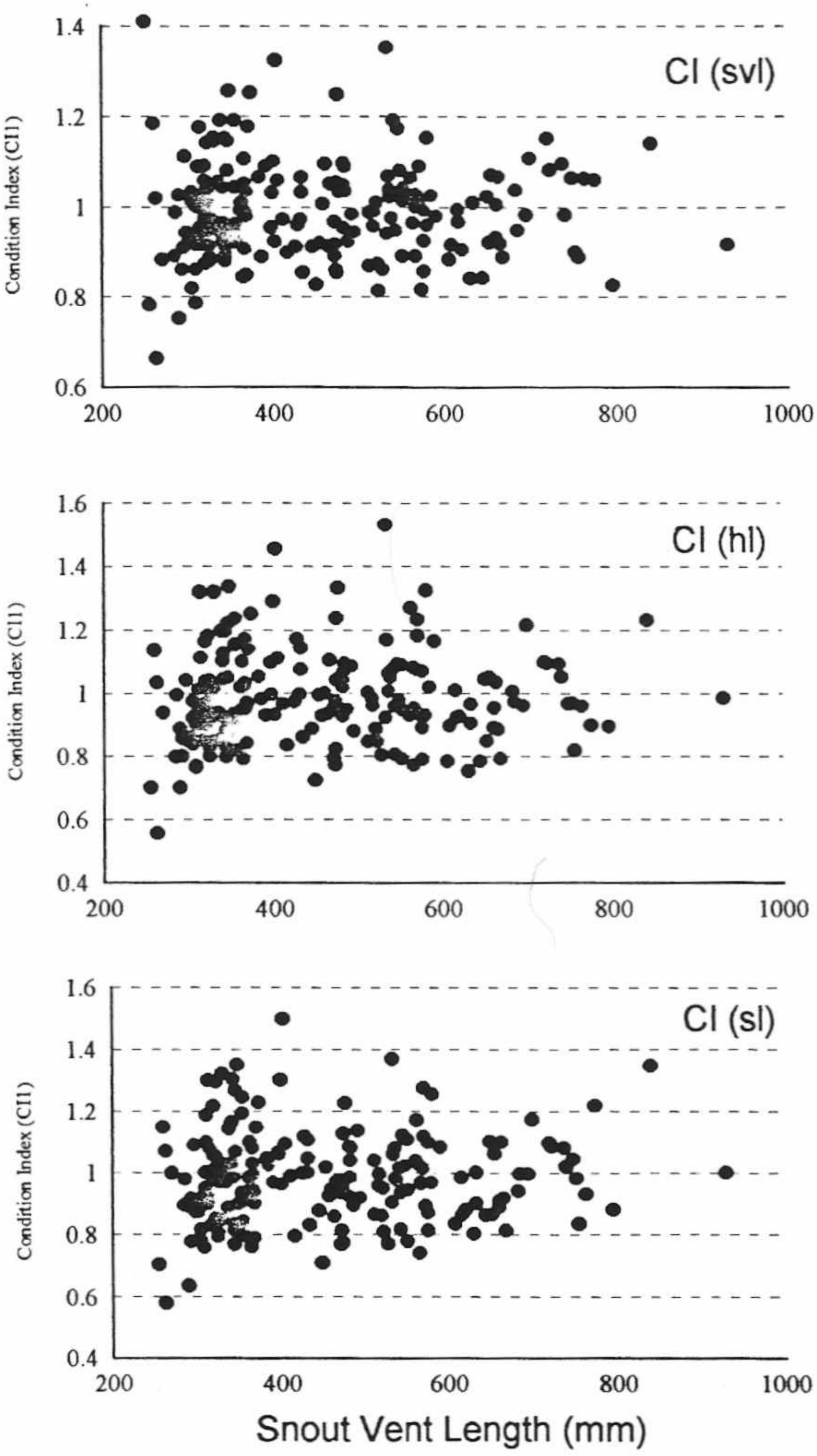


Figure 6-3. Scatter diagram of the Condition Indices versus the snout vent length (in mm) of Orinoco crocodiles from the Cojedes river system, Venezuela..

proportion of W and SL do not change as the individual grow. Under this conditions CI is truly independent of length (Le Cren 1951).

For the first set of analyses, only individuals without severe injuries were compared. The CIs of the individuals tend to decline as the dry season progress ($r=-0.411$, $P<0.0001$) (Fig. 6-4) . The impact of human activities became more apparent in the northern reaches of the CRS. Contamination due to urban, industrial and agricultural sources decreased from north to south (Chapter 3). Consequently, I expected the condition indices of crocodiles in the northern part of the study area to be relatively lower than the CI of crocodiles found downstream. I tested this hypothesis with an analysis of covariance, taking days into the dry season as the covariate. The outcome of the analysis, for animals captured in 1997, indicated that, in fact, there were differences in the CI of individuals from different river reaches. Unexpectedly, however, crocodiles from Cojedes Norte, the more eutrophicated and contaminated part of the study area (see Chapter 3) showed the highest CI (Table 6-3). Less stronger separation, but still highly significant, was obtained when using the entire sample that also included data for 1992, 1993 and 1996 ($F=11.128$, $P<0.0001$). There were no differences in the CI of the crocodiles related to sex (t-test, $P=0.64$, $n=121$).

Injuries and Parasites

Sixty-four crocodiles showed injuries (33.5%). Individuals with injuries were not evenly distributed among the different localities sampled. Most of the injured crocodiles (89.1%) were from Caño de Agua Sur or sections further downstream. Crocodiles from the northern section of the study area (Cojedes Norte and Caño de Agua Norte) showed a

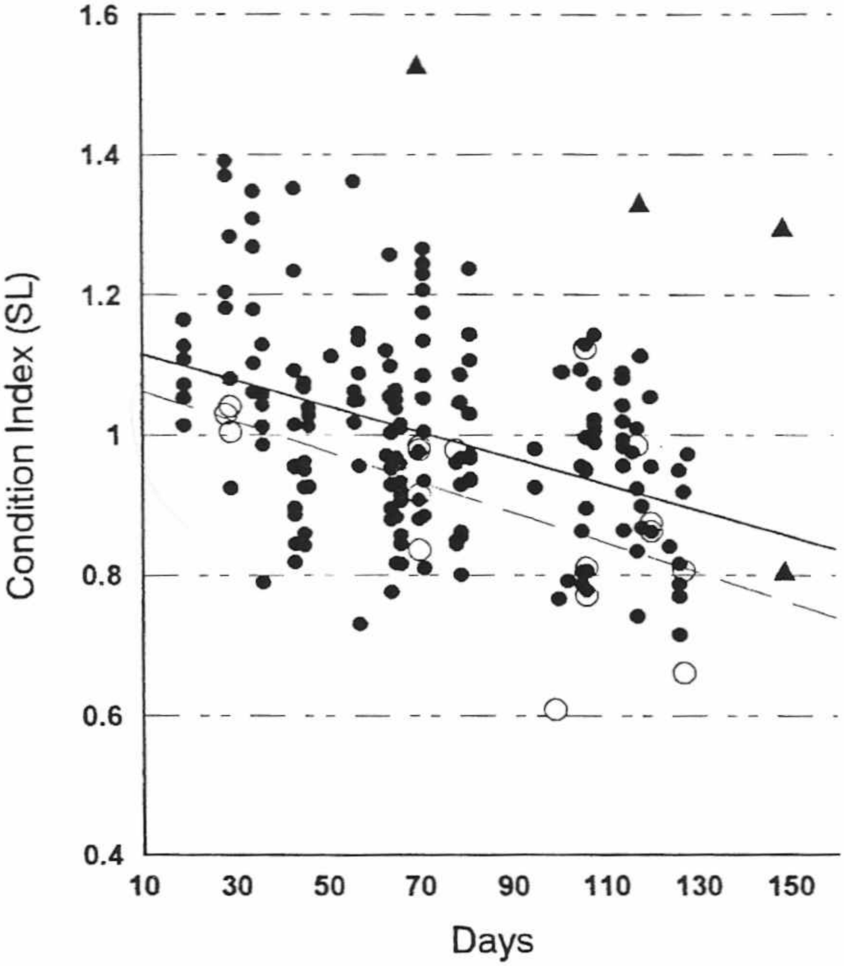


Figure 6-4. Variation with time of the Condition Index of Orinoco crocodiles from the Cojedes river system. 1 January was taken as day zero. Triangles identified outliers that were not used in the analyses. Circles represent individuals with injuries.

low frequency of injuries (only 3%), compared to crocodiles from Caño de Agua Sur and its downstream continuous river stretch (Merecure-Caño Amarillo) which showed 49.5% of individuals with injuries. These differences were highly significant ($X^2 = 55.2$, $P<0.0001$).

Table 6-3. Comparisons of condition indices (CI) for crocodiles from three river stretches in the Cojedes River system in 1997. The Least Squares Means (LSM) are estimators of the class marginal means (in this case, river stretches) that would be expected had the design been balanced (SAS Institute, Inc. 1987). LSM with the same grouping are not statistically different at the 0.05 alpha level.

		Least Squares		
River section	N	Means	Std Error	Grouping
Cojedes Norte	11	1.2506	0.0447	A
Caño de Agua Norte	37	0.9893	0.0217	B
Caño de Agua Sur- Caño Amarillo	26	0.9808	0.0253	B

The differences in injury rates among localities may be caused by the scarcity or absence of large predatory fishes in northern part of the river. In support of this hypothesis is the fact that in a sample of fish from Caño de Agua Norte, only 0.3% of them were represented by one species of piranha (*Serrasalmus irritans*). In a similar sample taken from Caño de Agua Sur-Cojedes, three species of piranhas (*Pygocentrus caribe*, S. *irritans* and *S. rhombeus* accounted for a 4% ($t=23.5$, $P<0.0001$). Another predatory fish, *Hoplias malabaricus,* was found to be relatively more abundant in Caño de Agua Sur (2.1%) than in Caño de Agua Norte (1.9%), although the differences were not statistically significant. Combining all these species, makes the proportion of predatory fishes in Caño de Agua Sur-Cojedes higher than in Caño de Agua Norte (X^2=11.43, *P*<0.001). This subject will be treated in more detail in Chapter 7.

Among the injured crocodiles, 14 (21.9%) were missing at least one extremity; three (4.7%) had broken or misaligned jaw; twenty (31.3%) had trunk scars, and 14 (21.9%) had missing toes. Some individuals had more than one type of injury. The most frequent injury, however, was the lack of a portion of the tail (70.5%). This fact is better appreciated when the number of rows in the single crested whorl (SCCW) are counted. The distribution of crocodiles according to the number of rows in SCCW is shown in Figure 6-5.

Three of the seven individuals captured, at night, with unhealed (bleeding) injuries were first observed, just before capture, out of the water. That number of individuals out of the water is higher than expected by chance (Fisher's Exact Test, *P*<0.0001) if we take into consideration that in data for 23 surveys that involve 687 crocodile sightings, only 1 was out of the water. The mean condition index of crocodiles with fresh injuries was 0.8801 ±0.1594, and several of them looked lean, according to the field notes. Since some of them had mutilation (which may have affected their weight), no statistical comparisons were made.

The percentage of individuals with injuries was 28.0% (7 of 25) among crocodiles more than 600 mm in SVL (Fig. 6-6). Among individuals less than 600 mm SVL, the percentage was 57.1% (40 of 75). These differences are significant (X^2=4.98, *P*=0.026).

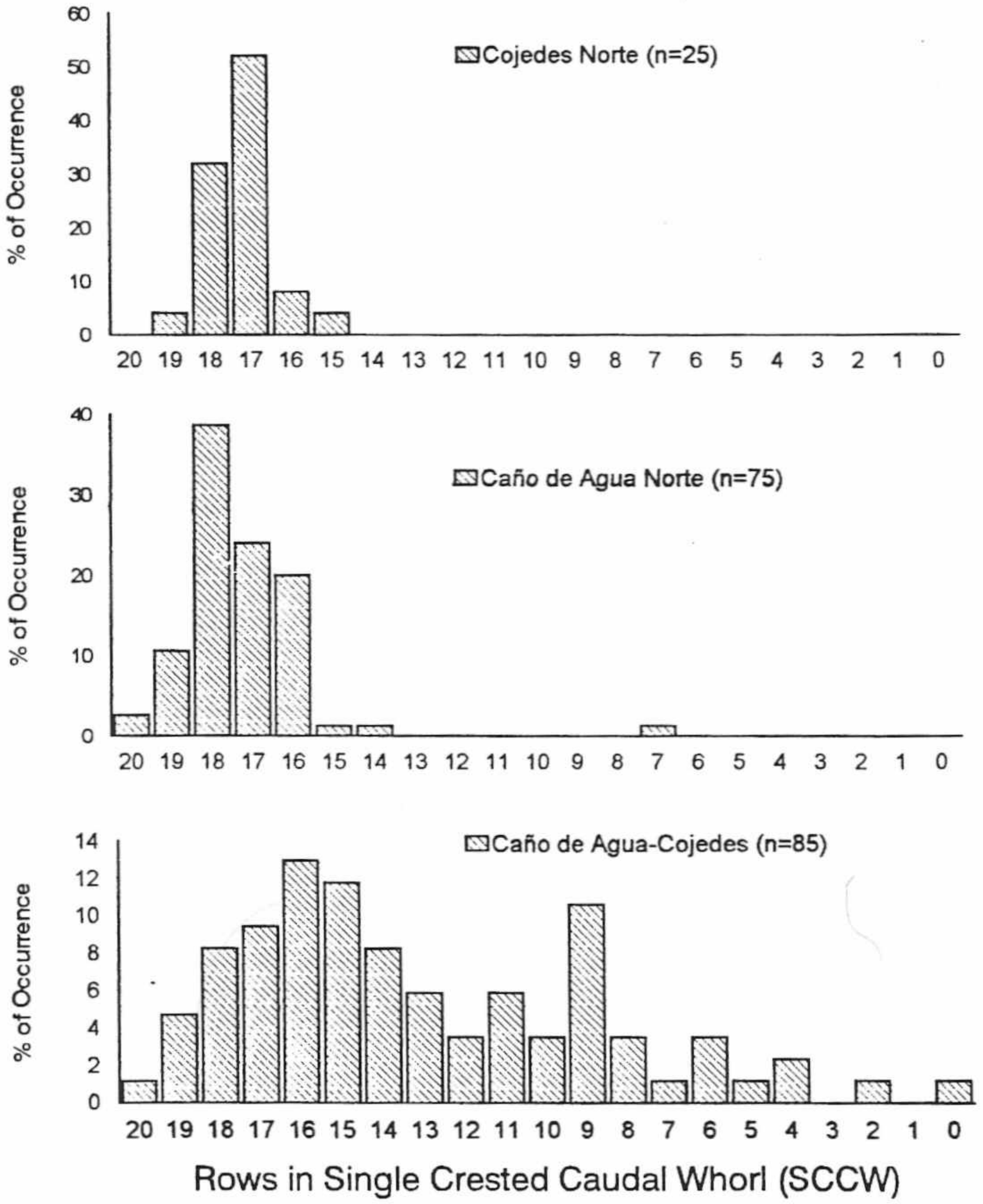


Figure 6-5. Distribution of crocodiles from the Cojedes river system according to the number rows in the Single Crested Whorl (SCCW).

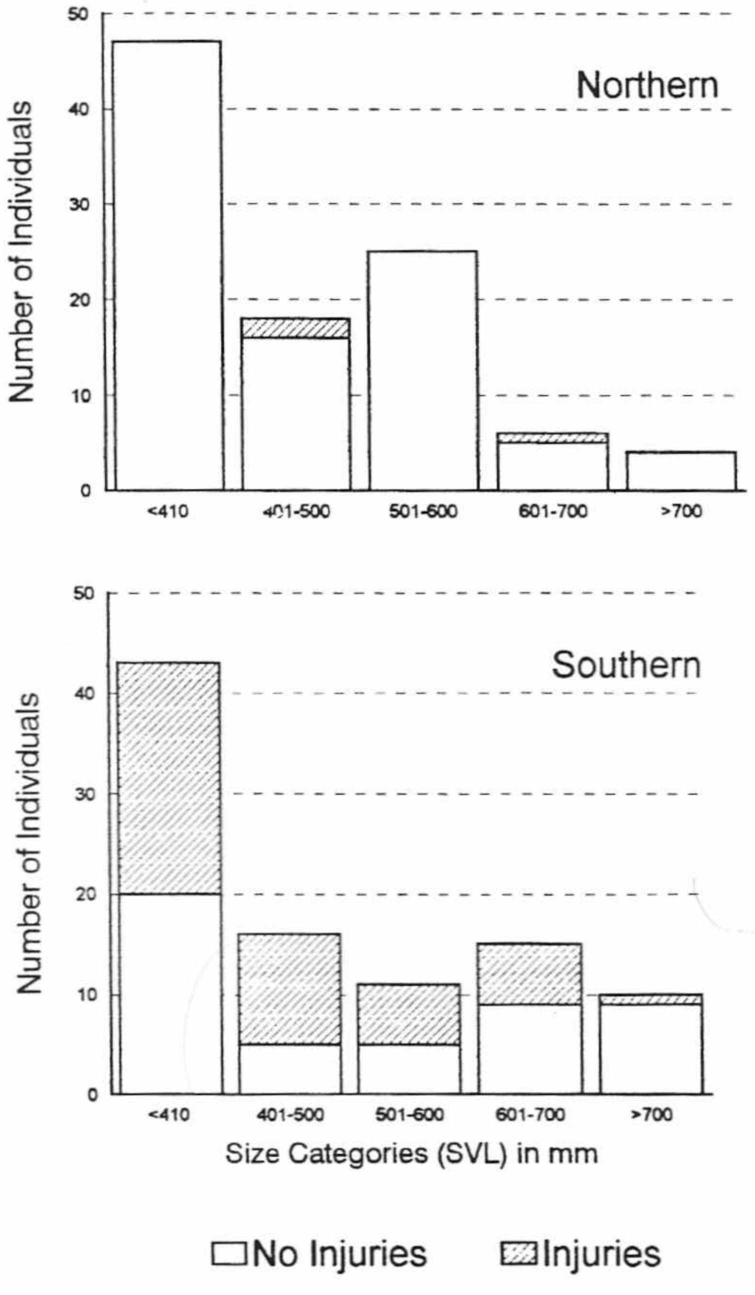


Figure 6-6. Frequency of crocodiles from the Cojedes river system with and without injuries. Northern locations include Cojedes Norte and Caño de Agua Norte. Southern locations include Caño de Agua Sur, Merecure-Caño Amarillo, Sucre, and La Culebra sections.

The tail girth (TG) was measured for 79 individuals. These data were used to generate the second condition index CI2 below:

(6.10) $CI2_{SVL} = 6.0437217 \cdot TG \cdot SVL^{-1.144819}$

(6.11) $CI2_{HL} = 2.4246205 \cdot TG \cdot HL^{-1.221890}$

(6.12) $CI2_{SL} = 0.7239825 \cdot TG \cdot SL^{-1.069892}$

Once again, the equation that involved snout length, was the one with the coefficient closest to 1, the value for perfect isometry for linear measurements.

Using CI2, I tested the hypothesis (Ho) that the presence of injuries did not affect the relative fatness of the crocodiles. That null hypothesis was accepted (t=0.023, *P*=0.982). No significant difference was found when only severely injured crocodiles (n=12) were compared with individuals without injuries (n=51) (t=0.012, *P*=0.99). In fact, the individual with the highest $CI2_{SL}$ had a severely mutilated tail, with only 4 single crested whorls. Unfortunately, seven animals with very severe mutilation were captured early during the study, before I had decided to take the measurement of the tail girth. Two of these animals were the leanest of the entire sample.

Only four crocodiles (2%) were observed with *Paratrichosoma* tracks on their ventral surface. All these crocodiles were above 500 mm SVL. The percentage for animals that size in the sample (74 individuals) was 5.4%. For animals more than 600 mm SVL, the percentage was higher: 8.8% (3 of 34). This percentage is lower than the 13.9% reported for *C. porosus* of comparable sizes (Webb and Messel 1977), and very low compared to the 82-100% for midsize and large *C. johnsoni* (Webb and Manolis 1983). The mean condition index of crocodiles with *Paratrichosoma* was 1.1292 (±0.0509), so, this nematode infestation did not appear to have a significant detrimental effect on the crocodiles in terms of their relative fatness.

Leeches were observed in nine crocodiles (4.5%), low infestation rate compared to the 9.7% reported for *C. porosus* (Webb and Manolis 1983) or the up to 100% for some crocodilians populations in the Amazon region (Magnusson 1985). No crocodile was observed with more than two leeches. Leeches were attached to the tongue (three cases) or the axillary region of the limbs. All the leech infestations were found in Caño de Agua Sur or downstream. Compared to localities upstream (Caño de Agua Norte and Cojedes Norte) those differences in infestation rates are highly significant (Fisher's Exact Test, P=0.0015). The other ectoparasite observed was ticks, in just three individuals.

Growth rate

Only 10 crocodiles were recaptured with a minimum interval between captures of 60 days. Nine of them were females. All these animals were from the Caño de Agua-Cojedes Section of the river. The elapsed time between captures ranged from 62 days to 1,475 days (a little more than four years)(Table 6-4).

Despite the small sample size, the data were fitted to the von Bertalanffy growth model. The resulting formula for predicting growth is the following:

$$X_{SVL} = 1.1360\ (1-0.8768e^{-0.1407t}) \tag{6.13}$$

where x (size) is expressed in m, and t (time) in years. This model explains 91.2% of the variation of the sample. The growth curve from hatchlings (0.14 m SVL) up to five years of age is shown in Figure 6-7.

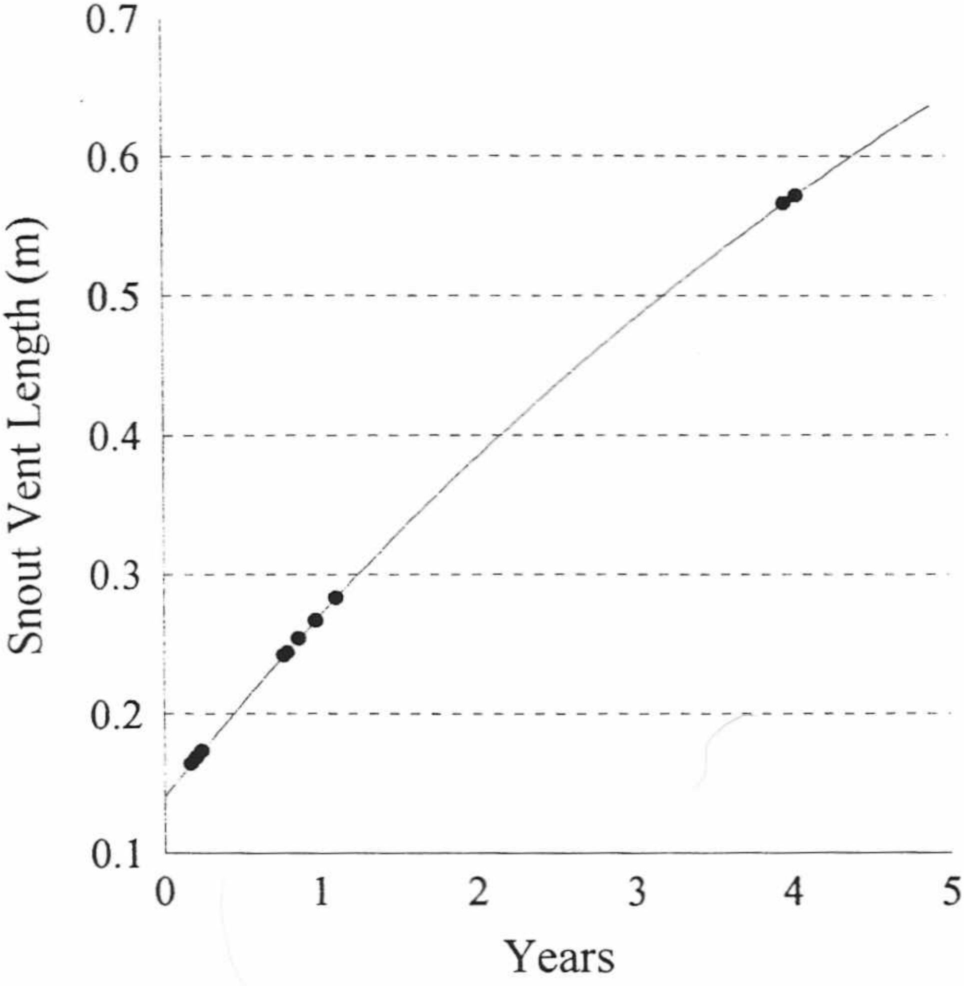


Figure 6-7. Growth curve based on captured-recaptured crocodiles from the Cojedes river system, Venezuela. Dots represent the animals in the data sample.

Table 6-4. Growth data for recaptured Orinoco crocodiles in the Cojedes River system, sections Caño de Agua Sur and Merecure-Caño Amarillo. Growth rates were calculated using the snout vent length (SVL). All but crocodile SNFS337 were females. Growth rate for the first three animals are entirely within the dry season.

Individual	Size (SVL in mm)		Elapsed time (days)	Growth rate (mm/month)
	Initial	Final		
E668/E669	565	572	62	3.45
E967/E968	335	344	74	3.72
E941/E949	720	723	87	1.05
234114/234115	471	579	280	11.74
234186/234187	470	542	287	7.75
SNFS304	675	737	314	6.00
SNFS381/IIB	366	532	355	14.20
SNFS337	353	390	403	2.79
C	343	652	1447	6.49
D	293	683	1475	8.04

To estimate the growth curve for total length, I calculated the TL (in mm) of captured and recaptured crocodiles using the regression equation:

(6.14) $TL = 44.844 + 1.81909\ SVL$

Only females with complete tails were used in the regression analysis to obtain equation 6.14 ($n=36$, $r^2=0.997$). The resulting growth model for TL was

(6.15) $X_{TL} = 2.1093\ (1-0.8673e^{-0.1406t})$

According to this growth model the expected total length of Orinoco crocodiles 1, 2 and 3 year of age from the CRS, were below the TL of captive reared crocodiles of this species the same age. They had also a lower growth rate than wild American crocodiles

(*Crocodylus acutus*), a very similar species in size at hatching and maximum total length (Brazaitis 1973)(Table 6-5).

Table 6-5. Expected total length of Orinoco crocodiles from the Cojedes River compared to TL of captive reared individuals of known age from the Universidad Nacional Experimental de los Llanos (UNELLEZ), and with expected total length of wild American crocodiles (pers. data).

	Cojedes River		UNELLEZ[1]		*C. acutus*[2]	
Age (Years)	TL (mm)	Growth rate (mm/month)	TL (mm)	Growth rate (mm/month)	TL (mm)	Growth rate (mm/month)
1	520	20.0	620	28.3	604	27.0
2	728	17.5	1111	40.9	846	20.2
3	910	15.0	1461	27.8	1028	15.2

[1] Ramo et al. 1992

[2] Personal unpublished data.

Discussion

There is no information on growth of wild Orinoco crocodiles to compare with the results of this study. A captive reared crocodile two years of age (84.5 cm TL) grew at a rate of 39.7 mm/months in its 16 months after released in El Frio Ranch, Apure state (Ayarzagüena 1984). Data from Lugo (1998) of 11 captive reared juveniles (680-1295 mm in TL), from 0.41 to 2.0 years after released into the wild in Caño Guaritico Wildlife Refuge, showed growth rates ranging from 23.2 to 53.7 mm/month. Three females released in Matiyure River (Apure state) at a total length ranging from 1144 to 1190 mm (Lugo 1998) grew at a rate ranging from 38.2 to 38.9 mm/month in the 3.7 years after release, although these animals may have been sporadically fed by tourists visiting the area

(Lugo 1998; John Thorbjarnarson pers. comm.). In any case, compared with these data, the estimated growth rate of crocodiles from the Cojedes River system seems to be low, and clearly well below its potential. The scarcity of data requires that these comparisons and conclusion be treated with care.

The Orinoco crocodiles in the CRS do not stop growing during the dry season, but the scarce data analyzed indicate that they grow very little during that period (Table 6-4). Fish kills are frequent toward the end of the dry season (see Chapter 3). The extent to which this phenomenon temporarily increases food availability (due to abundance of dead fish) or, in a longer term, decreases it, cannot be determined with the available data. A decrease in grow rate and, presumably loss of weight, has been observed during the dry season for other crocodilians species (Gorzula 1978; Webb et al. 1983) indicating that it is a more general phenomenon in which other factors (behavior, genetics) may be involved.

Unfortunately too few growth data were obtained, and all of them from the same river section. So, it was impossible to make comparisons between localities with different degrees of human impact.

Several factors have been mentioned to explain the seasonal changes in relative fatness (or in growth rates) of crocodilians under natural conditions. Because growth is a balance between energy intake minus expenditures and metabolic cost, any decrease in food availability or increase in cost could retard grow (Jacobsen and Kushlan 1989) or even produce a reduction in weight. It has been shown that in areas with a high fluctuation of temperatures between seasons, crocodilians stop growing (or grow at a very low rate) during the cool season and loose weight (Coulson and Hernández 1973; Chabreck and Joanen 1979; Hutton 1987).

Variation in temperatures between seasons is very slight in the Venezuelan llanos (generally less than 5°C). The mean temperature of the coolest month in the study area is 25.7. Although in most of the country the coolest months are December and January; however, in the Llanos region the coolest months are generally July and September, due to the high precipitation (MARNR 1995). The hottest months, on the other hand, are generally March and April. Consequently, variation in temperature does not seem to be a factor that explains the decrease in the relative fatness of Orinoco crocodiles in the CRS, particularly when CIs are the lowest during the hottest months.

Reduction of food availability is the other factor that could explain the decline in relative condition of crocodiles. However, fine-meshed seine sampling (see Chapter 7) indicated that at least in some part of the river a diverse, and supposedly abundant, prey population is present during the advanced dry season. Analysis of stomach contents (see Chapter 7) also showed that juvenile crocodiles did not stop eating during the dry season. Data on relative fish abundance or food consumption during the wet season are lacking, which precludes making conclusions in this regard.

Contrary to expectations, the crocodiles with the highest CIs (the fattest) were found in the northernmost part of the study area (Cojedes Norte). Which was the most contaminated and euthrophic river reach (see Chapter 3). In that river section oxygen content in the water was usually very low, rarely above 4.2 mg/l. Under this condition very low fish diversity or abundance is expected. Crocodiles in that part of the river may rely mostly on terrestrial prey. Iguanas, frogs, and particularly shorebirds, are relatively abundant in this part of the river (pers. observ.). Differences in temperature between northern and souther river sections may partially explain the differences in crocodile condition index. As was shown in Chapter 3, water temperature in Cojedes Norte were 2-4 °C lower than water temperature in souther sections. Consequently, crocodiles living in Cojedes Norte, could have a lower metabolic cost and allocate more energy in body tissue, as has been suggested for alligators (Brandt 1991). Future studies have to be undertaken to determine if the observed high CIs of crocodiles in this part of the river is a permanent phenomenon.

The presence of injuries did not seem to impair the ability of crocodiles to gather food. However, gravely injured crocodiles are unlikely to be captured, because frequently they die and disappear from the population. Juvenile crocodiles with fresh injuries tend to remain in very shallow waters or even outside the water, presumably to escape molestation from predatory fishes while healing. The ingestion of food should decrease during that period and they may be more exposed to terrestrial predators.

The higher proportion of injured crocodiles in the southern parts of the study area could be explained by a higher density of predatory fishes, particularly large piranhas (*Pygocentrus caribe*)(Chapter 7). An alternative explanation could be that injuries results from intra-and interspecific (with spectacled caiman) interactions. Several studies have shown that the frequency of injuries is greatest in crocodilians that concentrate in high densities (Staton and Dixon 1975; Webb and Manolis 1983). The density of crocodiles, and particularly of caiman, was higher in Caño de Agua Sur-Caño Amarillo (Chapter 4), the river reaches with the highest proportion of injured animals. But caiman were only found temporarily in the river and their distribution was clumped in river sections close to temporary lagoons or borrow pits (personal observations). Although negative intraspecific interactions may occur among coexisting crocodilians (Webb et al. 1983; Magnusson 1985; Seijas 1996) they may be rare events in a river where every crocodile is generally separated by more than a 100 from its nearest neighbor (crocodile or caiman). On the other hand, the nature of most of the injuries (missing toes, mutilation of the tip of the tail, round scars less than 2 cm in diameter) suggest that they were the results of relatively smaller predators. On the other hand, the high proportion of small individuals with injuries indicates that they are obtained at an early age, presumably in their first year, when they are probably more vulnerable to small predators.

The rate at which crocodiles were infected with parasites does not seem to be high compared to that reported for other crocodilians species (Cott 1961; Smith et al. 1976; Webb and Messel 1977; Webb and Manolis 1983; Magnusson 1985). Nematodes parasites are frequently found in the stomach of crocodiles (Chapter 7) but their effect on the general health of the species is unknown.

In summary, juveniles Orinoco crocodiles seem to grow relatively slow in the CRS compared to captive crocodiles and to captive-reared animals after they have been released into the wild. Crocodiles from moderate to highly eutrohphicated areas showed a lower rate of injuries and a higher condition indices than individuals from less euthrophicated sections of the river. To what extent these facts have contributed to produce the current pattern of distribution and abundance of the species in the CRS, needs to be more carefully investigated.

CHAPTER 7
JUVENILE CROCODILE DIET AND RESOURCE AVAILABILITY

Introduction

As has occurred in many places around the world, changes in land use, irrigation practices, urban use by an ever increasing human population and by industrial plants, have altered the quantity and quality of the water in many of the Venezuelan rivers (Winemiller et al. 1996). The Cojedes River System (CRS) is a clear example of that situation. The headwaters of the CRS are highly polluted due to the discharges of untreated wastewater from important industrial and urban centers in the north (Mogollon et al. 1987; Campo and Rodríguez 1995). Although the river continues to receive discharges from smaller urban centers and from agricultural lands as it flows toward the Portuguesa River, there is a general pattern of improvement in many parameters of water quality downstream (see Chapter 3).

Many studies have shown that crocodilians are opportunistic predators with an ontogenetic change in their diet (Cott 1961; Seijas and Ramos 1980; Ayarzagüena 1983; Taylor 1979; Webb et al. 1982; Seijas 1996). Consequently, differences in the diet among populations of the same crocodilian species inhabiting different localities, might reflect differences in prey availability. The direct or indirect impact that habitat deterioration might have had on crocodiles or on its food resources has not been evaluated. In this chapter, the diets of juvenile Orinoco crocodiles from river sections with contrasting degree of human impact are analyzed and compared. A partial evaluation of resource availability and of the biological integrity of the river (*sensu* Karr 1981) is carried out using data from fish sampling. The influences that changes in resource availability may have on the general well-being of the crocodiles are discussed.

Description of Collecting Sites

Although some crocodile stomach contents were collected in Cojedes Norte, most of the study was conducted in Caño de Agua Norte and Caño de Agua Sur-Merecure (Fig. 7-1). Caño de Agua Norte is a narrow (8-12 m) segment of the CRS that has been dredged and channelized and its margins have been deforested over the last 20-30 years. Grasses and bushes cover the banks of the river down to the water's edge. Part of Caño de Agua Norte has recovered its meandering condition. During the rainy season of 1996, the downstream end of it diverted into several smaller branches that drain toward Caño Camoruco.

Caño de Agua Sur is also very narrow (in general less than 12 m wide) and it is the most meandering segment of the entire study area. Most of the banks are forested and grasses are less abundant than in Caño de Agua Norte and do not usually reach the water's edge. Scattered bunches of logs and branches of fallen trees are found along the river. Dense clumps of the riparian shrub (*Coccoloba obtusifolia*) are also found frequently along the river's edge.

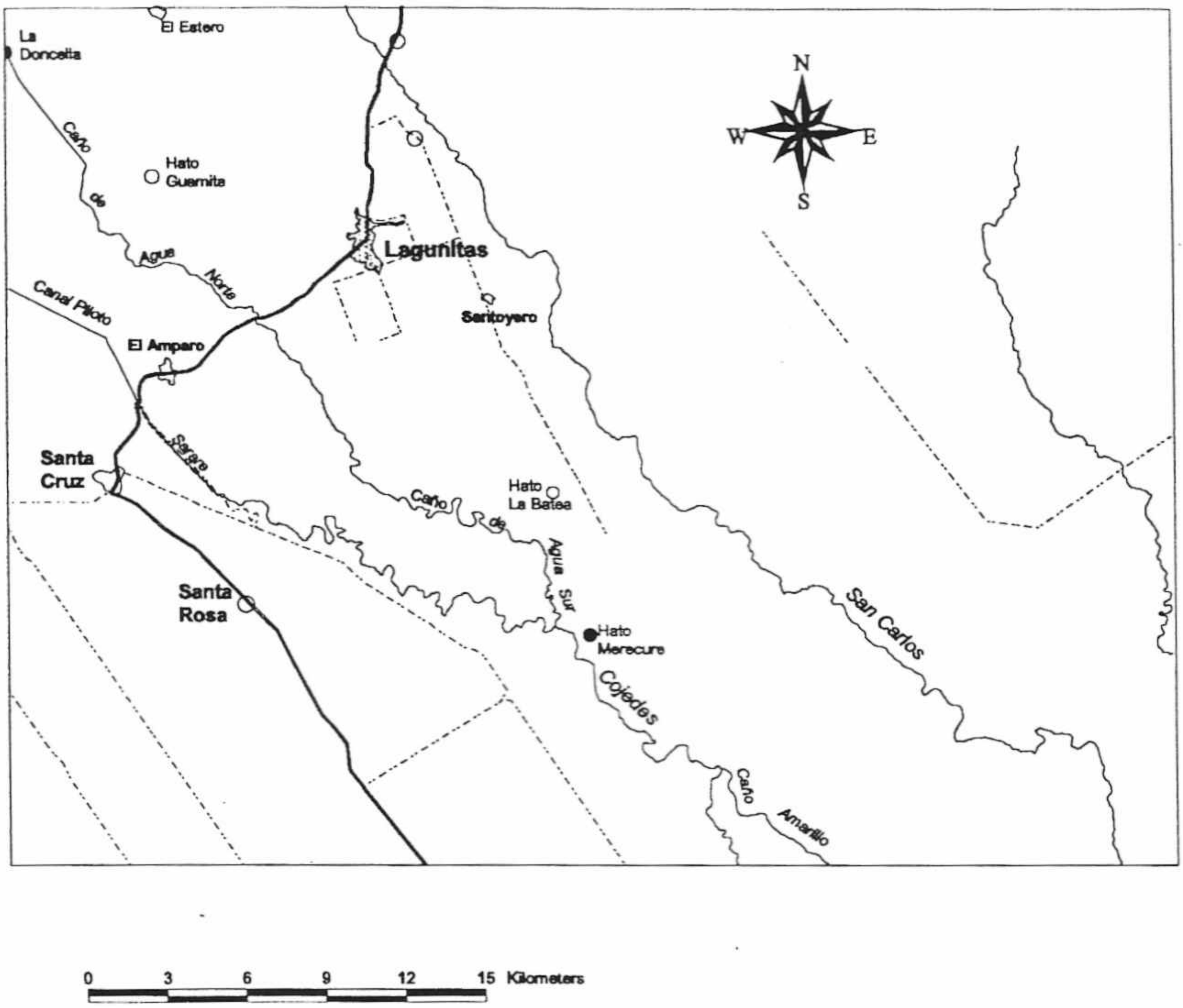


Figure 7-1. Detail of the study area in the Cojedes river system (Venezuela) showing the river sections where most of the crocodile's stomach contents were collected.

Because Caño de Agua Norte is closer to the heavily contaminated headwaters of the CRS and to the small towns of Apartaderos, Cojeditos and Retajao, it is expected to be more polluted and more eutrophic than Caño de Agua Sur-Merecure. On the other hand, Caño de Agua Norte has been affected by other man-induced alterations such as channelization and deforestation.

Methods

Juvenile crocodiles (less than 800 mm in TL) were captured at night or before dawn (from 0300 to 0600 h), and taken to a camp site to proceed with the collection of their stomach contents. Stomach contents were obtained by stomach pumping (Fitzgerald 1988). Most samples were collected within 1 to 3 hours after capture, but some were collected up to 12 hours after capture. After removal of their stomach contents, crocodiles were released where they had been captured. Stomach contents of sympatric spectacled caiman (*Caiman crocodilus*) were also obtained for comparison.

Stomach contents were preserved in ethyl alcohol for later analysis. In the lab, prey items were separated and identified to the lowest taxonomic category possible. They were lightly squeezed and patted on absorbent paper prior to the determination of volume, in milliliters, by water displacement. The number of whole prey items in stomachs was estimated from fragments. For the analyses, prey items were classified into broad categories as follow: aquatic insects, terrestrial insects, spiders, crabs, fish, and terrestrial vertebrates. The presence and number of nematodes and gastroliths was also recorded.

To partially evaluate the availability of food resources and the relative biotic integrity of the river, eight sampling efforts (five diurnal and 3 nocturnal), both in Caño de Agua Norte and Caño de Agua Sur, were carried out with 5 mm-meshed seines. One of the two seines (10 m and 30 m in length) was used depending on the characteristics of the river reach being sampled. Sampling sites were selected to cover as many microhabitats as possibly. Seines were swept downstream through the water keeping the lead line as close as possible to the bottom and dragging it onto a smooth beach. Organisms collected in each sampling effort were preserved in formaldehyde (10%) and taken to the lab to be identified, measured and weighed. The fishing effort in these two sites were assumed to be the same, so, the species abundance and composition, and fish biomass were compared. To determine if there were differences in the relative frequency of occurrence of species between the two river reaches, a Spearman Rank Correlation test was used. Total number of species, relative importance of species per trophic level, and relative abundance of predatory fishes were used as criteria to assess the relative biotic integrity (Karr 1981; Rivera and Marrero 1995; Rodríguez-Olarte and Taphorn 1995) of these two river reaches.

Results

Diet

Sixty-seven stomach contents were collected. Seven of them were taken at irregular intervals from 1992 to 1993. The remaining sixty were sampled in February and March 1997. This last sample was split evenly between Caño de Agua Norte and Caño de

Agua Sur (Table 7-1). Due to their larger sample size, most analyses refer to the comparisons between the last two places.

Table 7-1. Number of stomach contents of Orinoco crocodiles from the Cojedes River system collected and analyzed. The size range of the crocodiles from which they were collected is indicated.

Place	Year	No. Stomach Contents	Size Range (mm SVL)
Cojedes Norte	1993	4	260-572
Caño de Agua Norte	1997	30	540-1356
Caño de Agua Sur	1992	3	315-366
	1997	30	543-1224
Totals		67	260-1356

Overall, in terms of biomass, vertebrates (both aquatic and terrestrials) represented a high proportion of the diet of the juvenile crocodiles with 78.1% in Caño de Agua Norte and 76.9% in Caño de Agua Sur. Terrestrial vertebrates were represented mostly by Cricetidae rodents (remains found in 24 stomach contents), but Leptodactylidae frogs, a bird and a snake (*Leptodeira annulata*) were also found.

Terrestrial vertebrates represented a higher volume and were more frequently found in the stomach contents from Caño de Agua Norte. The differences between Caño de Agua Norte and Caño de Agua Sur could be considered biologically significant (X^2=3.3, P= 0.069). Terrestrial vertebrates accounted for 76% of the volume of the sample from Caño de Agua Norte but only for 26.6% of the sample from Caño de Agua Sur.

By volume, fish was the most important item in the stomach contents from Caño de Agua Sur (50.3%), but they accounted for only 2.1% of the volume in Caño de Agua Norte. However, the difference in frequency of fish between the samples of these two localities is not statistically significant (X^2=0.417, *P*= 0.519).

Aquatic insects, including Belostomatidae, and Hydrophilidae and Dytiscidae beetles, were more important as prey in Caño de Agua Norte than in Caño de Agua Sur both in terms of frequency encountered (X^2=17.78, *P*<0.001) and volume (Table 7-2).

Terrestrial insect included Carabidae and Scarabaeidae beetles, grasshoppers, moths and a wasp. By number terrestrial insects were relatively more important in Caño de Agua Norte than in Caño de Agua Sur, but the differences were not statistically significant.

Another important prey item found in similar frequencies and numbers in both places was the crab *Poppiana dentata*. Shrimp (*Macrobrachium sp.*) were not found in any of the stomach contents analyzed in 1997. But this item was the most important one (16 individuals) in the three stomach contents from Caño de Agua Sur analyzed in 1992.

The four stomach contents from Cojedes Norte taken in 1993, showed a scarcity of prey items (mostly insects) and remains of a catfish (Doradidae). Five stomach contents of spectacled caiman from the same locality were also almost empty, although fish scales and remains of aquatic insects were detected.

The frequency of appearance and the volume of gastroliths differed significantly between localities. Twenty-three stomachs (80.7%) in Caño de Agua Norte had

Table 7-2. Relative importance of major prey groups found in the stomach contents of Orinoco crocodiles from the Cojedes River System, Venezuela. Non-identifiable material was not used in the analysis.

ITEMS	Size Range (TL mm)	Frequency #	Frequency %	Items #	Items %	Volume (ml) Total	Volume (ml) %
CAÑO DE AGUA NORTE							
Poppiana dentata (crab)	651-898	4	13.3	5	5.3	14.3	6.5
Fish	540-1049	5	16.7	6	6.3	4.7	2.1
Aquatic Insects**	574-1356	26	86.7	33	34.7	21.5	9.8
Terrest. insects	565-1062	20	66.7	24	25.3	8.5	3.9
Spiders	624-1083	4	13.3	5	5.3	3.6	1.6
Thiara sp (snail)	700-920	2	6.7	4	4.2	0.1	<0.1
Terrest. vertebr.*	565-1356	17	56.7	18	18.9	167.0	76.0
Non-identifiable	-	-	-	-	-	22.4	
Total				95		219.7	
CAÑO DE AGUA SUR							
Poppiana dentata	570-1224	8	26.7	8	8.6	15.0	11.8
Fish	543-1207	7	23.3	8	8.6	63.7	50.3
Aquatic Insects	544-1001	10	33.3	12	12.9	6.0	4.7
Terrest. insects	543-1001	15	50.0	44	47.3	7.4	5.8
Spiders	684-1224	2	6.7	2	2.2	0.1	<0.1
Thiara sp	830-1165	2	6.7	9	9.7	0.9	0.7
Terrest. vertebr.	543-1195	10	33.3	10	10.8	33.6	26.6
Non-identifiable	-	-	-	-	-	21.8	
Total				93		126.7	

* Difference with Caño de Agua Sur close to significancy at the 0.05 alpha level (X^2=3.3, P=0.069)

** Difference with Caño de Agua Sur highly significant (X^2=17.8, P<0.001) gastroliths, compared to only 8 (13.9%) in Caño de Agua Sur (X^2=15.02, P<0.001). A small number of shells of the snail *Thiara* were also occasionally found.

A small piece of fabric was found in a stomach from Caño Cojedes Sur and a piece of plastic from another from Caño Cojedes Norte. Remains of a plastic glove were found in one of the stomach contents from Cojedes Norte.

Another non-prey item that should be considered are nematodes. They were much more abundant and frequent in the stomach contents from Caño de Agua Sur than in those from Caño de Agua Norte (X^2=8.3, P< 0.01).

Biotic Integrity and Food Availability

Twenty five fish species were collected in Caño de Agua Norte (Table 7-3). In terms of number the most important species were *Ctenobrycon spilurus*, *Steinchnacderina argenteus*, and *Bryconamericus spp.*, which as a whole represented 52.9% of the sample. The first two species were considered by Rodríguez-Olarte and Taphorn (1995) to be highly tolerant of habitat modification. The largest of these three fish species is *S. argentea*, which rarely exceeds 90 mm SL (Taphorn 1992) and average less than 7 g. Fourteen species in Caño de Agua Norte represented less than 1% of the sample each.

In terms of biomass, *Prochilodus mariae* was, by far (43.0%), the most important species. This species is considered as tolerant to habitat modification by Rodríguez-Olarte and Taphorn (1995). By weight, the other important species were *Markiana geayi* (13.2%), *Hoplias malabaricus* (12.4%), and *Steinchnacderina argentea* (11.2). While *Hoplias* is a carnivorous fish, the other species in this group depend upon small organisms

Table 7-3. Relative importance (by number and weight) of fish and other organisms collected in 1997 in two sections of Caño de Agua, Cojedes state, Venezuela.

	Caño de Agua Norte				Caño de Agua Sur			
Species	#Ind.	%	Weight	%	#Ind	%	Weight	%
Fish								
SILURIFORMES								
Auchenipteridae								
Auchenipterus galeatus	-	-	-	-	1	0.3	58	1.6
Asprendinidae								
Bunocephalus amaurus	6	0.7	21	0.3	1	0.3	2	<0.1
Pimelodidae								
Pimelodella sp1	8	0.9	13	0.2	62	19.0	335	9.1
Pimelodella sp2	1	0.1	7	0.1	-	-	-	-
Pimelodus blochii	-	-	-	-	1	0.3	14	0.4
Rhamdia sp	-	-	-	-	4	1.2	257	7.0
Pseudoplatystoma tigrinum	-	-	-	-	2	0.6	665	18.0
Ageneiosidae								
Ageneiosus vittatus	1	0.1	110	1.4	1	0.3	89	2.4
Callichthyidae								
Corydoras aeneus	1	0.1	2	<0.1	-	-	-	-
Loricariidae								
Loricaria sp	1	0.1	2	<0.1	4	1.2	60	1.6
Rineloricaria sp	-	-	-	-	5	1.5	38	1.0
Otocinclus sp	-	-	-	-	2	0.6	9	0.2
Hypostomus sp	1	0.1	23	0.3	-	-	-	-
Sturisoma sp	1	0.1	3	<0.1	-	-	-	-
CHARACIFORMES								
Characidae								
Aphyocharax alburnus	50	5.8	46	0.6	23	7.1	15	0.4
Astyanax bimaculatus	77	9.0	365	4.7	1	0.3	5	0.1
Astyanax integer	1	0.1	1	<0.1	-	-	-	-
Bryconamericus spp	105	12.2	74	1.0	16	4.9	6	0.2
Charax gibbosus	-	-	-	-	1	0.3	1	<0.1
Cheirodon sp	46	5.4	12	0.2	4	1.2	2	0.1
Ctenobrycon spilurus	218	25.4	387	5.0	1	0.3	1	0.1

Table 7-3. (Continued)

	Caño de Agua Norte				Caño de Agua Sur			
Species	#Ind.	%	Weight	%	#Ind	%	Weight	%
Characidae (continued)								
Markiana geayi	47	5.5	1023	13.2	11	3.4	220	6.0
Moenkhausia lepidura	-	-	-	-	8	2.5	7	0.2
Paragoniates alburnus	-	-	-	-	3	0.9	14	0.4
Pygocentrus caribe	-	-	-	-	5	1.5	237	6.4
Roeboides dayi	69	8.0	89	1.1	21	6.4	109	2.9
Serrasalmus irritans	3	0.3	56	0.7	5	1.5	67	1.8
Serrasalmus rhombeus	-	-	-	-	3	0.9	189	5.1
Tetragonopterus argenteus	-	-	-	-	4	1.2	48	1.3
Triportheus sp "coli roja"	-	-	-	-	36	11.0	807	21.9
Xenagoniates bondi	3	0.3	4	0.1	14	4.3	16	0.4
Erythrinidae								
Hoplias malabaricus	16	1.9	961	12.4	7	2.1	196	5.3
Gasteropelecidae								
Thoracocharax stellatus	24	2.8	37	0.5	72	22.1	60	1.6
Prochilodontidae								
Prochilodus mariae	40	4.7	3341	43.0	1	0.3	32	0.9
Curimatidae								
Steindachnerina argentea	131	15.3	869	11.2	5	1.5	27	0.7
Curimata cerasina	2	0.2	96	1.2	2	0.6	110	3.0
PERCIFORMES								
Cichlidae								
Aequidens pulcher	4	0.5	34	0.4	-	-	-	-
Caquetaia kraussii	3	0.3	188	2.4	-	-	-	-
Totals	859		7,764		326		3,692	
CRUSTACEA								
Machrobrachium sp. (Shrimp)	45		52		8		9	
Poppiana dentata (Crab)	7		153		-		-	

such as protozoans or bacteria from mud or detritus (*Prochilodus* and *Steindachnerina*) or are omnivores (seeds, small insects, aquatic vegetation) as in the case of *Markiana* (Taphorn 1992).

Thirty-one species were found in the sample from Caño de Agua Sur (Table 7-3). The most abundant were *Thoracocharax stellatus* (22.1%) and *Pimelodella* sp1 (19%). In relative terms, these species are considered less tolerant to habitat modification than the dominant ones in Caño de Agua Norte (Rodríguez-Olarte and Taphorn 1995). The third most important species in Caño de Agua Sur was *Triportheus sp.* (11.0%), a relatively large fish that can reach up to 200 mm SL (Taphorn 1992). This species is the least tolerant to habitat modification among the fish species sampled (Rodríguez-Olarte and Taphorn 1995).

Triportheus was also the most important species in terms of biomass (21.9%), followed by the catfishes *Pseudoplatystoma tigrinum* (18.0%), *Pimelodella sp.* (9.1%), and *Rhamdia* sp. (7.0%). The catfishes (Pimelodelidae) as a whole, accounted for 34.5% of the sample's biomass. *Triportheus* is an omnivore that feed on seeds and on terrestrial and aquatic insects (Taphorn 1992). The Relatively large carnivorous fish such as *Hoplias* and the piranhas (genus *Serrasalmus* and *Pygocentrus*) together accounted for 18.6% of the sample's biomass.

A Spearman Rank Correlation test shows that there was no relation between the relative order of importance of fish species of the two samples ($r_s = 0.1827$, $P=0.272$). For this test those species that do not represent more than 1% of any of the samples (rare species) were excluded. The diversity of fish in Caño de Agua Sur (S=31, Shannon-

Weaver Index = 2.62) was higher than in Caño de Agua Norte (S=25, Shannon-Weaver Index = 2.34). The coefficient of similarity of Jaccard ($0 \leq S_j \leq 1$)(Hendricks et al. 1980) between the two localities was S_j=0.47, which indicates the two fish communities are quite distinct.

Samples of fishing efforts were added successively from the one with the less number of individuals to the one with the largest number of individuals. The relationship between the cumulative number of species versus the cumulative number of individuals in the samples is shown in Figure 7-2. In Caño de Agua Norte the curve was approaching a plateau, whereas in Caño de Agua Sur the curve was steeper without signs of approaching a plateau. In fact, there were at least two species know to occur in this last locality that did not appear in the sample. They were the Characidae *Leporinus sp*. and *Mylossoma duriventris*.

Other species that were caught in the fishing nets were shrimps (*Macrobrachium*) and crabs (*Poppiana*). Crabs, however, were only collected in Caño de Agua Norte (7 individuals), although they have been observed in Caño de Agua Sur and they were relatively abundant in the stomach contents of crocodiles from that area. Shrimps, on the other hand, were more abundant in Caño de Agua Norte (45 individuals) than in Caño de Agua Sur (8 individuals).

Discussion

The diet of Juvenile crocodiles in the CRS consisted mostly on vertebrates which represented more than 75% de the biomass both in Caño de Agua Norte and in Caño de

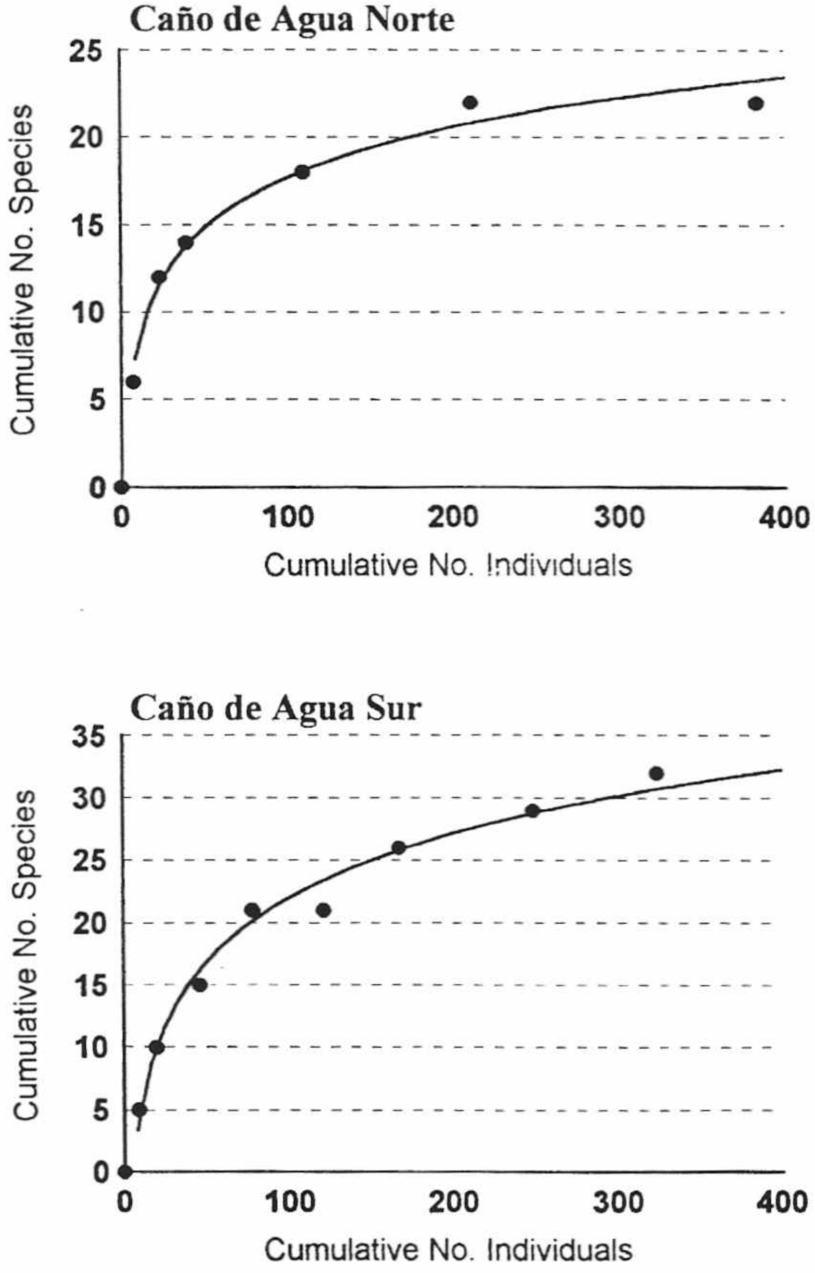


Figure 7-2. Increase in the number of fish species as the sample size increases in Caño de Agua Norte and Caño de Agua Sur, Cojedes river system, Venezuela. Samples were added successively from the one with the lower number of individuals to the one with the larger number of individuals.

Agua Sur. The relative importance of aquatic and terrestrial prey differed between these sites, reflecting distinct characteristics of the river and its surrounding banks.

The relative major importance of terrestrial prey (particularly vertebrates) in Caño de Agua Norte could be explained by the fact the banks of that river reach are covered by grasses and hanging branches of small trees. These banks may represent a better habitat for small rodents, terrestrial insects and (consequently) frogs, as compared to the steep and almost always denuded banks in Caño de Agua Sur-Merecure.

With the exception of fish and crabs, all other major food items were found more frequently and more abundantly in the stomach contents of juvenile crocodile inhabiting Caño de Agua Norte, as compared with individuals from Caño de Agua Sur-Merecure. In the case of aquatic insects and terrestrial vertebrates the differences were significant. This result was unexpected, since the sampling with seines revealed a lower fish biomass and smaller number of crabs in Caño de Agua Sur.

In terms of total number of species, diversity and relative dominance of species, relative proportion of carnivorous fish, and relative proportion of omnivores, the fish community in Caño de Agua Norte could be considered as more stressed by human activities than Caño de Agua Sur. This was expected, since Caño de Agua Norte have been dredged, channelized, its banks has been deforested, and is relatively close to human settlements, in contrast to Caño de Agua Sur that has been less modified by human activities and is farther from towns and cities. However, that does not necessarily translate into less food for crocodiles in the first locality. In fact, a larger biomass of fish, and supposed food availability, was obtained in Caño de Agua Norte, although that presumed higher resource availability did not appear reflected in frequency and volume of fish in the diet of crocodiles from Caño de Agua Norte.

Perhaps fish sampling and indicators of biological integrity cannot be used to assess food availability for crocodiles. It seems reasonable to think that the more abundant fish species found in the sampling are not necessarily the more accessible to the crocodiles. The behavior of both the crocodiles and their prey and the characteristics of the river, might play an important role in determining what is accessible or not.

The observed differences in abundance of predatory fishes between Caño de Agua Norte and Caño de Agua Sur, may explain why crocodiles in the later river stretch had a higher incidence of injuries (Chapter 6). It has been suggested that predation pressure may explain differences in physical condition (fatness) of crocodiles from different areas in Australia (Webb and Messel 1977; Taylor 1979).

I observed a lower number of species and a larger biomass in Caño de Agua Norte. But the water quality of the CRS deteriorates upstream from there, where the river pass closer to urban and industrial centers. The diversity of fish might continue to decline, and eventually, under very severe conditions, fish biomass must also decline. In Cojedes Norte, for example, the river is permanently stressed, with lower levels of dissolved oxygen and other evidences of pollution (see Chapter 3). The stomach contents (9) of crocodiles and caiman in this place seems to indicate a scarcity of prey, but this needs to be more carefully investigated. For example, analysis of physical conditions (Chapter 6) showed that juveniles crocodile from Cojedes Norte had a better condition (in terms of relative fatness) than juvenile crocodiles from river sections more impacted by human activities.

More river stretches and with much more contrast in anthropogenic impacts should be used in future studies.

CHAPTER 8
HUMAN PRESSURE AND CROCODILE DISTRIBUTION AND ABUNDANCE

Introduction

As was mentioned in Chapter 1, one of the reasons that may explain the survival of the Orinoco crocodile population in the Cojedes River, is the isolation in which that region remained during the years of peak commercial exploitation of the species (1929-1945). The Cojedes River basin is not today as isolated as it was in the recent past. Some areas of the river, however, are closer, and supposedly under greater human pressure, than others. The human population in the Cojedes state (and in its neighbor Portuguesa) is mostly concentrated in the north, close to the Piedmont of the Coastal Range. The southern part of the state is sparsely populated by humans, with El Baúl (5,236 inhabitants) as the most important town. Is this distinct pattern of human occupation of the space a factor that could explain the current distribution of the species in the study area? In this chapter, I explore that possibility. My hypothesis is that human proximity is a negative factor and that in each river section that was surveyed, and in the entire study area, crocodiles should tend to be found in the reaches farther from villages, towns and cities. As was briefly proposed in Chapters 2 and 3, other factors that may contribute to shape the current pattern of crocodile distribution are contamination and river navigability. All these factors are analyzed and discussed in this chapter.

Methods

Maps of main river courses, roads and broad categories of land cover were digitized and converted into raster images based on two Lansat TM satellite images of the study area, from 10 January and 27 February 1990 (early dry season). Based on the analysis of these images and data from more than 1500 GPS locations I updated the old cartographic information of the region. The basic land cover features considered for mapping were urban areas, agriculture, pasture lands and open savannas (taken together as a unit), water bodies, forests, permanent rivers, and roads.

Using Geographic Information System software (IDRISIS, Clark University 1997), I generated a cost-distance surface from every major city and for those small towns, villages and other human settlements in close proximity to the river. The initial raster image generated from the classification of the satellite images had a spatial resolution of 32x32 m. Due to the extension of the land surface been modeled (9,660 km²), and in need to speed the GIS analyses, the raster images used for the final analyses had a spatial resolution of 64x64 m. The friction surface used to calculate the cost-distance surface was generated according to the relative cost shown in Table 8-1. Primary roads were assigned a friction of 1. That, in fact, means that there was no cost for traveling by car on that surface, and that cost-distances measured along them are equivalent to Euclidean distances. Because it is possible to travel on average 80 km/h on primary roads, the friction values assigned to other land cover types was related to how much longer it takes to travel an equivalent distance through them (using the fastest transportation method than can be used on that surface). Friction values assigned to rivers

Table 8-1. Relative cost of movement through land cover types in the study area. The relative cost was calculated assigning a friction of 1 (no friction) to the movement through primary roads. The average speed of traveling by car on primary roads was taken as 80 km/h. The relative friction of other surfaces was calculated considering the average speed that could be reached, by any means of transportation, traveling through them. Traveling on the rivers in boats was not taken into account.

Land Cover Type	Average Speed (Km/h)	Relative friction
Primary roads	80	1.00
Secondary roads	60	1.33
Improved dirt roads	40	2.00
Dirt roads	20	4.00
Urban areas	35	2.29
Main rivers	–	80.00
Secondary rivers	–	60.00
Smaller rivers	–	40.00
Agricultural lands	4	20.00
Savannas	4	20.00
Forests	2	40.00
Lakes	–	100.00

were somewhat arbitrary but larger than the values assigned to most land cover surfaces, to reflect the fact that they are important obstacles to human movements (when boats are not available). The highest friction was assigned to lakes, which in practice, for the goals of this study, were considered barriers to human movement.

The cost-distance surface obtained for each town or city was used to model the presumed human pressure exerted by it on every river reach of the Cojedes River system (in fact, on every location within the study area). The human pressure index (HPI) is a value that indicates the strength of the expected impact of a particular urban area on every point in its surrounding landscape. The HPI of a particular spot (i.e., cell in the raster image) was calculated as a function of its proximity to human settlements and of the human population size of these particular human settlements, i.e., river reaches close to cities and towns were assumed to be under greater human pressure than river reaches located farther from those urban areas. On the other hand, big cities were expected to exert a higher pressure than small ones. The formula to calculate human pressure was

$$\text{HPI} = \frac{\text{Human Population Size}}{(\text{Distance in km})^2} \tag{8.1}$$

This formula is in essence a particular case of a gravity model (Forman 1995), which states that the movement or interactions between two nodes increase with node size, but decrease with the square of the distance between nodes. In my case, one of the nodes (the particular river reach) was assigned, arbitrarily, an unitless value of 1. The HPI as expressed in eq. 8.1 has the units of density (ind/km²). To avoid confusion, however, the HPI will be presented without units.

The urban centers considered in the model are listed in Table 8-2. Many other small villages (Retajao, El Estero, La Palmita, and others) and cattle ranching operation centers (La Batea, Merecure, Las Guardias and a few others) were used to generate cost-distance surfaces. Due to lack of precise information on human population size in these human settlements, I assigned a figure of 500 inhabitants to small villages and hamlets, and 100 inhabitants to the cattle ranching operation centers.

Because any particular point on the study area may be simultaneously under the influence of several human settlements, the final map of HPI of the entire study area was obtained adding all the HP layers of all these settlements. The HPI on every reach of the river was obtained overlaying the layer of the river on the final HPI layer.

During 1996 and 1997, the position of most crocodiles seen in the river during nocturnal spotlight surveys were determined with a GPS (see Chapter 4). The GPS locations for those surveys with the highest number of crocodile sightings were used to generate a new map layer. The HPI of the spot in which each crocodile was seen, was obtained overlaying the crocodile locations' layer on the HPI layer. Contingency table analyses were used to compare distribution of crocodiles in the relation to the HPI of the surveyed river sections.

To assess the importance of other human related factors in determining the abundance of crocodiles in the Cojedes River system, I performed a non-parametric correlation analysis between crocodile density in each river section surveyed with the

Table 8-2 . Cities and other human settlements in states Cojedes and Portuguesa (Venezuela) that were used to model the human pressure in the Cojedes river system.. Population size based on OCEI (1993).

Human settlements	Human population
Portuguesa state	
Acarigua-Araure	171,850
Agua Blanca	9,393
San Rafael de Onoto	7,206
Pimpinela	4,563
Santa Cruz	4,090
Cojedes State	
San Carlos-Tinaco	68,325
Las Vegas	6,897
El Baúl	5,236
Apartadero	4,260
Cojeditos	4,911
Lagunitas	3,353
Sucre	1,886
El Amparo	1,105

relative importance of the following variables: isolation from human populations, navigability, and contamination. I ranked each river section according to the relative importance of these variables. Information on isolation from human population was obtained from the GIS analysis previously mentioned. Ranking according to contamination was based of information presented in Chapter 3. Regarding navigability, the only river sections that are navigated in a regular basis are those close to Sucre and, to a lesser extent, La Culebra. People living in the towns of Sucre and El Baúl, use the Cojedes River as a mean of transportation. The river is an essential means of communication between these urban centers and some cattle ranches year-round. There is commercial and subsistence fishing and, presumably illegal caiman hunting, around Sucre and in La Culebra. Upstream, the section Merecure-Caño Amarillo could also be navigated year round, but in fact it seems to be only navigated sporadically, with the exception of a family that has a small canoe. Caño de Agua Sur is difficult to navigate due to obstructions created by fallen trees and urban debris and garbage that drift down from towns upstream. This section seems to be occasionally visited, and partially navigated, by hunters and campers. Caño de Agua Norte and Cojedes Norte are rarely, if ever, navigated by people besides myself and other crocodilian researchers.

Results

The relative position of the main urban centers of the study area and of the surveyed river sections is shown graphically in Figure 8-1. Some of these river sections were in areas of high HPI due to their proximity to towns and cities. HPI was particularly

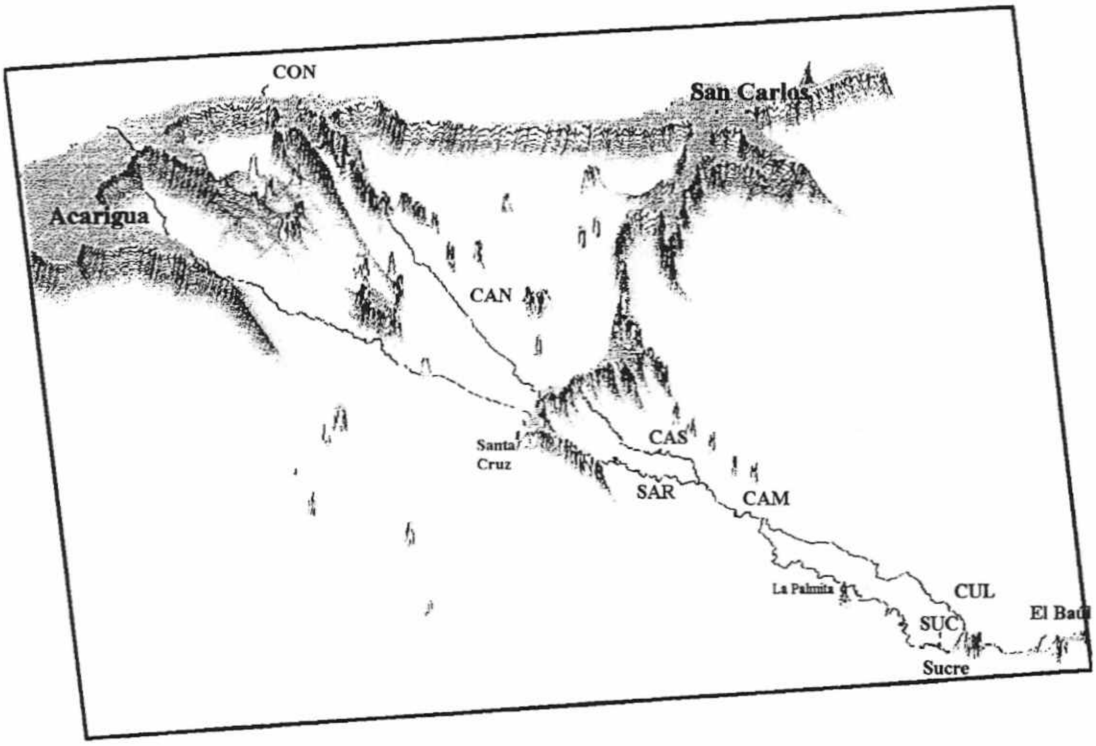


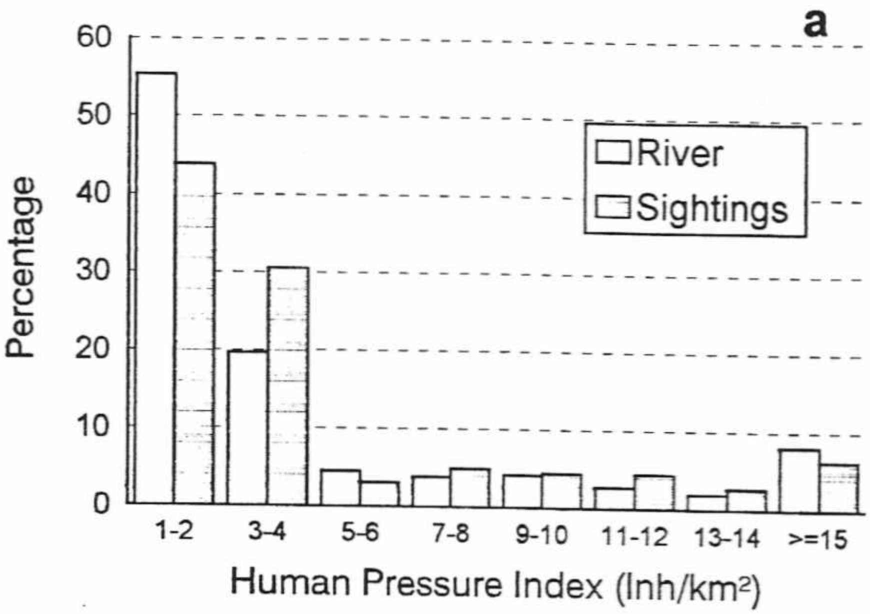
Figure 8-1. Tri-dimensional representation of Human Pressure Index (states Cojedes and Portuguesa, Venezuela) generated with the GIS software IDRISIS. Areas in clear grey or white are under low human pressure (HPI<2). Different tonalities of gray represent the intensity of human pressure, with the highest HPI (in dark grey) in towns and cities (HPI >100) represented as plateaus. The acronyms indicate the position of the surveyed river reaches. CON, Cojedes Norte; CAN, Caño de Agua Norte; CAS, Caño de Agua Sur; CAM, Caño Amarillo Merecure; SAR, Sarare river; SUC, Sucre; CUL, Caño La Culebra.

high in Cojedes Norte and the Sarare River. On the other extreme, HPI was relatively low near Sucre and, especially so, in La Culebra. (Table 8-3).

Table 8-3. Human pressure index (HPI) and mean crocodile population index (PI, see Chapter 4) in surveyed river sections of the Cojedes River system in Venezuela. River reaches are listed from north to south (from upstream to downstream).

River section	Mean HPI	Range	Mean PI (Ind./km)
Cojedes Norte	15.6	7-56	2.0
Caño de Agua Norte	7.2	1-100	4.4
Sarare	11.7	1-78	3.1
Caño de Agua Sur	2.0	1-6	7.3
Sucre	1.7	1-19	0.6
La Culebra	1.0	1	1.4

The locations of 226 crocodiles (more than one year old) were recorded. If human pressure affect negatively the distribution and abundance of crocodiles, crocodile sightings should be more frequent in river reaches under relatively low HPI. A comparative analysis of the distribution of all these crocodile sightings according to the HPI of the specific spot where they were observed (Figure 8-2a), indicated that, contrary to expectations, crocodiles were under-represented in river reaches of very low human pressure (HPI 1-2). That was a consequence of low densities of crocodiles near Sucre and in Caño Culebra, the river sections with under the lowest HPI, whereas crocodile densities in river reaches under moderate HPI such as Caño de Agua Sur had the highest crocodile densities. A chi-square test indicated that the distribution of HPI of crocodile sightings and of available river spots were statistically different (X^2=19.30, *P*=0.007).



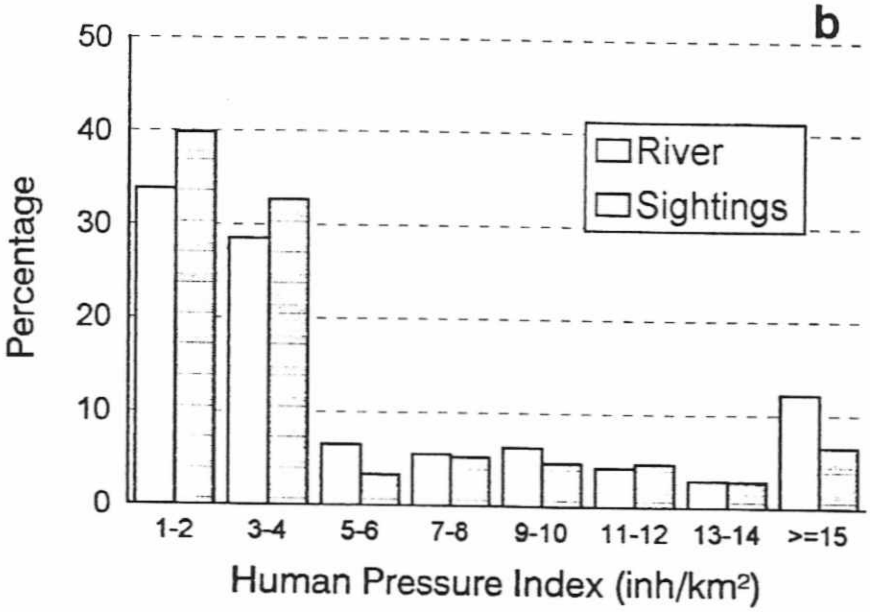


Figure 8-2. Frequency of crocodile sightings in comparison to the distribution of Human Pressure in different river sections of the Cojedes river system, Venezuela. The bars labeled 'rivers' represent the distribution all segments (64 m in length) of the surveyed river sections according to their corresponding HPI. Top (a). all river sections. Bottom (b) excluding those river sectios that are navigable (Sucre and La Culebra).

In contrast to other river sections surveyed, La Culebra and Sucre are navigable (and navigated) year-round. When data from these river sections were dropped from the analysis, the frequency distribution of HPI of locations of crocodile sightings and HPI of river reaches differed in the direction predicted by the above mentioned hypothesis. The statistical analysis showed a low, although not significant, probability (X^2=12.30, P=0.091). In the non navigable section's crocodile abundances are negatively related to human pressure (Fig. 8-3).

In some areas with high HPI that were not properly surveyed at night, some crocodiles were observed. Seven crocodiles, for example, were observed on 14 January 1993 in Toma Cojedes, an area with HPI of 46-48. In Retajao, a hamlet along the left margin of Caño de Agua, a nesting female and a sub-adult crocodile were observed in 1996 and 1997. The later mentioned individual was observed just across the street from an elementary school, spot with a HPI of 50.

Data presented in previous chapters allowed to rank each river section according to its crocodile density, isolation from urban areas, contamination, and navigability (Table 8-4). The correlation analysis indicates that the variable with strongest relationship with crocodile densities was navigability, but that correlation (negative) was not statistically significant (Spearman Rho -0.52, P=0.29). The correlation between isolation and crocodile densities was negative but weak (Spearman Rho = -0.2, P=0.7) in agreement, as would be expected, with the analysis presented before with HPI.

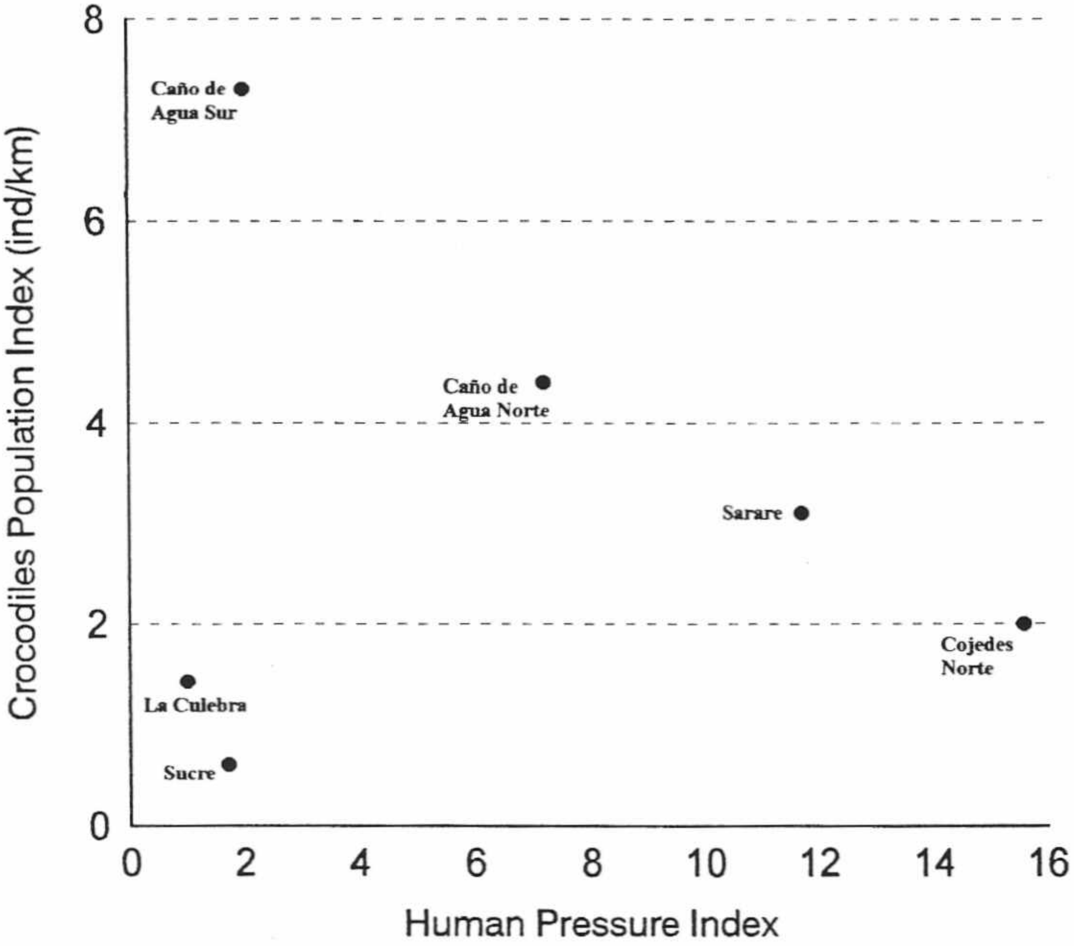


Figure 8-3. Relatioship between mean Human Pressure Index (HPI) and mean crocodile population index in river sections of the Cojedes River system, Venezuela. La Culebra and Sucre are the only sections that are navigable.

Table 8-4. Ranks of crocodile densities, isolation from urban areas, contamination and navigability of the different river sections that were surveyed in the Cojedes River system, Venezuela. Contamination ranks were based on information presented in Chapter 3. Navigability are based on personal observations.

River section	Crocodile Density	Isolation from Urban areas	Contami-nation	Navigability
Cojedes Norte	4	6	1	5
Caño de Agua Norte	3	5	2	5
Caño de Agua Sur	1	4	3	4
Merecure-Caño Amarillo	2	2	4	3
Sucre	6	3	5	1
La Culebra	5	1	6	2

Discussion

Although the isolation of the Cojedes River may have played an important role historically in preserving a small population of Orinoco crocodiles (Ayarzagüena 1987), today the river sections with the highest crocodile densities are moderately isolated from urban centers, whereas the most isolated areas with low human population densities have also the lowest crocodile densities. Low densities in parts of the river, such as those close to Sucre or in caño La Culebra, suggest that navigability and difficulty of access are probably important factors explaining the current patter of distribution of the species. A combination of isolation and impossibility of navigation have been used to explain the persistence of other small population of Orinoco crocodile in the Tucupido River (Ramo and Busto 1986; Thorbjarnarson and Hernández 1992). According to Thorbjarnarson and

Hernández (1992) crocodiles in the Capanaparo River are protected during the dry season because due to its low water level it is not navigable.

It could not be statistically demonstrated that proximity to towns and cities per se explain the abundance and distribution of crocodiles in the CRS, but there was a pattern pointing toward that that direction. Future studies should include more river sections under relative high human pressure, such as the upper section of Caño de Agua near Cojeditos, and river reaches in the Sarare River close to Pimpinela and south to Agua Blanca.

Anecdotal information indicated that downstream from Sucre, and particularly downstream from El Baúl, the Orinoco crocodile remains as decimated as it was almost 20 years ago when first evaluated by Godshalk (1978). Young crocodiles are seen occasionally in the Cojedes River near El Baúl (Manuel González, pers. comm.). They probably represent migrant individuals or individuals that have been drifted downstream by the river during the peak of the rainy season. Some of these crocodiles are taken by people in El Baúl, failing to establish themselves in the river. Other crocodiles are presumably killed by fishermen, accidentally or deliberately, or move farther downstream toward the Portuguesa River.

As was discussed in Chapter 5, most reproduction of the Orinoco crocodile in the Cojedes River system, takes place in the middle reaches of Caño de Agua and lower Sarare. These river sections are population sources. The data also indicate that reproduction is poor or absent in Sucre and La Culebra sections but, in the long term, migrant individuals from upstream should be enough to maintain at least non-reproductive populations in those reaches. Under the current circumstances, due to low reproduction and presumably high risk of being killed by people, the later mentioned river sections are population sinks for the Orinoco crocodile.

Contamination is highly negatively correlated with isolation (or distance) from human population. As was shown before, isolation, and consequently, contamination, are not good predictors of crocodile distribution and abundance. But as was discussed in Chapter 3, the effects of contamination on living beings are not usually immediate. The long term effect of contamination on the survival of the crocodile population is yet to be assessed.

CHAPTER 9
CONCLUSION AND MANAGEMENT RECOMMENDATIONS

This study supports early findings by Godshalk (1978, 1982) and Ayarzagüena (1987, 1990) regarding the importance of the Orinoco crocodile population in the Cojedes River System (CRS). Unfortunately, differences in scope and methodologies used by these authors do not allow a determination if the species has experienced an increase or decrease in its size and distribution in the region in the last 20 years. The bulk of the population is clearly not as concentrated in a relatively short segment of the Caño de Agua, as was suggested by Ayarzagüena (1987, 1990).

Many factors can explain the current pattern of distribution and abundance of the Orinoco crocodile in the CRS. Although today almost no commercial exploitation exists, the sections of the river most isolated from the main urban and industrial centers in the north are the ones with the lowest population densities of the species. These are the river sections that are navigable year round, which strongly suggest that accidental or intentional killing of crocodiles by people are responsible for the low population levels there.

Compared to the navigable river reaches in the south near Sucre and El Baúl, the chance of crocodile-human encounters in river reaches near more human populated areas should be low due to their lack of navigability and high contamination levels, which make them not utilizable for some human uses such as recreational, and subsistence fishing. However, anecdotal information gathered from people living in San Rafael de Onoto, Lagunitas and Retajao, indicated that occasional killing of crocodiles occurs near these towns. The farther the river section from human developed areas, the lower the probabilities of negative crocodile-people interactions. When the navigable sections of the river are not taken into considerations, there is a clear indication that crocodile abundance is negatively related to relative proximity to human settlements.

Habitat quality is another important factor affecting the characteristics of Orinoco crocodile population in the CRS. River banks with soil's substrate composed in a high proportion of sand is relatively abundant in river reaches in the north, particularly those that conserve their meanders. Most of the reproductive population is concentrated in these river sections, specially in Caño de Agua Sur

The opportunistic nature of the feeding habits of the Orinoco crocodile, as occurs with many species of crocodilians studied to date, may have helped this species to survive in river sections modified by human activities. Terrestrial prey constitutes an important component in the diet of juvenile crocodiles in river sections that have been altered by deforestation, which may compensate, in the short term, for loses or reduction of aquatic food resources. On the other hand, in some river sections with high to moderate anthropogenic impacts, such as Cojedes Norte and Caño de Agua Norte, a reduction of predatory fish may have occurred, which may contribute to the survival of juvenile crocodiles, as suggested by the very low injury rate of individuals from these river reaches

It is important to take into account that the very highly degraded and polluted river sections near the towns of San Rafael de Onoto, Apartaderos and Cojeditos, were not studied. Only considering, additionally, the situation of the Orinoco crocodile in these portions of the CRS can we have a comprehensive understanding of the impact of eutrophication and other forms of human impacts on the species.

It is necessary to state clearly that, in the long run, habitat degradation in the CRS is detrimental for the survival of the Orinoco crocodile. The growth rate found in this study, well below the growth rate of crocodiles living in non-polluted rivers of Apure state, is a reminder of that fact. The effects of contamination on key survival factors such as reproduction were not addressed in this study. Studies with other wildlife species, and in particular with the *Alligator mississippiensis* in some Florida lakes, have strongly suggested the negative impact on populations exposed to high contamination levels (Guillete 1995; Guillete et al 1994; Guillete et al. 1996).

Habitat degradation, which includes not only contamination, but other human-related impacts, such as channelization, may also affect, directly or indirectly, the survival of the Orinoco crocodile. Channelization results in a loss of the habitat available due to the reduction of the total length of the river, the reduction or elimination of nesting beaches, and the increase of the speed of the water. The last factor may increase the probability of predation of hatchlings that drift away from pods and from the protection of their mother.

The Orinoco crocodile has colonized, or persisted in, areas that have been channelized, as is the case in most of Caño de Agua Norte. The species is capable of rapidly colonizing recently created channels. On 26 April 1997, for example, at least 4 juvenile crocodiles were observed in a recently filled (less than one week ago) 350m-channel, in the river section of Merecure-Caño Amarillo. No caiman were observed in that channel, although in the surrounding area caiman outnumbered crocodiles 2.6:1.

The common caiman (*Caiman crocodilus*) outnumbers the Orinoco crocodile, at least during the dry season, in all the surveyed river sections of the CRS. Human activities have favored the expansion and increase in population number of caiman in the Venezuelan Llanos. Since the caiman has been regarded as an important predator-competitor of the Orinoco crocodile, the negative pressure that high population densities of caiman may exert over the Orinoco crocodile, can be considered as an indirect human impact. More detailed investigations, including experimental removal of caiman, are necessary to elucidate more clearly the importance of the ecological relationships caiman-crocodile.

Being the largest know population of a highly endangered species in the world. The importance of the Orinoco crocodile in the CRS transcends the narrows limits of the Cojedes region. The CRS is a key locality for the recovery of the species, and it needs to be the focus of a major national conservation program

The high reproductive potential of the Orinoco crocodile population in the CRS can and should be used to support the recovery efforts elsewhere (Ayarzagüena 1990). That has been done in a very limited extent, and a few individuals from the CRS have been released in Guaritico Wildlife Refuge, in Apure state (Lugo 1998). The most important conservation effort, however, should be directed to protect this species *in situ*, in the CRS itself.

Several management measures to protect the Orinoco crocodile or to improve the quality of its habitat in the CRS, have been proposed in the past (Godshalk 1978; Ayarzagüena 1987; Campo and Rodríguez 1995), but none of them have been implemented. Those actions are dictated by common sense and go from enforcing the laws and regulations regarding the use and disposal of agrochemicals, to the creation of a protected area in the region. The later action will be discussed in more detail here.

In spite of its importance for the future of the Orinoco crocodile, no portion of the CRS is legally protected. The emphasis of the conservation efforts currently underway in Venezuela has been the reintroduction of the species or reinforcement of its population in protected areas of Apure and Guárico state (FUDENA 1993; PROFAUNA 1994; Lugo 1998). Any strategy for the long term survival of the Orinoco crocodile in the Cojedes region, must consider the creation of a protected area. According to the "Ley Forestal de Suelos y Aguas (LFSA)" (Forest, Water, and Soils Law) rivers are considered national resources. The trees within a margin of 50 m from the river banks cannot be cut and there are severe restrictions on the development of human activities along those river margins. Unfortunately, that Law is rarely enforced. But even if there were a strict enforcement of the LFSA, the crocodiles in the Cojedes River would not be fully protected from human encroachment: a forest fringe only 50 m wide would not be enough to efficiently keep most people away from the river.

There are many categories of protected areas considered in the Venezuelan legal system (Ley Orgánica de Ordenación del Territorio (LOOT), Ley Forestal de Suelos y Aguas (LFSA), Ley para la Protección de la Fauna Silvestre (LPFS)). The categories that may be suitable for the Cojedes River conditions are National Park, Wildlife Refuge, Wildlife Sanctuary, and Wildlife Reserve. The first three categories are very restrictive. They do not allow the consumptive use of the resources within the protected area. These categories do not seem to be very good alternatives if we expect to reduce the frictions with land owners and local people, who use the river for irrigation purposes. The Wildlife Reserve is a protection category that could allow the development of programs for the sustained utilization of its resources. This category should be the most suitable for the protection of the Orinoco crocodile in the Cojedes River region. I believe that at least a 100 km of the river already occupied by the species, should be declared as Wildlife Reserve. The selected river reaches are those with relatively high crocodile densities. The protected zone should include a fringe of land, forested or not, at least 1,500 m wide on each side along the river. This would guarantee the inclusion of relicts of the riparian forest, and a small part of the floodplain. It would also provide an umbrella of protection to many other forest species that have experienced a shrinkage of their habitat in the last 50 years. There seems to be no direct relationship between vegetation type and crocodile distribution, as was mentioned by Godshalk (1978), although that has not been properly tested. In any case, the riparian forest buffers the impact of people (Ayarzagüena 1987) and, probably, increases the variety of prey available for the species.

The location and boundaries of the proposed protected area are shown in Figure 9-1. This reserve would have a total area of approximately 27,000 ha, with 26.8% of it represented by forests. The proposed reserve would be almost exclusively within the

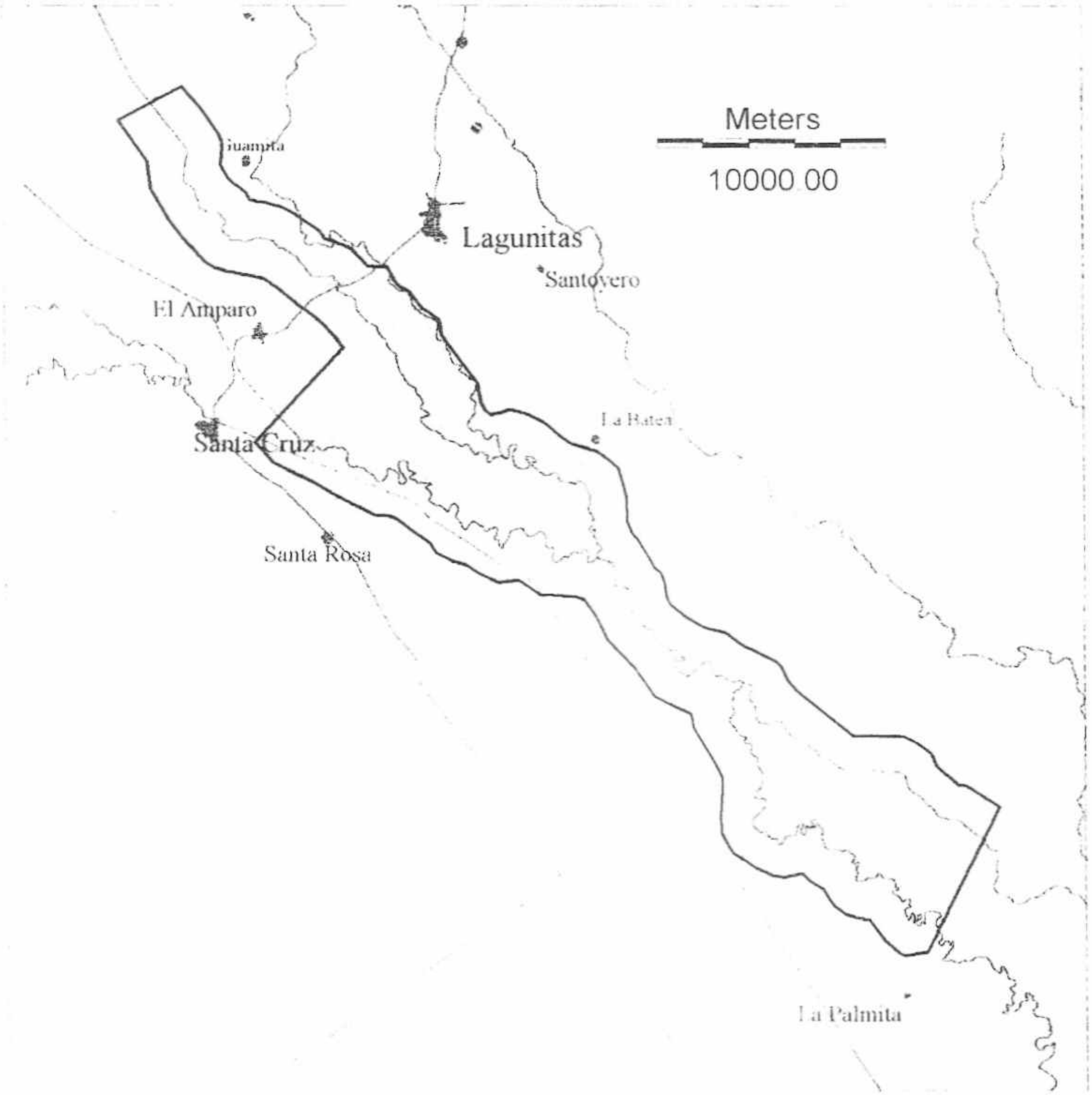


Figure 9-1. Boundaries of proposed wildlife reserve for the conservation of the Orinoco crocodile in the Cojedes river system, Venezuela.

Cojedes state, and would represent just 1.8% of its total surface. I estimate that 85% of the crocodiles in the CRS would be protected by the reserve.

A program of education and law enforcement against poaching must be implemented to protect the individuals or populations outside the protected area, particularly in the middle Sarare River, which has not been surveyed in the last ten years. Nuisance animals must be removed and translocated by wildlife officials to reduce to a minimum negative human-crocodile interactions. With the agreement of land owners some population outside the protected area could be increased by translocation of captive reared crocodiles or nuisance animals.

Within a Wildlife Reserve it would be possible, under special circumstances in the future, to implement a ranching program once the species has achieved population levels to support it. Ranching involves the captive rearing of crocodiles collected from the wild as eggs or hatchlings (Hutton and Webb 1993; Thorbjarnarson 1992). Because eggs and juveniles have a very high mortality rate, removing them from the wild has less impact on the wild population than does the removal of breeding size individuals. The effects of such a ranching program on the status of wild populations can be ameliorated by mandating that a certain fraction of the slaughter size crocodiles be returned back to the wild. This strategy has been put into effect in several countries with satisfactory results (Blake 1974; Blake and Loveridge 1975; Singh et al. 1986). Breeding Orinoco crocodiles for the release of animals into the wild has also been implemented with success in Venezuela (Thorbjarnarson and Arteaga 1995; Seijas 1993, 1995; Lugo 1998).

One problem with this alternative is that crocodiles reared through ranching cannot be commercialized into the international market unless the Venezuela population is transferred from Appendix I to the Appendix II of CITES. This is not an easy task, and surely is not one that could be accomplished in the short term. Transfer of populations from Appendix I to Appendix II must be based on scientific evidence that the population can sustain commercial utilization, including results of surveys indicating population recovery. Profits from this management scheme would be limited at the beginning, and they could be obtained exclusively on the internal commercialization of the crocodiles and its products (skin, meat, teeth, fat, etc.) or through tourism.

But even a protected area and management recommendations like the ones proposed above would not be enough to ensure the long term survival of the species in the region. The conservation of the Orinoco crocodile must be one of the many goals of a more comprehensive program at a regional scale. If the deterioration of the CRS continues, species-focuses programs as that for the Orinoco crocodile are doomed to failure. Definitions of the characteristics of that regional-scale program are outside the scope of this study.

A rigorous monitoring program of the Orinoco crocodile population in the CRS should be implemented by the Venezuelan wildlife service (PROFAUNA). Nocturnal surveys should take place in early dry season (November-January) period when the largest number of crocodiles, of all size classes can be observed and, consequently, more reliable assessments of population size and population structure can be done. The monitoring program should also evaluate the size and distribution of the reproductive population based on the location and number of nests that successfully hatch every year. Although this type of monitoring is more difficult to implement because some river sections are not navigable due to low water levels, it provides reliable information to assess population trends.

This study did not consider in detail the possible impact that the creation of a new dam upstream, in Las Palmas, could have on the population of Orinoco crocodile. This is an issue that needs to be approached urgently. On the other hand, prospecting for oil has been undertaken recently in the CRS and there are big expectancies among politicians, land owners and people in general about the possibilities of exploitation of that resource. Even though the Orinoco crocodile has shown some persistence to the many modifications that the CRS has experienced in the last 50 years, we do not know if a new change in the already altered hydrology of the region and a new source of contamination would turn into a catastrophe for the species and for the hope of its full recovery.

APPENDIX A
GEOGRAPHIC COORDINATES OF KEY LOCATIONS

Geographic coordinates of landmarks and reference points in the Cojedes river system, Venezuela. Coordinates in Universal Transverse Mercator (UTM, Zone 19)

Location	Northing	Easting
Rio Claro (water sample taken)	504503	1081506
Cojedes Norte. Beginning (Upstream) of survey 1997	501470	1075699
Toma Cojedes	503910	1072132
Retajao bridge	510984	1057955
La Doncella bridge	519586	1042651
Hato Guamita. Water pump	523383	1036880
Camoruco bridge (Lagunitas-El Amparo)	531499	1031744
Puente Nuevo (new bridge Caño de Agua)	529780	1030918
Location of "Carama" April 1996	532580	1026815
Sarare bridge (Amparo-Santa Cruz)	525233	1027707
Lorenzo bridge (Hato Santa Cruz)	538144	1023293
Sarare. Beginning of survey 1997 (Downstream)	532259	1022786
Sarare. End surveys 1997 (upstream)	525860	1026620
La Batea (Endpoint Merecure-La Batea Surveys)	540276	1022458
Confluence Cojedes-Sarare	540929	1019149
Merecure. Water pump	541619	1018777
Beginning Caño Amarillo	546904	1013754
Sucre section. Beginning surveys (upstream)	560614	996518
Sucre (town). End of surveys	566489	992361
La Culebra. Beginning surveys	564058	1000739
Confluence La Culebra-Cojedes	569883	993496

APPENDIX B
NOCTURNAL SURVEYS OF CROCODILES (*Crocodylus intermedius*) AND CAIMAN (*Caiman crocodilus*) IN THE COJEDES RIVER SYSTEM, VENEZUELA.

B-1. Sections Toma Cojedes (San Rafael de Onoto) and Cojedes Norte upstream from Toma Cojedes) WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include hatchlings. Figures within parentheses under the Density column represent total crocodilian densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
Toma Cojedes (Sao Pin) From the bridge (14 Jan 93)	*Crocodylus*	-	-	-	3	2	1	-	6	---
Upstream from Toma Cojedes (7 km) 19 January 1993	*Crocodylus*	-	2	12	2	1	0	2	19	2.7
	Caiman	12	6	16	13	1	-	3	39	5.6
	N.I.								12	(10.0)
Upstream from Toma Cojedes (4 km) 11 March 1993	*Crocodylus*	-	3	2	1	0	2	2	10	2.5
	Caiman	0	7	8	7	0	-	0	22	5.5
	N.I.								2	(8.5)
Upstream from Toma Cojedes (5.6 km) 28 January 1997	*Crocodylus*	0	2	10	4	0	0	1	17	3.3
	Caiman	1	6	21	3	0	-	5	35	6.3
	N.I.								12	11.4
Upstream from Toma Cojedes (5.6 km) 3 February 1997	*Crocodylus*	-	-	13	3	0	-	5	21	3.8
	Caiman	0	3	12	9	0	-	14	38	6.9
	N.I								1	10.2

B-2. Sections Caño de Agua Norte, from La Doncella bridge to Puente Nuevo (new bridge between the towns of Lagunita and El Amparo). WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include hatchlings. Figures within parentheses under the Density column represent total crocodilian densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
From La Doncella to Puente Nuevo (14 km) 3 July 1993	*Crocodylus*	24	-	3	2	11	8	6	30	2.1
	Caiman	0	0	0	0	0	0	0	0	0.0
	N.I.								4	(2.4)
From La Doncella to Puente Nuevo (16 km) 1 December 1993[1]	*Crocodylus*	-	37	8	-	-	23	6	74	4.6
	Caiman	1	0	4	4	2	-	1	11	0.7
	N.I.								4	(4.4)
From La Doncella to Puente Nuevo (16 km) 8 May 1996	*Crocodylus*	85	-	11	5	3	16	1	36	2.3
	Caiman	3	6	10	9	3	-	16	44	2.8
	N.I.								8	(5.5)
From La Doncella to Puente Nuevo (16 km) 24 February 1997	*Crocodylus*	0	0	48	19	2	3	14	86	5.4
	Caiman	1	0	18	9	3	-	21	51	3.2
	N.I.								11	(9.3)
From La Doncella to Puente Nuevo (16 km) 28 April 1997	*Crocodylus*	198	0	32	6	2	11	12	63	3.9
	Caiman	8	15	23	11	7	-	51	107	6.7
	N.I.								16	(11.6)
Guamita to Puente Nuevo (10.5 km) 22 March 1996	*Crocodylus*	-	6	32	9	0	1	9	57	5.4
	Caiman	35	7	25	18	1	-	37	88	8.4
	N.I.								7	(14.5)
Guamita to Puente Nuevo (10.5 km) 18 April 1996	*Crocodylus*	137	-	21	5	0	7	5	38	3.6
	Caiman	41	8	24	30	9	-	70	141	13.4
	N.I.								19	(18.9)

B-2. (continued)

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
From Guamita to Puente Nuevo (10.5 km) 24 April 1996	*Crocodylus*	160	-	22	5	2	5	7	41	3.9
	Caiman	47	11	3	4	1	-	112	131	12.5
	N.I.								9	(17.2)
From Guamita to Puente Nuevo (10.5 km) 12 March 1997	*Crocodylus*	0	0	42	4	0	1	13	60	5.7
	Caiman	5	7	30	15	3	-	94	149	14.2
	N.I.								8	20.7
From Guamita to Puente Nuevo (10.5 km) 28 April 1997	*Crocodylus*	105	0	18	5	0	7	10	40	3.8
	Caiman	8	13	14	7	4	-	38	76	7.2
	N.I.								10	12.0
Upstream from Puente Nuevo (7 km approx.) 12 November 1993[2]	*Crocodylus*	-	11	10	4	4	2	3	34	4.8
	Caiman	0	0	0	0	-	-	0	0	0.0
	N.I.								0	(4.8)
Upstream from Puente Nuevo (5.2 km) 20 March 1996	*Crocodylus*	-	10	16	2	0	1	0	29	5.6
	Caiman	35	3	5	5	2	-	0	15	2.9
	N.I.								7	(9.8)
Upstream from Puente Nuevo (5.2 km) 22 March 1996	*Crocodylus*	-	6	13	2	0	1	5	27	5.2
	Caiman	33	1	7	6	0	-	7	21	4.3
	N.I.								2	(8.5)

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1 Survey carried out by John Thorbjarnarson, Miriam Lugo, and Carlos Chávez.

2 Survey carried out by Carlos Chávez, Miriam Lugo, and Manuel González

B-3. Sections Caño de Agua from Puente Nuevo to La Batea. WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include hatchlings. Figures within parentheses under the Density column represent total crocodilian densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
From Puente Nuevo to Hato La Batea (20 km approx.) 4-5 March 1992[1]	*Crocodylus*	0	0	8	12	21	8	17	66	3.3
	Caiman	82	4	17	37	7	-	249	314	15.7
	N.I.								11	(19.6)
From c. Camoruco to Hato La Batea (6.7 km) 13 February 1992	*Crocodylus*	0	0	2	7	4	6	4	23	3.4
	Caiman	-	-	5	4	1	-	-	10	1.5
	N.I.								9	(6.3)
From c. Camoruco to Hato La Batea (6.7 km) 4 March 1992	*Crocodylus*	0	-	5	6	14	5	13	43	6.4
	Caiman	40	-	8	9	2	-	22	41	6.1
	N.I.								4	(13.1)
From c. Camoruco to Hato La Batea (6.7 km) 5 March 1992	*Crocodylus*	-	0	7	4	5	2	13	31	4.6
	Caiman	40	4	4	16	2	-	12	38	5.7
	N.I.								6	(11.2)
Downstream from Puente Nuevo (2 km).2 Dec. 1993[2]	*Crocodylus*	-	8	-	-	-	10	5	23	11.5
	Caiman	0	0	0	0	-	-	0	0	0.0
Downstream from Puente Nuevo (4.3 km) 12 April 1996	*Crocodylus*	120	-	8	3	1	6	4	22	5.1
	Caiman	-	5	3	1	3	-	1	13	3.0
	N.I.								4	(9.1)
Downstream from Puente Nuevo (4.7 km) 15 April 1996	*Crocodylus*	140	-	5	1	0	8	2	16	3.4
	Caiman	-	3	3	2	1	-	7	16	3.4
	N.I.								6	(8.1)

B-3. (Continued)

Place and Date	Species	Size Categories (cm of TL)						WD	Total	Density Ind./km
		H	<60	60-120	120-180	180-240	>240			
Downstream from Puente Nuevo (to *carama*) (1.9 km) 7 March 1997	*Crocodylus*	0	0	15	1	0	13	2	31	16.3
	Caiman	0	0	1	1	0	-	-	2	1.1
	N.I.								-	
Upstream from Hato La Batea (2 km) 17 April 1996	*Crocodylus*	20	-	1	1	0	2	2	6	3.0
	Caiman	-	1	10	6	2	-	13	32	16.0
	N.I.								3	(20.5)
Upstream from Hato La Batea (2 km) 6 May 1996	*Crocodylus*	51	-	1	1	0	2	1	5	2.5
	Caiman	1	1	6	8	1	-	4	20	10.0
	N.I.								2	(13.5)
Upstream from La Batea (Lorenzo) (3 km) 12 February 1997	*Crocodylus*	0	0	6	6	0	2	8	22	7.3
	Caiman	0	0	5	8	1	-	4	18	6.0
	N.I.								2	14.0
Upstream from La Batea (Lorenzo) (2.9 km) 15 February 1997	*Crocodylus*	0	0	7	3	0	2	3	15	5.2
	Caiman	1	1	6	10	4	-	1	22	7.6
	N.I.								1	13.1
Upstream from La Batea (Lorenzo) (2.9 km) 16 April 1997	*Crocodylus*	0	0	6	3	0	2	6	17	5.7
	Caiman	12	4	15	10	0	-	10	39	13.4
	N.I.								3	20.3

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1 Combination of surveys conducted in consecutive nights.

2 Survey carried out by John Thorbjarnarson, Miriam Lugo, and Carlos Chávez.

B-4. Sections Hato La Batea to Hato Merecure. WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include hatchlings. Figures within parentheses under the Density column represent total crocodilian densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
From Hato La Batea	*Crocodylus*	-	3	35	4	2	8	4	56	10.8
to Hato Merecure	*Caiman*	2	0	5	8	0	-	20	33	6.3
(5.2 km)	N.I.								4	(17.9)
25-26 Febr 1993[1]										
From Hato La Batea	*Crocodylus*	-	3	9	4	3	1	4	24	4.6
to Hato Merecure	*Caiman*	10	6	33	16	1	-	73	129	24.8
(5.2 km)	N.I.								12	(31.7)
11 March 1996										
From Hato La Batea	*Crocodylus*	-	1	5	6	5	8	3	28	5.4
to Hato Merecure	*Caiman*	2	2	20	15	1	-	101	139	26.7
(5.2 km)	N.I.								7	(33.5)
19 March 1996										
From Hato La Batea	*Crocodylus*	7	-	9	9	3	8	9	38	7.3
to Hato Merecure	*Caiman*	1	5	10	13	3	-	75	106	20.4
(5.2 km)	N.I.								8	(29.2)
16 April 1996										
From Hato La Batea	*Crocodylus*	47	-	6	5	6	4	2	23	4.4
to Hato Merecure	*Caiman*	0	1	14	14	2	-	23	54	10.4
(5.2 km)	N.I.								12	(17.1)
6 May 1996										
From Hato La Batea	*Crocodylus*	-	-	-	-	-	-	49	49	9.4
to Hato Merecure	*Caiman*	-	-	-	-	-	-	8	8	1.5
(5.2 km)	N.I.								5	(11.9)
30 January 1997										
From Hato La Batea	*Crocodylus*	0	0	14	1	1	13	16	45	8.7
to Hato Merecure	*Caiman*	0	0	2	3	1	-	8	14	2.7
(5.2 km)	N.I.								7	(12.7)
5 February 1997										

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[1] Combination of surveys conducted in consecutive nights.

B-4. (continued)

Place and Date	Species	Size Categories (cm of TL)								
		H	<60	60- 120	120- 180	180- 240	>240	WD	Total	Density Ind./km
From Hato La Batea	*Crocodylus*	120	0	12	5	3	18	8	46	8.8
to Hato Merecure	*Caiman*	-	4	14	25	3	-	63	109	21.0
(5.2 km)	N.I.								6	(31.0)
27 April 1997										
Downstream from	*Crocodylus*	60	-	2	0	2	0	3	7	2.8
Hato La Batea	*Caiman*	0	1	7	10	2	-	32	52	20.8
(2.5 km approx.)	N.I.								4	(25.2)
14 June 1991										
Downstream from	*Crocodylus*	0	0	8	5	2	14	9	38	12.7
Hato La Batea 3 km	*Caiman*	0	0	1	1	1	-	1	4	1.3
14 February 1997	N.I								2	0.7
Downstream from	*Crocodylus*	0	0	2	1	0	5	3	11	5.5
Hato La Batea 3 km	*Caiman*	0	0	1	1	0	-	1	3	1.5
26 February 1997	N.I.								0	7.0

B-5. Sections Cojedes river upstream from the opening of Caño Amarillo to Merecure Ranch. WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include individuals less than 60 cm in total length. Figures within parentheses under the Density column represent total crocodilians densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
Caño Amarillo to Hato Merecure (8.4 km) 13 June 1991	*Crocodylus*	-	-	2	3	3	0	0	8	1.0
	Caiman	0	0	1	2	2	-	0	5	0.6
	N.I.								4	(2.0)
Caño Amarillo to Hato Merecure 8.4 km 5 May 1994	*Crocodylus*	169	-	21	-	4	5	1	35	4.2
	Caiman	5	-	17	36	8	-	100	161	19.2
	N.I.								22	(26.0)
Caño Amarillo to Hato Merecure 8.4 km 7 May 1996	*Crocodylus*	5	-	12	9	1	5	0	27	3.2
	Caiman	-	7	11	15	3	-	17	53	6.3
	N.I.								9	(10.6)
Caño Amarillo to Hato Merecure (8.4 km) 29 January 1997	*Crocodylus*	0	0	23	16	3	5	10	57	6.8
	Caiman	5	12	31	27	6	-	30	106	12.6
	N.I.								12	20.8
Caño Amarillo to Hato Merecure 8.4 km 4 February 1997	*Crocodylus*	0	0	15	18	2	8	9	52	6.2
	Caiman	-	3	23	24	8	-	30	88	10.5
	N.I.								14	18.3
Caño Amarillo to Hato Merecure (8.4 km) 30 April 1997	*Crocodylus*	63	0	17	24	0	7	1	49	5.8
	Caiman	7	13	32	40	15	-	47	147	17.5
	N.I.								8	24.3

B-6. Section: southern part of the study area. WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include individuals less than 60 cm in total length. Figures within parentheses under the Density column represent total crocodilians densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
Upstream from Sucre (10 km) 16 March 1994	*Crocodylus*	0	0	0	1	-	-	-	1	0.1
	Caiman	67	-	80	186	21	-	405	692	69.2
										(69.3)
Upstream from Sucre (11.6 km) 9 April 1996	*Crocodylus*	-	3	0	1	0	0	0	4	0.3
	Caiman	19	13	37	99	6	-	85	238	20.5
	NI.								8	(21.5)
Upstream from Sucre (11.6 km) 10 April 1996	*Crocodylus*	0	-	3	0	1	0	0	4	0.3
	Caiman	18	13	50	82	7	-	75	227	19.6
	N.I.								8	(20.6)
Upstream from Sucre (11.6 km) 25 April 1996	*Crocodylus*	0	-	3	0	0	0	1	4	0.3
	Caiman	34	25	27	70	5	-	72	199	17.2
	N.I.								22	(19.4)
Upstream from Sucre (12.5 km) 18 April 1997	*Crocodylus*	0	-	2	0	0	0	2	2	0.2
	Caiman	71	46	87	66	7	-	177	325	26.0
	N.I								8	26.8
Caño La Culebra 12.8 km upstream from Cojedes river 11 April 1996	*Crocodylus*	-	0	4	3	1	0	4	12	0.9
	Caiman	18	7	22	47	8	-	139	223	17.4
	N.I.								25	(20.3)
Caño La Culebra 12.8 km upstream from Cojedes river 26 April 1996	*Crocodylus*	0	-	5	2	1	0	3	11	0.9
	Caiman	0	14	30	46	3	-	123	216	16.9
	N.I.								35	(20.5)
Caño La Culebra 12.8 km upstream from Cojedes river 19 April 1997	*Crocodylus*	-	0	5	4	0	0	1	10	0.8
	Caiman	57	12	53	44	0	-	170	279	21.8
	N.I.								25	24.5

B-7. Other sections of the study area. WD = Without Data, individuals for which the species was identified but not the size. N.I. means Not identified crocodilian. Total does not include hatchlings Figures within parentheses under the Density column represent total crocodilian densities. Surveys are organized chronologically and from the most inclusive to the less inclusive.

		Size Categories (cm of TL)								
Place and Date	Species	H	<60	60-120	120-180	180-240	>240	WD	Total	Density Ind./km
SARARE RIVER										
Caño Masato	*Crocodylus*	-	4	3	-	1	-	-	8	4.0
(Pimpinela) 2 km.	*Caiman*	-	-	-	1	1	-	4	6	3.0
5 April 1993	N.I								-	(6.5)
RIO COJEDES-SARARE										
Downstream from	*Crocodylus*	64	-	8	8	9	6	8	39	4.9
Amparo-Santa	*Caiman*	-	7	8	9	-	-	2	26	3.3
Cruz bridge (8 km)	N.I								12	(9.6)
4 May 1993										
Downstream from	*Crocodylus*	256	0	16	4	0	6	0	26	3.1
Amparo-Santa	*Caiman*	0	7	5	17	6	-	16	51	6.1
Cruz bridge (8.4 km)	N.I.								4	9.6
29 April 1997										
LAS MAJAGUAS										
9 km of shoreline	*Caiman*	-	1	8	3	5	-	1	18	2.0
18 Feb 1993	N.I.								7	(2.8)

LITERATURE CITED

André, E. 1904. A naturalist in the Guianas. Thomas Nelson &Sons, London.

Angermeier, P. L., and J. R. Karr. 1996. Biological Integrity versus biological diversity as policy directives: Protecting biotic resources. Pp. 264-275 *in*: Samson, F. B., and F. L. Knopf (eds). Ecosystem Management. Selected readings. Springer, New York.

Appun, K. F. 1961 [1871]. En los trópicos. Universidad Central de Venezuela. Ediciones de la Biblioteca. Caracas.

Arcand, B. 1976. Cuiva food production. Canadian Review Sociol. Anthrop. 13:387-396.

Ashford, R. W., and R. Muller. 1978. *Paratrichosoma crocodilus* n. gen n. sp. (Nematoda: Trichosomoididae) from the skin of a New Guinea crocodile. J. Helminthol. 52:215-220.

Arteaga, A., A. E. Seijas, C. Chavez, and J. Thorbjarnarson. 1994. Status and conservation of the Orinoco crocodile. An update. Pp. 143-150 *In:* Crocodiles. Proceedings of the 12th Working Meeting of the Crocodile Specialist Group, IUCN-The World Conservation Union, Gland, Switzerland. Volume 1.

Ayarzagüena, J. 1983. Ecologia del caiman de anteojos o baba (*Caiman crocodilus* L) en los llanos de Apure, Venezuela. Doñana Acta Vertebrata 10(3):1-134.

Ayarzagüena, J. 1984. Primeros datos de crecimiento de *Crocodylus intermedius* en semilibertad. Mem. Soc. Cienc. Nat. La Salle 44(122):149-150.

Ayarzagüena, J. 1987. Conservación del caimán del Orinoco (Crocodylus *intermedius*) en Venezuela. Parte I. Rio Cojedes. FUDENA, WWF-US, Proyecto 6078.

Ayarzagüena, J. 1990. An update on he recovery program for the Orinoco crocodile. Crocodile Specialist Group Newsletter 9:16-18.

Becker, C. D., and D. A. Neitzel (eds.). 1992. Water quality in North American rivers systems. Battelle Press, Columbus, OH.

Beintema, A. J. 1994. Condition indices for wader chicks derived from body-weight and bill-length Bird Study 41:68-75.

Blake, D. K. 1974. The rearing of crocodiles for commercial and conservation purposes Rhodesia Science News 8(10):315-324.

Blake, D. K., and J. P. Loveridge. 1975. The role of commercial crocodile farming in crocodile conservation Biol. Conserv. 8:261-271.

Blohm, T. 1948. Observaciones sobre los caimanes traidos del río Orinoco en abril de 1946. Mem. Soc. Cienc. Nat. La Salle 8(22):129-132.

Blohm, T. 1973. Conveniencia de criar cocodrilos en Venezuela con fines económicos y para prevenir su extinción. Primer Simposio Internacional sobre la Fauna Silvestre y Lacustre Amazónica Manaus, Brazil. November 26-December 1.

Blus, L. J., B. S. Neely, Jr., A. A. Belisle, and R. M. Prouty. 1974. Organochlorine residues in brown pellican eggs: relation to reproductive success. Environ. Pollut. 7:81-91.

Brandt, L. 1991 Growth of juveniles alligators in Par Pond, Savannah River site, South Carolina Copeia 1991(4):1123-1129

Brazaitis, P. 1973 The identification of living crocodilians Zoologica 58:59-101.

Calzadilla V., F. 1948 Por los Llanos de Apure Ediciones del Ministerio de Educación Nacional, Direccion de Cultura Caracas, Venezuela

Campo, M., and F. Rodriguez 1995. Evaluacion de la calidad del ambiente acuático del rio Cojedes PROFAUNA MARNR. Direccion de Manejo de Fauna Acuática Unpublished report, 202 pp

Chabreck, R. H., and T. Joanen 1979 Growth rates of the American alligator in Louisiana Herpetologica 35(1):51-57.

Codazzi, A. 1940 [1841] Resumen de la Geografia de Venezuela. Venezuela en 1841. Tomo I. Geografia Fisica. Biblioteca Venezolana de Cultura. Taller de Artes Gráficas Escuela Técnica Industrial, Caracas

Colborn, T., F. S. vom Saal, and A. M. Soto. 1993. Developmental effects of endocrine-disturbing chemicals in wildlife and Humans. Environmental Health Perspectives 101(5): 378-384

Cole, G. A. 1983. Textbook of limnology. The C. V. Mosby Company. St. Louis.

Contreras, M. A. 1989. Hidroquimica de los rios Guanare, Portuguesa, Morador, Acarigua y Cojedes, Venezuela. M.Sc. Thesis. Instituto Venezolano de Investigaciones Cientificas (IVIC). Centro de Estudios Avanzados.

COPLANARH. 1976. Criterios para la clasificación legal y control de calidad de las aguas. Pub. No. 46. Comisión del Plan Nacional de Aprovechamiento de los Recursos Hidraúlicos. Caracas, Venezuela.

Cott, H. B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (*Crocodilus niloticus*) in Uganda and Northern Rhodesia. Transactions of the Zoological Society of London 29(4):211- 358.

Coulson, T. D., R. A. Coulson, and T. Hernandez. 1973. Some observation on the growth of captive alligators. Zoologica 58:47-52.

Crawshaw, P. G. 1987. Nesting ecology of the Paraguayan caiman (*Caiman yacare*) in the Pantanal of Mato Grosso, Brazil. Master's thesis, University of Florida, Gainesville.

Culp, J. M., H. R. Hamilton, A. J. Sosiak, and R. W. Davies. 1992. Longitudinal zonation of the biota and water quality of the bow river system in Alberta, Canada. Pp. 29-49. *In:* C. D. Becker and D. A. Neitzel (eds.). Water quality in North American rivers systems. Battelle Press, Columbus, OH.

Da Silveira, R. Da, W. E. Magnusson, and Z. Campos. 1997. Monitoring the distribution, abundance and breeding areas of *Caiman crocodilus crocodilus* and *Melanosuchus niger* in the Anavilhanas Archipelago, Central Amazonia, Brazil. J. Herpetol. 31:514-520.

Depretis, P. J., and J. E. Paolini. 1991. Biochemical aspects of South American rivers: The Paraná and the Orinoco. Pp. 105- 125. *In:* E. T. Degends, S. Kempe, and J. E. Richey (eds.) Biogeochemistry of major world rivers. John Wiley & Sons, Chichester. UK.

Dodson, P. 1975. Functional and ecological signifficance of relative growth in *Alligator*. J. Zool. Lond. 175:315-355.

Donadio, R. 1981. Legislación para la fauna silvestre en Colombia. Pp. 193-198 *in*. Medem, F. 1981. Los Crocodylia de Sur America, Vol. I. Los Crocodylia de Colombia. Editorial Carrera 7a. Ltda, Bogotá.

Donoso-Barros, R. 1966a. Contribución al conocimiento de los cocodrilos de Venezuela Parte 2. Physis 26:15-32.

Donoso-Barros, R. 1966b. Contribución al conocimiento de los cocodrilos de Venezuela Conclusion. Physis 26:263-274.

Ewel, J. J., and A. Madriz. 1968. Zonas de vida de Venezuela. Memoria explicativa sobre el mapa ecológico. República de Venzuela. Ministerio de Agricultura y Cria Dirección de Investigación. Editorial Sucre, Caracas

Fabens, A. J. 1965. Properties and fitting of the Von Bertalanffy growth curve. Growth 29:265-289.

Fitzgerald, L. 1988. An evaluation of stomach flushing techniques for crocodilians. J Herpetology 23(2):170-172.

Forman, R. T. T. 1995. Land mosaics. The ecology of landscapes and regions. Cambridge University Press, New York..

Foth, H. D. Fundamentals of soil science. John Wiley & Sons, New York.

Franz, R., S. Reid, and C. Puckett. 1985. Discovery of a population of Orinoco crocodile Crocodylus intermedius in Southern Venezuela. Biological Conservation 32:137-147.

FUDENA. 1993. Plan de Acción. Supervivencia del caimán del Orinoco en Venezuela 1994-1999. Grupo de Especialistas en Cocodrilos de Venezuela. Caracas.

Garrick, L. D., and J. W. Lang. 1977. Social signals and behaviors of adult alligators and crocodiles. Amer. Zool. 17:225-239

Gerhart, K. L., R. G. White, R. D. Cameron, and D. E. Russell. 1996. Estimating fat content of caribou from body condition scores. J. Wildl. Manage. 60(4):713-718.

Godshalk, R. 1978. El Caimán del Orinoco, Crocodylus intermedius, en los Llanos Occidentales deVenezuela con observaciones sobre su distribución en Venezuela y recomendaciones para su conservación. FUDENA, Caracas, 58 pp.

Godshalk, R. 1982. Status and conservation of *Crocodylus intermedius* in Venezuela. Pp 39-53 *In:* Crocodiles. Proceedings of the 5th Working Meeting of the IUCN/SSC Crocodile Specialist Group, Gainesville, FL. IUCN Publ. N.S., Gland, Switzerland

González-Fernández, M. 1995. Reproducción del Caimán del Orinoco (*Crocodylus intermedius*) en el río Cojedes: Propuesta para su conservación. Tesis de Maestría. Universidad Nacional Experimental de los Llanos Occidentales 'Ezequiel Zamora' (UNELLEZ). Guanare.

Gorzula, S. 1978. An ecological study of *Caiman crocodilus crocodilus* inhabiting Savanna lagoons in the Venezuelan Guayana. Oecologia (Berl.) 35:21-34.

Gorzula, S., and A. E. Seijas. 1989. The common caiman. Pp 44-61 in: Crocodiles, Their Ecology Management and Conservation (IUCN Publications New Series. ISBN 2-88032-987-6).

Gould, S. J. 1966. Allometry and size in ontogeny and phylogeny. Biol. Rev. 41:587-640

Greer, A. E. 1975. Clutch size in crocodilians. J. Herpetol. 9:319-322.

Guillette, L. J., Jr. 1995. Endocrine disrupting enviromental contaminants and developmental abnormalities in embryos. Human and Ecological Risk Assessment 1(2):25-36.

Guillette, L. J., Jr. T. S. Gross, G. R. Masson, J. M. Matter, H. F. Percival, and A. Woodward. 1994. Developmental abnormalities of the gonad and abnormal sex hormone concentrations in juvenile Alligators from contaminated and control lakes in Florida. Environmental Health Perspectives 102(8):679-688.

Guillette, L. J., Jr., D. B. Pickford, D. A. Crain, A. A. Rooney, and H. F. Percival. 1996. Reduction of penis size and plasma testosterone concentration in juvenile alligators living in a contaminated environment. General and Comparative Endocrinology 101:32-42.

Gumilla, J. 1963 [1745]. El Orinoco Illustrado y Defendido. Biblioteca Nacional de la Historia. No. 68. Caracas.

Heinz, G. H., H. F. Percival, and M. L. Jenning. 1991. Contaminants in the American alligator eggs from Lake Apopka, Lake Griffin, and Lake Okeechobee, Florida. Enviromental Monitoring and Assessment 16:277-285.

Hendriks, A. J. 1995. Bioaccumulation of pollutants and its consequences. Pp. 175-180. *In* D. M Harper and A. J. D. Ferguson (eds.), The ecological basis for river management. John Wiley & Sons Ltd. Chichester. UK.

Hendricks, M. L., C. H. Hocutt, and J. R. Stauffer. 1980. Monitoring of fish in lotic habitats. Pp. 205-231 *In*: Hocutt, C. H. and J. R. Stauffer, Jr. (eds). Biological monitoring of fish. Lexington Books, Lexington, MA.

Herron, J. C. 1985. Population status, spatial relations, growth, and injuries in black and spectacled caiman in Cocha Cachu. Unpublished AB thesis, Princeton University

Hitchcock, C. B. 1948. La región Orinoco-Ventuari, Venezuela. Relato de la expedicion Phelps al Cerro Yavi. Ministerio de Educación Nacional, Dirección de Cultura. Imprenta El Compás, Caracas.

Horne, A. J., and C. R. Goldman. 1994. Limnology. McGraw-Hill, Inc., New York.

Humboldt, A. 1975 [1859-1869]. Del Orinoco al Amazonas. Viaje a las regiones equinocciales del Nuevo Continente. Edt.Labor, Barcelona. 429 p.

Hutton, J. M. 1987. Growth and feeding ecology of the Nile crocodile *Crocodylus niloticus* at Ngezi, Zimbabwe. J. Anim. Ecol. 56:25-38.

Hutton, J. M., and M. E. J. Woolhouse. 1989. Mark-recapture to assess factors affecting the proportion of a Nile crocodile population seen during spotlight counts at Ngezi, Zimbabwe, and the use of spotlight counts to monitor crocodile abundance. J. Applied Ecology 26:381-395.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Toronto.

Jacobsen, T., and J. A. Kushlan. 1989. Growth dynamics in the American alligator (*Alligator mississippiensis*). J. Zool. Lond. 219:309-328.

Joanen, T., and L. McNease. 1992. Sequence of nesting, clutch size, and hatch rate for alligators in Southwest Louisiana. Pp. 207-221. *In:* Proceeding of the 11th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission of the IUCN- The World Conservation Union, Gland, Switzerland. Volume I. ISBN 2-8317-0132-5.

Johnson, D. H., G. L. Krapu, K. J. Reinecke, and D. G. Jorde. 1985. An evaluation of condition indices for birds. J. Wildl. Manage. 46(3):569-575.

Jolicoeur, P. 1963. The multivariate Generalization of the allometry equation. Biometrics 19:497-499.

Kadlec, R. H., and R. L. Knight. 1996. Treatment wetlands. CRC Lewis Publishers, Boca Raton.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6):21-27.

King, F. W. 1973. Summary of the surveys of the status of crocodilian species in South America undertaken by Professor F. Medem. *In:* Crocodiles. IUCN Publ. N.S. Supl. Paper 41:33-36.

King, F. W. 1978. The wildlife trade. Pp. 253-271. *In:* H. P. Brokaw (ed.). Wildlife and America. U. S. Govt. Printing Office, Washington, DC.

King, F. W. 1989. Conservation and Management. Pp. 216-229. *In:* Ch. Ross, (edt.), Crocodiles and Alligators. Golden Press Pty Ltd, Silverwater, NSW, Australia.

King, F. W., and P. Brazaitis. 1971. Species identification of commercial crocodilian skins. Zoologica 56(2):15-69.

Laws, E. A. 1993. Aquatic pollution. An introductory text. John Wiley & Sons, Inc., New York.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J. Anim. Ecol. 20:201-219.

Lind, O. T. 1974. Handbook of common methods in limnology. The C. V. Mosby Company, Saint Louis.

Lugo, M. 1998. Evaluación del programa de liberación del caimán del Orinoco (*Crocodylus intermedius*)en el Refugio de Fauna Silvestre "Caño Guaritico" y alrededores. Estado Apure. M.Sc. Thesis. UNELLEZ, Guanare, Venezuela.

Machado-Allison, A. 1987. Los peces de los llanos de Venezuela. Un ensayo sobre su historia natural. Universidad Central de Venezuela. Consejo de Desarrollo Científico y Humanístico. Caracas.

Magnusson, W. E. 1985. Habitat selection, parasites and injuries in Amazonian crocodilians. Amazoniana 9(2): 193-204.

MARNR, 1995. Balance ambiental de Venezuela 1994-1995. Centro de Información y Estadísticas Ambientales. DGSIA, MARNR, Caracas.

Maitland, P. S. 1990. Biology of fresh waters. Chapman and Hall. New York.

MARNR. 1997. Datos mensuales y anuales de precipitacion (mm). Estación Palo Quemado. DGSICASV, Dirección de Hidrología y Metereología. SINAIHME. (unpublished information)

Martins, O., and J. Probst. 1991. Biogeochemestry of major African rivers: Carbon and mineral transport. Pp.127-155. *In:* E. T Degens, S Kempe, and J. E. Richey (eds.), Biogeochemistry of major world rivers. John Wiley & Sons, Chichester, UK.

Mason, C. F. 1995. River managemnt and mammal populations. Pp. 289-305. *In:* D. M Harper and A. J. D. Ferguson (eds.), The ecological basis for river management. John Wiley & Sons Ltd., Chichester, UK.

Medem, F. 1981. Los Crocodylia de Sur America, Vol. I. Los Crocodylia de Colombia. Editorial Carrera 7a. Ltda, Bogotá. 354 pp.

Medem, F. 1983. Los Crocodylia de Sur América, Vol. II. Editorial Carrera 7a. Ltda, Bogotá. 270 pp. Medina, G. 1960. Caza y conservación de fauna en Venezuela. El Agricultor Venezolano 22(216):22-28.

Medina, G. 1960. Caza y conservación de fauna en Venezuela. El Agricultor Venezolano 22(216):22-28

Messel, H., G. C. Vorlicek, A. G. Wells, and W. J. Green. 1981. Surveys of tidal rivers system study in the Northern Territory of Australia and their crocodile populations. Monograph 1. The Blyth-Cadell rivers systems study and the status of *Crocodylus porosus* in tidal waterways of Northern Australia. Oxford and Sydney.

Mitsch, W. J., and J. G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York

Mogollón, J., J. B. Colina, and C. Bifano. 1987. Geoquimica de la contaminación de dos cuencas hidrográficas de Venezuela. Interciencia 12(2):70-78.

Mondolfi, E. 1957. La conservación de nuestra fauna autóctona. Conservación 3:3-18.

Mondolfi, E. 1965. Nuestra fauna. Revista El Farol 214:2-13.

Montague, J. J. 1983. Influence of water level, hunting pressure and habitat type on crocodile abundance in the Fly River drainage, Papua New Guinea. Biol. Conserv. 26:309-339.

Montague, J. J. 1984. Morphometric analysis of Crocodylus novaeguineae from the Fly River Drainage, Papua New Guinea. Aust. Wildl. Res. 11: 395-414.

Montague, J. J. 1984. Abnormalities and injuries in New Guinea freshwater crocodile (Crocodylus novaguineae). J. Herpetology 18(2):201-204.

Mozans, H. J. 1910. Up the Orinoco and down the Magdalena. D. Appleton and Company, New York and London.

OCEI, 1993. El censo 90 en Cojedes. República de Venezuela. Oficina Central de Estadística e Informática (OCEI).

Ogden, J. C. 1978. Status and nesting biology of the American crocodile, *Crocodylus acutus*, (Reptilia, Crocodilidae) in Florida. J. Herpetol. 12:183-196.

Páez, R. 1980 [1868]. Escenas rústicas en Sur América o Vida en los Llanos de Venezuela. Ediciones Centauro. Caracas.

Parra-Pardi, G. 1974. Estudio sanitario integral del Río Yaracuy. Pub. No. 74-01, Dirección de Malariología y Saneamiento Ambiental, MSAS, Caracas, Venezuela

Pedrañez, H. 1980. Historia del estado Cojedes. Ediciones de la Presidencia de la República. Caracas, Venezuela.

Petrullo, V. 1939. The Yaruros of the Capanaparo river, Venezuela. Smithsonian Institution Bulletin (Bureau of American Ethnology) 123:167-289.

Petts, G., and P. Calows. 1996. River restoration. Blackwell Science. Oxford.

PROFAUNA. 1994. Plan Estratégico: Supervivencia del caiman del Orinoco en Venezuela. MARNR, Servicio Autónomo de Fauna, PROFAUNA, Caracas.

Ramo, C., and B. Busto. 1986. Censo aéreo de caimanes (*Crocodylus intermedius*) en el río Tucupido (Portuguesa, Venezuela) con observaciones sobre su actividad de soleamiento. Crocodiles, IUCN Publ. (New Series):109-119.

Ramo, C., B. Busto, and J. Utrera. 1992. Breeding and Rearing the Orinoco crocodile *Crocodylus intermedius* in Venezuela. Biological Conservation 60:101-108.

Rebêlo, G. H., and W. E. Magnusson. 1983. An analysis of the effect of hunting of *Caiman crocodilus* and *Melanosuchus niger* based on the sizes of confiscated skins. Biological Conservation 26:95-104.

Rivera, M., and C. Marrero. 1995. Determinación de la calidad de las aguas en las cuencas hidrográficas, mediante la utilización del Indice de Integridad Biótica (IIB). Biollania 11:127-148.

Rivero-Blanco, C. 1968. El caimán y su valiosa piel. Lineas 136:11-13.

Rodriguez, J. P., and F. Rojas. 1995. Libro Rojo de la Fauna Venezolana. PROVITA, Fundación Polar, Caracas.

Rodriguez-Olarte, D., and D. C. Taphorn. 1995. Los peces como indicadores biológicos: Aplicación del Indice de Integridad Biótica en ambientes acuáticos de los Lanos Occidentales de Venezuela. Biollania 11:27-56.

Rootes, W. L., V. L. Wright, B. W. Brown, and T. J. Hess. 1991. Growth rates of American alligators in estuarine and palustrine wetlands in Lousiana. Estuaries 14(4):489-494.

Roze, J. A. 1964. Pilgrims of the river. Nat. Hist. 73:35-41.

SAS Institute Inc. 1987. SAS user guide: Statistics. SAS Institute Inc., Cary, North Carolina.

Seijas, A. E. 1992. Status of Orinoco crocodile populations in some localities in the Venezuelan llanos. Pp 79 *In*: Crocodiles. Proceedings of the 11th Working Meeting of the Crocodile Specialist Group of the Species Survival Commission. IUCN-The World Conservation Union, Gland, Switzerland. Vol. 2.

Seijas, A. E. 1993. Cria de caimanes del Orinoco en la UNELLEZ, Venezuela. Pp. 182-195 *in*: Zoocria de los Crocodylia. Memorias de la I Reunión Regional del CSG, Grupo de Especialistas de Cocodrilos de la IUCN. IUCN-The World Conservation Union, Gland, Switzerland.

Seijas, A. E. 1995. Captive breeding and rearing as a conservation tool for the Orinoco crocodile. Pp. 596-598 in: J. A. Bissonette and P. R. Krausman, eds. Integrating People and Wildlife for a sustainable future. Proceedings of the first International Wildlife Management Congress. The Wildlife Society, Bethesda, Md.

Seijas, A. E. 1996. Coexistencia de babas y caimanes en la región costera venezolana. Pp 217-253. *In:* J. E Péfaur, Herpetología Neotropical. Actas II Congreso Latinoamericano de Herpetología. Vol. II. Universidad de Los Andes. Consejo de Publicaciones. Consejo de Desarrollo Científico, Humanístico y Tecnológico, Mérida, Venezuela.

Seijas, A. E., and I. González. 1994. Incubación artificial de huevos de caiman del Orinoco. Biollania 12(2):36-41.

Seijas, A. E., and P. Meza. 1994. El caimán del Orinoco (*Crocodylus intermedius*) en el embalse del rio Tucupido, estado Portuguesa, Venezuela.

Seijas, A. E., and S. Ramos. 1980. Caracterizacion de la dieta de la baba, *Caiman crocodilus*, durante la estacion seca en las sabanas moduladas del Estado Apure, Venezuela. Acta Biol. Venez. 10(4):373-389.

Seijas, A. E., C. Ramo, and B. Busto. 1989.Manejo de habitat para la baba: ¿Utopía o Realidad?. Trabajo presentado en el II Taller Sobre Conservación y Manejo de la Baba (*Caiman crocodilus*) en Venezuela. UNELLEZ, FUNDAFAUNA, FUNDACITE, MARNR. Guanare 21 al 23 de agosto de 1989.

Setzler-Hamilton, E. M., and J. H. Cowan. 1993. Comparing the applicability of weight-length relationship, the relative condition index and morphometric criteria to asses larval condition: A test case with striped bass. Northeast Gulf Science 13(1):13-22.

Singh, J., S. Kar, and B. Choudhury. 1986. Indian crocodilians. A ten year review of management. Pp. 62-79. *In*: Crocodiles, IUCN Publ., New Series, Gland, Switzerland.

Smith, E. N., C. R. Johnson, and B. Voigt. 1976. Leech infestation of the American alligator in Texas. Copeia 1976(4):842.

Spengler, T. J., P. L. Leberg, and W. C. Barrow. 1997. Comparison of condition indices in migratory passerines at a stopover site in coastal Louisiana. Condor 97:438-444.

Staton, M., and J. R. Dixon. 1975. Studies on the dry season biology of *Caiman crocodilus crocodilus* from the Venezuelan Llanos. Mem. Soc. Cienc. Nat. La Salle 35:237-265.

Suthers, I. M., A. Fraser, and K. T. Frank. 1992. Comparison of lipid, otolith and morphometric condition indices of pelagic juvenile cod *Gadus morhua* from the Canadian Atlantic. Mar. Ecol. Prog. Ser. 84:31-40.

Tablante-Garrido, P. N. 1961. Provincia de Apure. Monografia del Gobernador General José Cornelio Muñoz [1831]. Cuadernos Geográficos No. 1. Instituto de Geografia y de Conservación de Recursos Naturales. Universidad de Los Andes Venezuela.

Taphorn, D. C. 1992. The Characiform fishes of the Apure river drainage, Venezuela. Biollania, especial edition No. 4. Guanare, Venezuela.

Taylor, J. A. 1979. The food and feeding habits of subadult *Crocodylus porosus* Schneider in Northern Australia. Aust. Wildl. Res. 6:347-359.

Thorbjarnarson, J. (compiler) 1992. Crocodiles: An action plan for their conservation. H. Messel, F. W. King and J. P. Ross (eds.). IUCN/SSC Crocodile Specialist Group, Gland, Switzerland. 136 pp.

Thorbjarnarson, J. 1996. Reproductive characteristics of the Order Crocodylia. Herpetologica 52(1):8-24.

Thorbjarnarson, J., and A. Arteaga. 1995. Estado poblacional y conservación del caimán del Orinoco en Venezuela. Pp. 159- 170 *In:* La Conservación y el Manejo de los Caimanes y Cocodrilos en América Latina. Volume 1. Publicado por Fundación Banco Bica, Santo Tomé, Santa Fe, Argentina

Thorbjarnarson, J., and R. Franz. 1987. *Crocodylus intermedius* (Graves).Orinoco crocodile. Pp.406.1-406.2. *In*: Catalogo of American Amphibians and Reptiles. Society for the Study of Amphibian and Reptiles (SSAR)

Thorbjarnarson, J., and G. Hernández. 1992. Recent investigation on the status and distribution of Orinoco crocodile *Crocodylus intermedius* in Venezuela. Biological Conservation 62:179-188.

Thorbjarnarson, J., and G. Hernández. 1993a. Reproductive ecology of the Orinoco crocodile (*Crocodylus intermedius*) in Venezuela. I. Nesting ecology and egg and clutch relationship. J. Herpetol. 27(4):363-370.

Thorbjarnarson, J., and G. Hernández. 1993b. Reproductive ecology of the Orinoco crocodile (Crocodylus intermedius) in Venezuela. II. Reproductive and social behavior. J. Herpetol. 27(4):371-379.

Trihadiningrum, Y., N. De Pauw, I. Tjondronegoro, and R. F. Verheyen. 1996. Use of benthic macroinvertebrates for water quality assessment of the Blawi river (East java, Indonesia). Pp. 199-221 *In:* F. Sciemer and K. T. Boland (eds.)., Perspectives in tropical limnology. SPB Academic Publishing bv, Amsterdam

Val, A. L., and V. M. F. de Almeida Val. 1995. Fishes of the Amazon and their environment. Physiological and biochemical aspects. Springer, Berlin.

Venezuela. 1970. Ley de Protección a la Fauna Silvestre. Gaceta Oficial N0. 29289 August 11, 1970.

Verstraeten, P. B. 1939. Les caimans L'Apure. Bull. Commercial Belge 58:15-17.

Vila, M. A. 1956. Aspectos Geográficos del Estado Cojedes. Corporación Venezolana de Fomento. Ed. Ragón C. A. Caracas.

Virgl, J. A., and F. Messier. 1993.Evaluation of body size and body condition indices in muskrats. J. Wildl. Manage. 57(4):854-860.

Webb, G. J. W., and S. C. Manolis. 1983. *Crocodylus johstoni* in the McKinlay River area, N. T. V. Abnormalities and injuries. Australian Wildlife Research 10:407-420.

Webb, G. J. W., S. C. Manolis, and R. Buckworth. 1982. *Crocodylus johnstoni* in the McKinley river area. N. T. I. Variation in the diet and a new method of assessing the relative importance of prey. Aust. J. Zool. 30(6): 877-899.

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

Webb, G. J. W., and H. Messel. 1977. Abnormalities and injuries in the estuarine crocodile, *Crocodylus porosus*. Aust. Wildl. Research 4:311-319.

Webb, G. J. W., and H. Messel. 1978. Morphometric analysis of *Crocodylus porosus* from the North Coast of Arnhem Land, Northern Australia. Aust. J. Zool. 26:1-27.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Company. Philadelphia.

Whitney, C. 1912. The flowing road. Adventuring on the great rivers of South America. J. B. Lippincott Company, Philadelphia & London.

Wilkinson, P., A. Abercrombie, and C. Hope. 1997. Length-mass relationships in Crocodilians. Memorias 4ta. Reunión Regional del Grupo de Especialistas en Cocodrilos de America Latina y El Caribe. Villahermosa, Tabasco, México.

Winemiller, K., C. Marrero, and D. Taphorn. 1996. Perturbaciones causadas por el hombre a las poblaciones de peces de los Llanos y del Piedemonte Andino de Venezuela. Biollania 12:13-48.

Wood, J. M., A. R. Woodward, S. R. Humphrey, and T. C. Hines. 1985. Night counts as an index of American alligator population trends. Wildl. Soc. Bull. 13(3);262-272.

Woodward, A. R., and W. R. Marion. 1978. An evaluation of factors affecting night-light counts of alligators. Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32:291-302.

BIOGRAPHICAL SKETCH

Andrés Eloy Seijas Y. was born in Los Teques, Venezuela, on 13 December 1949. He is the sixth of seven childrens of the late Luis Seijas and of Gladys Yanes de Seijas. Andrés received his degree in biology from the *Universidad Central de Venezuela* in 1979. He started studying crocodilians in 1977, when he was an undergraduate student, and his interest in the conservation and sustainable management of those reptiles increased when he began working for the *Servicio Nacional de Fauna Silvestre* of Venezuela (now PROFAUNA) in 1979. He was one of the key biologist that contributed to the design of the internationally renowned caiman management program of his country.

From 1985 to 1988 Andrés was a graduated student in the Department of Wildlife and Range Sciences, University of Florida, under the Program for Studies in Tropical Conservation. He got his master's degree working on the ecological interrelationships between caiman and American crocodiles along the Venezuelan coast.

In 1989 Andrés got a position as a teacher in the Master Program in Wildlife Management in the *Universidad Nacional Experimental de los Llanos Occidentales* 'Ezequiel Zamora' (UNELLEZ). Since that time he has also been in charge of the Orinoco crocodile rearing and breeding facility of that institution and has participated actively in the program for the recovery of that species.

Andrés has been member of the Crocodile Specialist Group, Species Survival

Commission of the IUCN, since 1983, and was deputy vice-chairman for Latin American and the Caribbean of that organization from 1990-1992.

Andrés married Lemnie Falkenhagen in 1980. They met early that year when he was taking English classes in a Venezuelan Institution in preparation for his expected trip to the United States of American to pursue graduate studies. They have two children, Andrés Eloy and Sara Fabiola.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

F. Wayne King

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Conservation

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

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This dissertation was submitted to the Graduate Faculty of College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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