Status and Life History of the American Crocodile in Belize

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EXECUTIVE SUMMARY

The American crocodile (Crocodylus acutus) is one of two species of crocodiles which occur in Belize, being found on offshore cays and atolls, and in mainland coastal habitats. Because high-quality leather can be prepared from American crocodile skins, the species was subject to an intense period of over-exploitation beginning in the 1940's and ending by the late 1970's. During this period C. acutus was nearly extirpated in Belize. Legal protection was afforded the American crocodile under the Wildlife Protection Act of 1981.

Prior to the present study little was known about the abundance and distribution of the American crocodile in Belize. The limited data available suggested C. acutus was rare on the mainland, present in small numbers on several widely scattered cays, and most abundant in the Turneffe Atoll. The lack of comprehensive survey and ecological data on which to base an effective conservation strategy provided the impetus for the present study. The objectives of this study were to asses the status of C. acutus in the coastal zone, identify populations that would benefit from protection, and provide conservation recommendations to enhance recovery and insure the maintenance of viable populations in Belize.

Spotlight surveys were conducted throughout the coastal zone from July 1996 to October 1997. A total of 263 crocodiles were observed along 956.9 km of survey route (0.27 crocodiles/km). In general, the highest densities were found in the Turneffe Atoll, and somewhat lower densities on most cays. Low densities were also found on Ambergris Cay, and Bacalar Chico National Park is the only protected area where significant populations of C. acutus occur. American crocodiles are extremely rare on the mainland and most observations were of subadults, which probably represent dispersing individuals rather than members of an established population. C. acutus does not occur in any inland freshwater habitat, but is instead replaced by the more abundant Morelet's crocodile (C. moreletii). In comparison with published values from elsewhere, American crocodile densities in Belize are among the lowest reported.

Searches for nesting beaches were conducted concurrently with population surveys. Suitable nesting habitat is rare, and only 16 nesting areas were located. Forty-one (70.6%) of the 58 nests examined during this study were found in the Turneffe Atoll. The largest site was a beach on Northern Cay, Turneffe Atoll where 10 nests were found in 1997. Four additional nesting sites were identified on Blackbird Cay, Turneffe Atoll.

Elevated beach ridges are the preferred nesting habitat of the American crocodile in Belize. These ridges are usually associated with cay littoral forest, the most endangered habitat in the coastal zone, and are also frequently used as nesting sites by marine turtles.

Shallow, brackish lagoons were located adjacent to two crocodile nesting beaches. These lagoons provide essential nursery habitat for hatchlings and are a vital source of freshwater for size classes most vulnerable to osmotic stress. The presence of nursery habitat greatly increases hatchling survival, and hence recruitment. Spoilbanks were utilized as nesting habitat to a much lesser extent, but may be important where beaches are unavailable. Colonial nesting occurred at five (31.2%) of 16 sites indicating suitable nesting habitat is a limited resource.

Fourteen crocodile nests containing eggs were found during this study. Mean clutch size was 22.3, and mean clutch mass was 1.8 kg. These values are among the lowest reported for any population of C. acutus. Furthermore, the limited growth data obtained in this study indicate growth rates are likewise among the lowest reported. Diminished reproductive output and slow growth rates are thought to depress recruitment among American crocodile populations in Belize.

The largest C. acutus population in Belize occurs in the Turneffe Atoll. This population plays an extremely important role in regional metapopulation dynamics by serving as a source population for C. acutus on other cays and the mainland. Based on demographic data obtained in spotlight surveys, nest counts, and estimates of reproductive parameters, approximately 250 non-hatchling crocodiles, including 20 to 30 breeding females are present in the atoll. Using density estimates based on the area of mangrove habitat, an additional 370 crocodiles are believed present on the cays and 272 on the mainland. Summing these estimates gives a country-wide population of only about 900 non-hatchling crocodiles.

While C. acutus is legally protected, a number of threats cast doubt on the continued survival of the species in Belize. Opportunistic killing and the drowning of crocodiles in monofilament gill nets removes small numbers from the population each year. However, given the limited size of the population, the loss of even a few animals, especially breeding females constitutes a significant source of mortality.

Habitat destruction, especially the development of nesting beaches and associated nursery habitat, is the greatest threat to the continued viability of C. acutus populations. Because beaches often represent the only elevated ground on cays otherwise at or slightly below sea level, they are highly sought as sites for fishing camps and tourist resorts. Consequently, beach ridges and associated cay littoral forest are considered the most critically endangered coastal habitat in Belize. The preservation of beach ridges and nursery habitat is therefore crucial to long-term population viability, and is the single most important element of American crocodile conservation strategy in Belize.

The results of this study indicate that American crocodile populations have not recovered from past exploitation, and the status of the species remains tenuous. The largest population (Turneffe Atoll) numbers less than 300 individuals, and reproduction is dependent on two major beaches which remain unprotected and vulnerable to development. The continued protection and classification of the American crocodile as an endangered species in Belize is therefore warranted. Together with marine turtles and manatees, the American crocodile should be considered a flagship species essential to the preservation of critical coastal zone habitats.

The objective of the following recommendations is to ensure the continued survival and enhance recovery of populations in Belize. Recommendations are listed in order of importance necessary to achieve this goal. Unless appropriate conservation measures are swiftly enacted the American crocodile could become locally extinct early in the next century.

I. Preservation of known and potential nesting habitat.

Viable crocodile populations cannot be maintained without adequate protection of nesting beaches, and freshwater and brackish pools associated with these sites. If nesting beaches are developed, recruitment will be drastically curtailed and perhaps cease. Protection of beach ridges will also ensure the preservation of marine turtle nesting habitat and significant tracts of cay littoral forest. The following is a list of critical sites which warrant the most stringent protection. These sites are listed in order of priority and a description and coordinates of each is provided in Table 13 (page 87).

1. Northern Cay, Turneffe Atoll

This is the most significant nesting beach yet identified in Belize, and preservation is essential to maintain viable populations in the Turneffe Atoll. Given the importance of the atoll in regional metapopulation dynamics, protection of this site is also vital for long-term survival of C. acutus in Belize. There is an adjacent nursery lagoon which must also be protected. This beach is within the boundaries of the proposed Turneffe Atoll. National Park.

2. Blackbird Cay, Turneffe Atoll

This privately owned beach is considered critical crocodile nesting habitat, and also encompasses known marine turtle nesting sites, and the largest contiguous tract of cay littoral forest remaining in the Turneffe Atoll. Every effort should be made to include this beach within the proposed national park.

3. Other sites in Turneffe Atoll

The nesting beach on Deadmans Cay should be protected against development as it is highly likely that crocodiles will utilize this site in the future. Also beaches along the eastern shore of Calabash and elsewhere on Deadmans Cay represent potential nesting habitat and as much area as possible should be protected from future development.

4. Long Cay

This is the most significant nesting site outside of the Turneffe Atoll. A sheltered lagoon adjacent to the beach provides excellent nursery habitat. There is also a large stand of cay littoral forest along part of this beach. Some form of protection should be afforded this site.

5. Other Sites

Nest sites at University College of Belize, and the WASA facilities in San Pedro are already on public property and can be protected by the responsible GOB entities. A number of potential nesting sites are available on spoilbanks at the WASA facility, and the surrounding swamps provide significant nursery habitat.

II. Long-term monitoring program.

A long-term (10+ years) population monitoring program, based on nest counts and spotlight surveys is essential to detect future population trends and evaluate the success of conservation strategies. Protection of nesting beaches should be tightly coupled with an annual survey of these sites. Nest monitoring is recommended for the following sites which are listed in order of priority (numbers in parentheses correspond to Table 13; page 87):

1. Northern Cay, Turneffe Atoll (12).
2. Blackbird Cay, Turneffe Atoll (10, 11).
3. Ambergris Cay (2, 3).
4. Long Cay (7).
5. Cay Caulker (5).
6. Belize City (4).
8. Maps Cay (8).

Additionally, Deadmans Cay (13) and the beaches along the eastern shore of Turneffe Atoll (Appendix 3) should be monitored for future nesting activity. It is also essential to continue to search other potential habitat in an attempt to locate additional nesting areas. Reconnaissance should be conducted opportunistically during the discharge of other duties. As additional sites are found every effort should be made to incorporate them into the existing framework of protected areas. Furthermore, it is imperative to evaluate all coastal development projects with regards to their potential impact on crocodile nesting habitat before the relevant permits are issued. Permits should not be issued for development of any known nesting area.

In addition to nest counts, population trends should be monitored with spotlight surveys which are readily comparable to baseline data resulting from this study. Spotlight surveys are recommended for population monitoring at the following sites (numbers in parentheses correspond to site accounts listed in Appendix 1):

Turneffe Atoll

1. Northern Lagoon (6).
2. Northern Lagoon to Crikozeen Creek (7).
3. Cay Bokel to Tarpon Creek (1).
4. Blackbird Cay - western shore (3).
5. Blackbird Cay - eastern shore (4).
6. Calabash Cay (4).

Ambergris Cay

1. San Pedro Lagoon (3).
2. Western Shoreline (4).
3. WASA Facility (5).
4. BCNP - Laguna Cantena (9).
5. BCNP - Western Shore of Ambergris Cay (8).
6. BCNP - Santa Cruz Lagoon (7).

An on-going mark-recapture program at Bacalar Chico National Park would also prove a valuable supplement to nest monitoring and spotlight surveys. Technical assistance and data analysis could be provided by Wildlife Conservation Society biologists.

III. Restrict the use of monofilament gill nets

The drowning of crocodiles in monofilament gill nets represents a significant source of mortality throughout the coastal zone. The use of monofilament nets in Bacalar Chico National Park should be immediately banned. Monofilament nets should also be prohibited in the proposed Turneffe Atoll National Park, and all other protected areas in the coastal zone. Banning gill nets and replacing them with wire mesh on fish traps will eliminate the incidental drowning of crocodiles, brown pelicans, and cormorants.

Additionally, the widespread use of gill nets in southern Belize is inhibiting regionally recovery of C. acutus. Nets placed across rivers often completely obstruct the channel, and although this practice is illegal, existing laws are not being enforced. In addition to drowning crocodiles, these nets deny manatees upstream passage to critical refuge habitats. Laws prohibiting this practice need to be rigorously enforced.

IV. Crocodiles should be promoted as an ecotourism attraction

Because tourism is the fastest growing industry in Belize, and estimated to be the largest source of foreign exchange, the government of Belize has specifically listed small-scale ecotourism as a preferred option in the 1994 to 1998 Development Plan. Crocodiles have considerable ecotourism potential as they are readily located at night and become habituated to the presence of tourists. Additionally, most tourists are enthusiastic about the prospect of encountering large crocodiles at close-range, and crocodiles are usually the most sought after species on wildlife viewing trips. Therefore crocodile watching should be actively promoted as a form of non-consumptive wildlife use. While many tour operators already advertise C. moreletii as a featured species on boat trips, C. acutus has been largely overlooked.

Potential opportunities for C. acutus-based ecotourism exist, especially in San Pedro where large crocodiles are easily found in San Pedro Lagoon, a short boat ride from town. Meetings should be held with tour operators in San Pedro, Cay Caulker, and elsewhere along the coast to make them aware of these potential opportunities. Members of the community, especially entrepreneurs, whose livelihood depends on the continued survival of the American crocodile can be expected to support and enhance future conservation efforts.

V. Public Education

A public education campaign should be conducted, emphasizing that crocodiles are not a threat to humans, and killing is unnecessary and illegal under Belizean law. Public education must also stress the need for proper disposal of fish and lobster offal to avoid attracting crocodiles into the vicinity of habitations. Additionally, there is an urgent need to conduct workshops with local police and magistrates, who are often unaware of existing conservation legislation concerning crocodiles and other wildlife.

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INTRODUCTION

The American crocodile (Crocodylus acutus) is widely distributed in the northern neotropics, being found on the Atlantic and Pacific coasts of Mexico, Central America, and northern South America, as well as the Caribbean islands of Cuba, Jamaica, Hispaniola, and the southern tip of Florida, USA (Figure 1). Although primarily a coastal species, C. acutus is known to extend its distribution well inland, especially along major rivers, and may inhabit land-locked lakes of varying salinities (Thorbjarnarson, 1989). C. acutus populations have declined throughout much of this range due to over-exploitation and habitat destruction, and most populations are now considered threatened (Thorbjarnarson, 1989).

The American crocodile is one of two species of Crocodylus which occur in Belize (Groombridge, 1987). C. acutus is found in mainland coastal habitats and offshore islands, while Morelet's crocodile (Crocodylus moreletii) occurs in both mainland coastal and inland habitats (Platt 1996; Platt and Thorbjarnarson, 1996). Both species are currently listed as endangered under the United States Endangered Species Act and are on Appendix I of the Convention on Trade in Endangered Species of Flora and Fauna (Thorbjarnarson, 1992). The American crocodile is also considered threatened by the Coastal Zone Management Program, Department of Fisheries, Government of Belize due to opportunistic killing, habitat loss, and past over-exploitation by commercial skin hunters (McField et al., 1996).

High quality leather can be prepared from C. acutus and C. moreletii skins (Groombridge, 1987) and past over-harvesting has depleted crocodile populations throughout Central America (Thorbjarnarson, 1992). Commercial crocodile hunting began in Belize during the late 1930's and early 1940's as the importance of forest products in the local economy declined (Hope and Abercrombie, 1986). Subsequent over-harvesting led to the depletion of both C. acutus and C. moreletii populations (Charnock-Wilson, 1970). Crocodile skins were sold to buyers in villages and larger towns, and after progressing through a chain of middlemen, exported to Europe for processing (Abercrombie et al., 1982; Hope and Abercrombie, 1986). Unfortunately, quantitative survey data from this period are lacking, and the practice of categorizing both spotted cat and crocodile skins as simply 'hides and skins" in government trade statistics makes it difficult to determine past levels of exploitation (Frost, 1974; Abercrombie et al., 1982; Hope and Abercrombie, 1986). Charnock-Wilson (1970) estimated 3,000 linear feet (ca. 950 m) of crocodile skins were legally exported each year, but makes no distinction between C. acutus and C. moreletii. Additionally, a considerable number of crocodiles were shot by sport hunters and members of the British army garrison, and an unknown number of skins were illegally exported (Charnock-Wilson, 1970).

By the 1960's C. acutus and C. moreletii were nearly extirpated in Belize (Charnock-Wilson, 1970). Limited surveys conducted in northern Belize during the late 1970's found few adult C. moreletii (Abercrombie et al., 1980; 1982). Abercrombie et al. (1982) estimated a country-wide population of only 2,200 to 2,500 C. moreletii, although

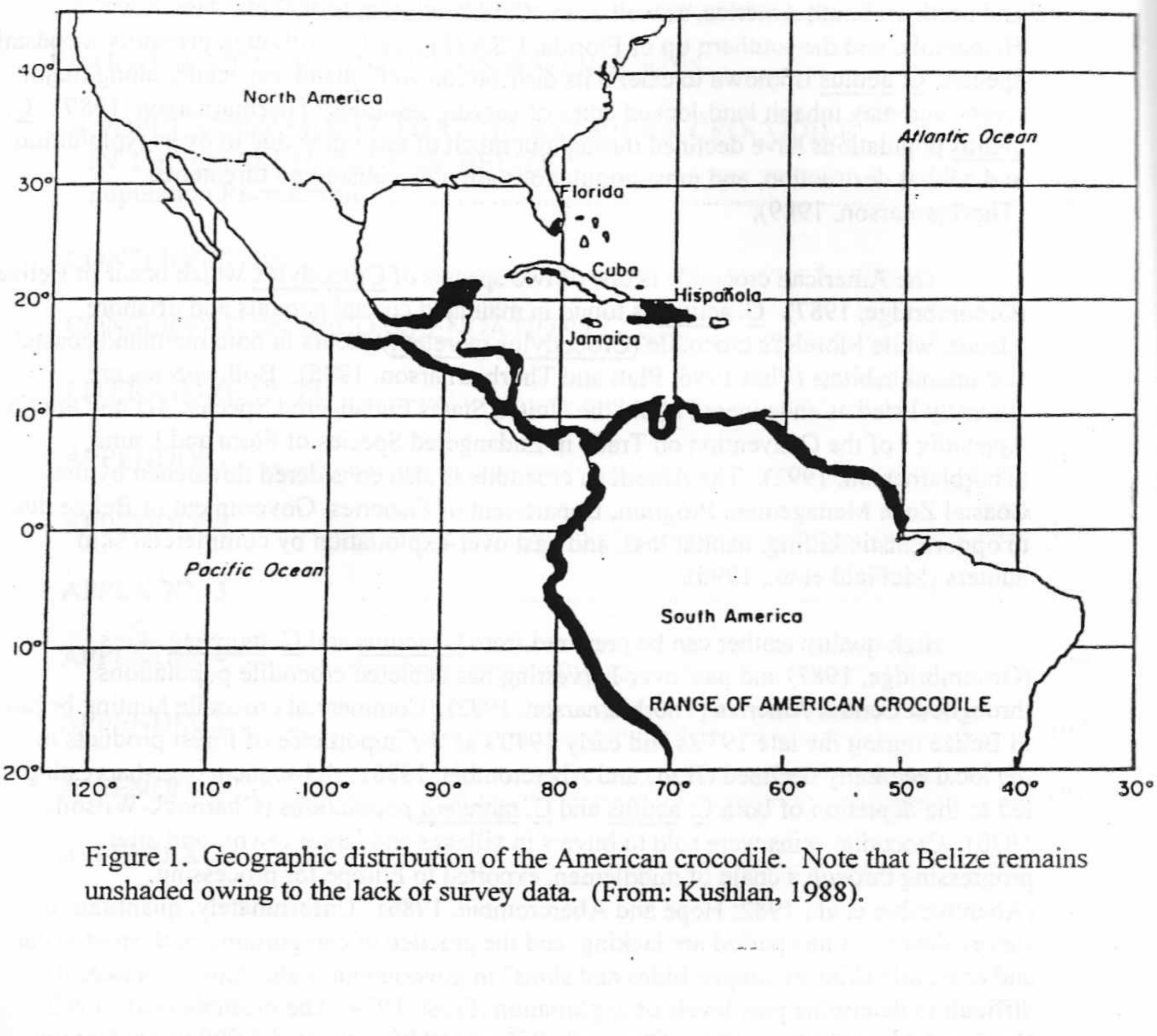


Figure 1. Geographic distribution of the American crocodile. Note that Belize remains unshaded owing to the lack of survey data. (From: Kushlan, 1988).

the authors caution that total population size was probably underestimated. Legal protection was afforded to both species of crocodile under the Wildlife Protection Act of 1981 (Marin. 1981; Klemm and Navid. 1989). More recent surveys have noted a substantial increase in C. moreletii populations. suggesting recovery from past over-harvesting has occurred (Platt. 1996).

However, little is known about the abundance and distribution of C. acutus in Belize. According to Lee (1995) the distribution of the American crocodile in the Yucatan Peninsula and Belize is uncertain owing to confusion with Morelet's crocodile. Neill and Allen (1961) reported the collection of a juvenile American crocodile from a mangrove swamp in Belize City and considered the species rare. Powell (1971; 1973) concluded C. acutus were present on some offshore islands, but extinct on the mainland. and King et al. (1982) noted some island populations had been extirpated. According to Ross (1997). persons interviewed in Belize during 1972 and 1973 stated that few, if any C. acutus remained on offshore islands. Abercrombie et al. (1980; 1982) and Platt (1996) failed to find American crocodiles during surveys of mainland habitats. Based on an interview of a local skin dealer, Perkins (1983) estimated a country-wide population of C. acutus as high as 10,000 to 20,000, but caution that these numbers are highly speculative.

The largest remaining American crocodile population in Belize may occur in the Turneffe Atoll (Perkins, 1983; Thorbjarnarson, 1992), and this is the only locality given on the range map of Lee (1995). However, American crocodiles are also present on Cay Caulker (Meerman, 1993), and the northern Corozal District (Meerman. 1992: Ouboter. 1993). Platt and Thorbjarnarson (1996) present additional survey data from the Turneffe Atoll, northern Ambergris Cay, and Maps Cay, and summarize existing distributional records.

These reports notwithstanding, the current status of the American crocodile in Belize remains poorly known, and comprehensive survey data are lacking. Furthermore. virtually nothing is known concerning the ecology of this species in Belize. Such information is essential for the development of appropriate conservation strategies. and surveys of American crocodile populations in Belize have been accorded high priority by the IUCN/SSC Crocodile Specialist Group (Thorbjarnarson. 1992).

The objectives of this study were to obtain baseline data and assess the status of American crocodile populations in the coastal zone of Belize. identify populations that could benefit from protection, gather basic life history data. resolve the systematic status of the C. acutus/C. moreletii complex in coastal Belize. and provide conservation recommendations based on these findings.

STUDY AREA

The Coastal Zone Management Unit, Department of Fisheries, Government of Belize, broadly defines the coastal zone (CZ) to include shoreline, coastal alluvial plains and watersheds, estuaries, cays, atolls, and the subtidal area within the 12 mile (19.2 km) territorial limit and the 200 mile (320 km) Economic Exclusion Zone (McField et al., 1996). However, for the purpose of this study, the coastal zone is defined as all offshore cays and atolls, and all wetlands, both freshwater and saline, within 10 km of the Caribbean Sea.

Coastal Cays

The CZ includes 1,060 sand and mangrove cays, three offshore atolls, and extensive mainland wetlands. The Belize barrier reef extends 220 km along the coast, from Ambergris Cay in the north to the Gulf of Honduras in the south, and is separated from the mainland by a narrow (19-30 km) stretch of water known as the inner channel (McField et al., 1996). Within the inner channel there are approximately 450 cays with a land area of 689 km^2. These cays range in size from small ephemeral sand spits to large permanent islands which sustain human settlements (Hartshorn et al., 1984). While Ambergris Cay is traditionally considered the largest of Belizean Cays, it is actually a mainland extension of the Xcalac Peninsula of Mexico. As such it encompasses a diversity of upland habitats not typically found on other cays (Hartshorn et al., 1984). Much of northern Ambergris Cay is included in Bacalar Chico National Park (BCNP). Most cays are low-lying islands less than 1.0 m above mean sea level, and subject to periodic inundation. Elevated beach ridges occur on the windward (eastern) shore of some islands, but wave action is significantly dissipated by the barrier reef, and consequently beaches are absent or greatly reduced on many cays (Hartshorn et al., 1984).

The low-lying portions of cays are dominated by red (Rhizophora mangle) and black mangrove (Avicennia germinans) swamps, with a transition zone of buttonwood (Conocarpus erectus) and white mangrove (Laguncularia racemosa) bordering more elevated habitats (McField et al., 1996). Mangrove vegetation is found on 8,771 ha in the Turneffe Atoll, and 12,913 ha on other cays (McField et al., 1996). Beach ridge habitats are characterized by cay littoral forest composed of black poisonwood (Metopium brownei), gumbo limbo (Bursera simarubra and Gilibertia concinna), cocoplum (Chrysobalanus icaco), wild sea grape (Cocoloba uvifera) and saltwater palm (Thrinax radiata) (McField et al., 1996). Much of this habitat type has been cleared for human settlements or converted to coconut (Cocos nucifera) plantations, and cay forest is now considered the most threatened coastal habitat in Belize (McField et al., 1996). Coconut palms have also escaped from cultivation and inhibit regeneration of native tree species in many remaining stands of cay forest (Minty et al., 1995).

Many cays are surrounded by extensive turtle grass (Thalassia testudinum) beds, which support a diverse assemblage of marine fauna (Hartshorn et al., 1984). Most turtle grass beds are still intact, and damage from human activity is considered minimal and restricted to a few developed areas (McField et al., 1996).

Atolls

Three atolls are found outside of the Belize barrier reef: Turneffe Atoll, Lighthouse Atoll, and Glovers Reef (Figure 2). There is only one other such atoll in the Western Hemisphere, Banco Chinchorro on the coast of Quintana Roo, Mexico (Stoddart, 1962). Turneffe Atoll (Figure 3) is located approximately 35 km east of Belize City, and is 50 km long and 16 km wide, with an estimated surface area of 533 km^2 (Perkins, 1983). Turneffe Atoll consists of a chain of islands partially enclosing three shallow lagoons: Southern, Central, and Northern or Vincents Lagoon. A near continuos beach ridge extends along the windward shore of the atoll, with a maximum elevation about 1.5 m above sea level (Stoddart, 1962; Minty et al., 1995). Atoll vegetation has been described by Stoddart (1962) and Minty et al. (1995), and is similar to habitats found on other cays.

Turneffe Atoll remains largely undeveloped. Resorts are located on Cay Bokel, and at the northern and southern ends of Blackbird Cay. Coral Cay Conservation/ University College of Belize has established a Marine Research Center (MRC) on Calabash Cay. There are also many small fishing camps of varying degrees of permanence scattered throughout the atoll, and most are constructed on beach ridges. The atoll is under increasing pressure for development, and the construction of several additional tourist facilities has been proposed (Platt and Thorbjarnarson, 1996).

Lighthouse Atoll (Figure 2 and 3) is located approximately 75 km east of Belize City and has an estimated surface area of 126 km^2 (Hartshorn et al., 1984). Much of this is underwater, and terrestrial habitat is restricted to Northern Cay, Sandbore Cay, Long Cay, and Half-Moon Cay. The latter is encompassed within the Half-Moon Cay National Monument (McField et al., 1996; Zisman, 1996), while the remainder of the atoll is privately owned. A resort with an airstrip is located on Northern Cay, and Sandbore and Long Cay remain undeveloped. Glovers Reef is not included in the present study as it contains little terrestrial habitat and American crocodiles are not present (James Powell, Wildlife Conservation Society, pers. comm.).

Mainland Habitats

Lagoons and estuaries occur along the coastal mainland of Belize (Figure 4) and receive the discharge of 18 major watersheds (Hartshorn et al., 1984). The coastal mainland is categorized as northern (north of Belize City) and southern (south of Belize City). Northern Belize is a low karst platform with much of the coastline below sea level. The southern section is uplifted and characterized by many short streams draining the Maya Mountains that terminate in short deltas (McField et al., 1996). Cayetano (1995) recognized four physiographic provinces along the coastal mainland of Belize: the northern coast extending from the Mexican border to Rocky Point (Corozal District), the lagoon systems and associated wetlands from Rocky Point south to Belize City, the lagoons and river deltas south of Belize City extending to Placencia Lagoon, and the southern swamps and small river deltas from Placencia to the Guatemalan border.

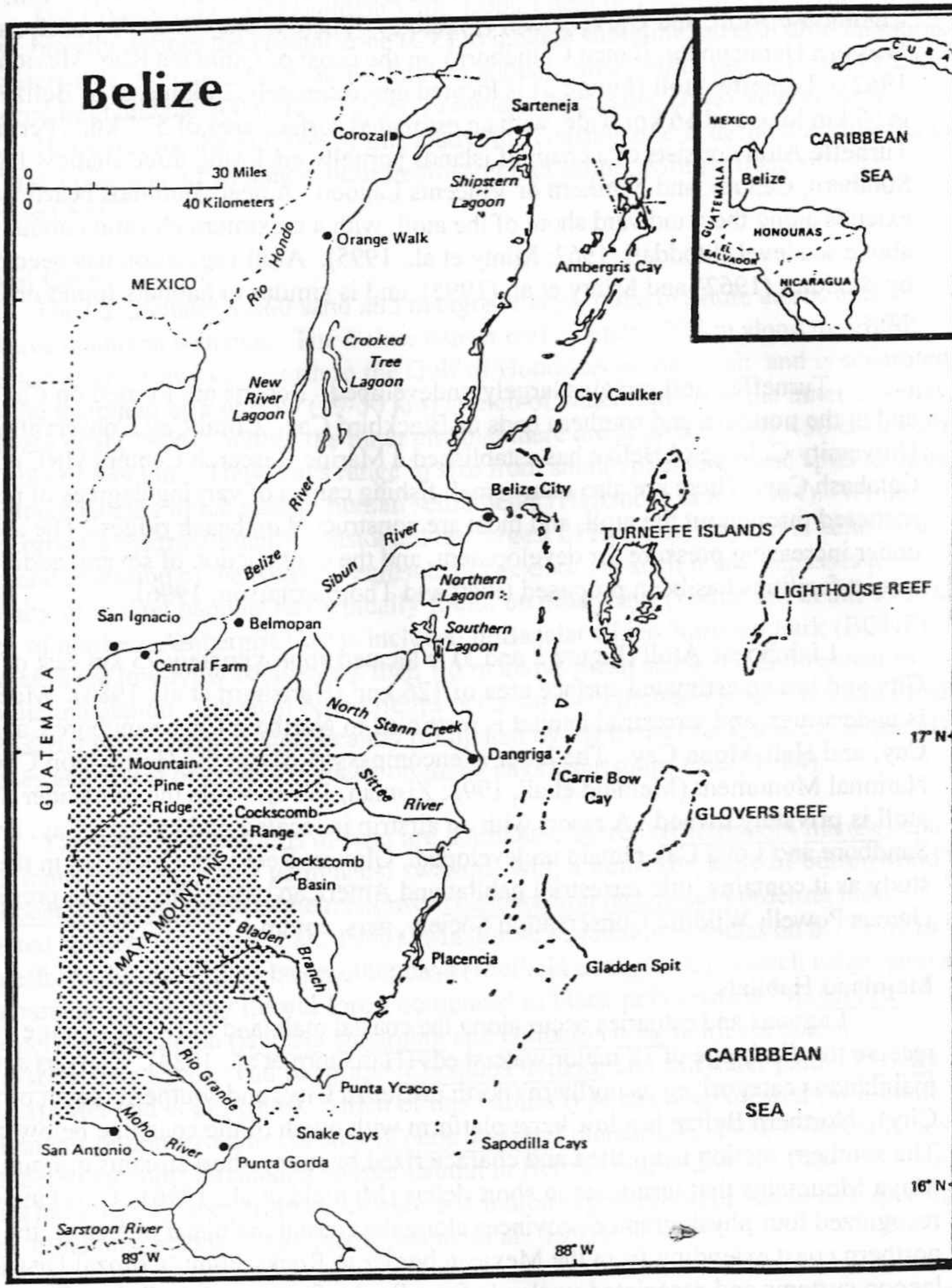


Figure 2. Map of Belize showing major geographical features, including offshore atolls and coastal lagoons (From: Hartshorn et al., 1984).

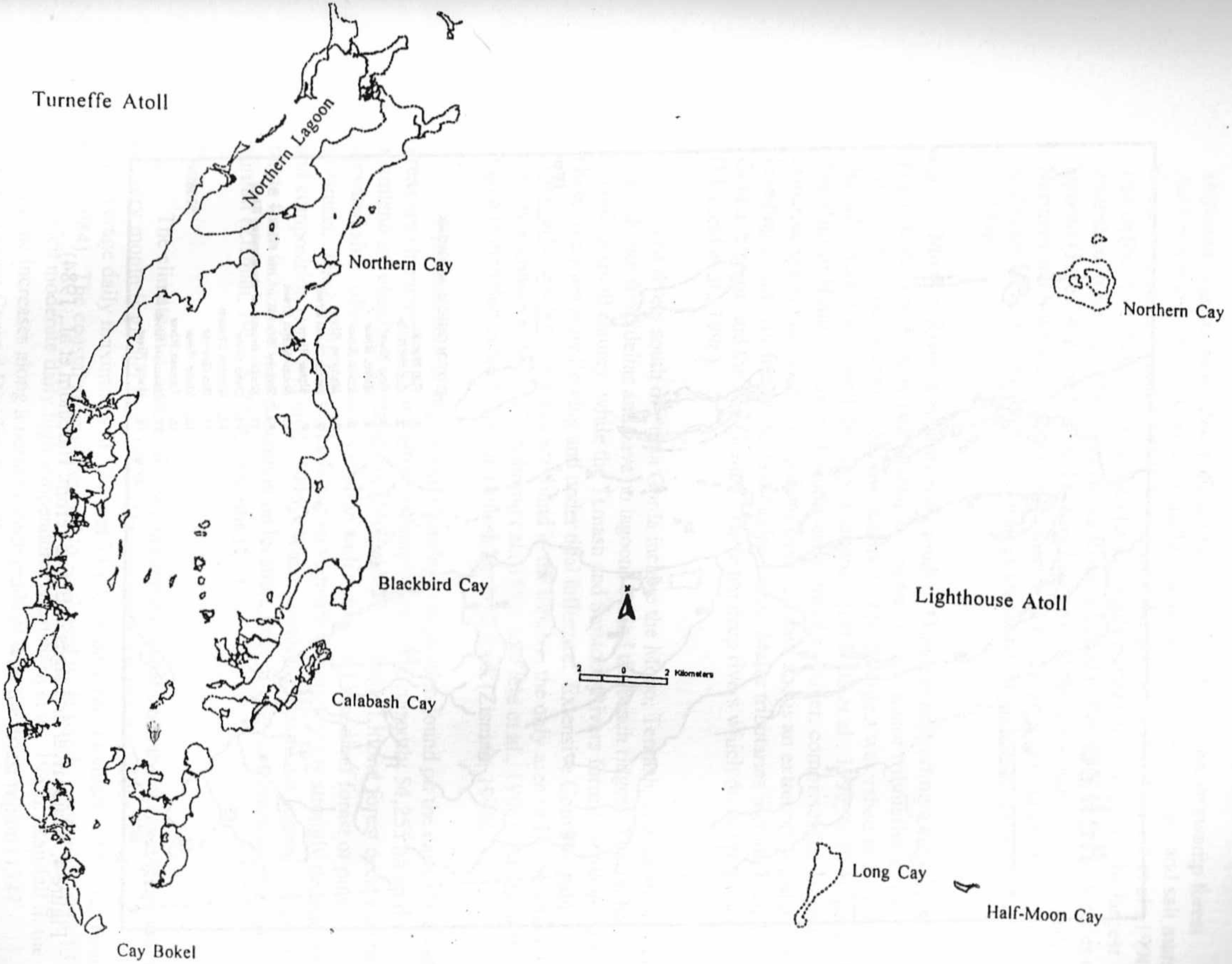


Figure 3. Turneffe and Lighthouse Atolls.

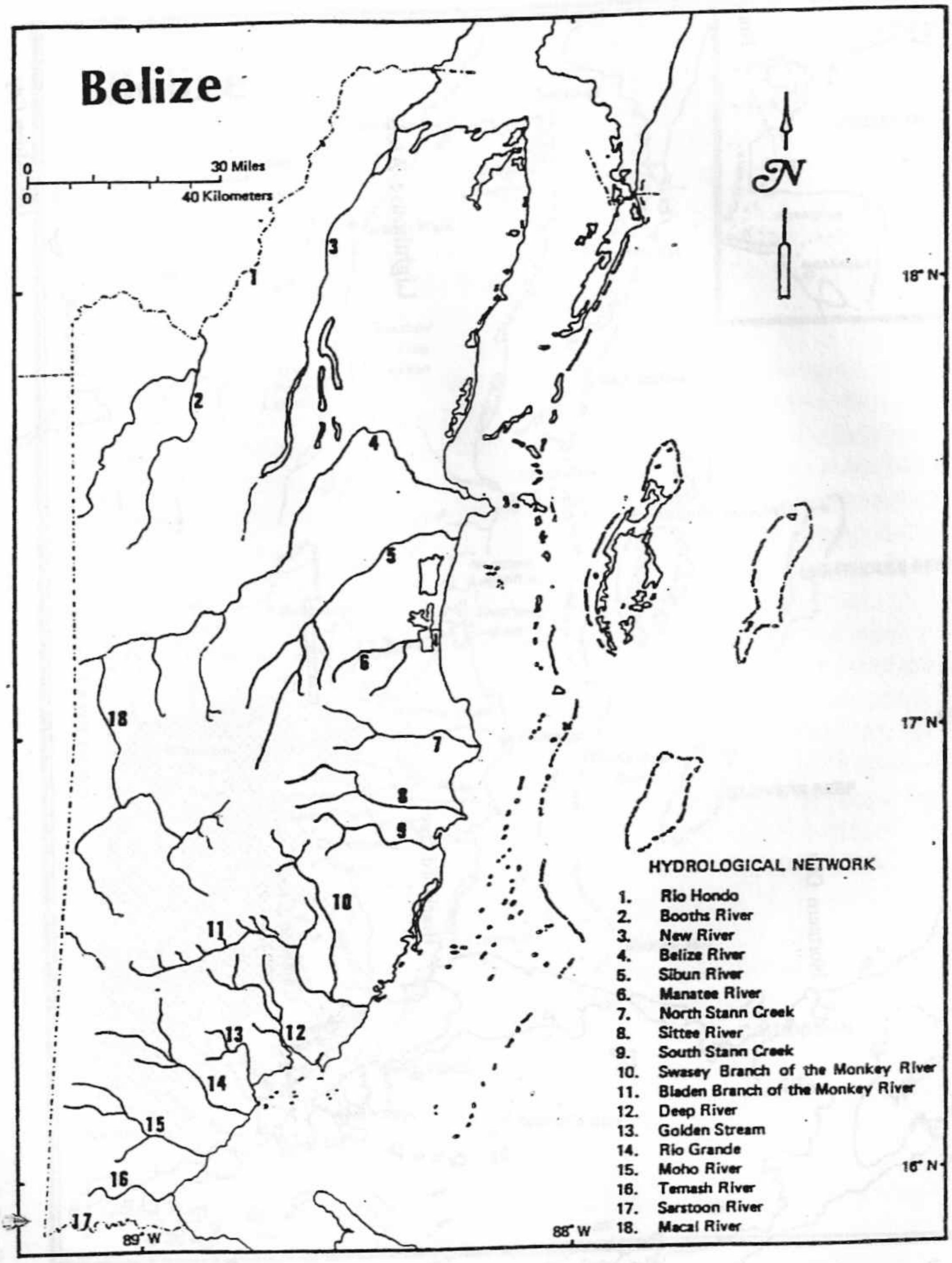


Figure 4. Major river drainages in Belize (From: Hartshorn et al., 1984).

Shipstern Lagoon, an extensive lagoon system fringed by mangrove swamp forest (McField et al., 1996). A series of shallow lagoons, mangrove swamps, and salt marsh are found from Rocky Point south to Belize City (King et al., 1992; McField et al., 1996). The Belize River/Haulover Creek Delta surrounds Belize City and drains the largest watershed in Belize. The lower Belize River is linked to the Sibun River by a series of lagoons (Jones, Almond Hill, and Fabers Lagoon) and the man-made Burdon Canal. Northern and Southern Lagoons are connected to the Sibun River via creeks and man-made canals. Extensive mangrove swamps are found throughout this region (McField et al., 1996).

Monkey River is the only river south of Dangriga supporting a significant human population. The Swasey and Bladen Rivers are the two major tributaries of the Monkey River. This river system is shallow, drains the fourth largest watershed in Belize, and is the only system with well-developed sandbars (McField et al., 1996; S. Platt, pers. obs.). The Gulf of Honduras, located southwest of Monkey River, comprises the largest estuarine system in Belize. It contains over 130 cays and is an extremely productive breeding ground for freshwater and marine fauna. Major tributaries include Deep River, Golden Stream, and the Rio Grande. These are deep rivers which do not form deltas (McField et al., 1996).

The rivers south of Punta Gorda include the Moho, Temash, and Sarstoon. These rivers do not form deltas and have no lagoons behind the beach ridges. The Moho River has only a small estuary, while the Temash and Sarstoon Rivers form a single estuary. These rivers are slow flowing and under tidal influence. Extensive Comfray palm (Manicaria saccifera) swamps are found in the estuary, the only area in Belize where this species is known to occur (Hartshorn et al., 1984; McField et al., 1996). Much of this region is included in the Sarstoon-Temash National Park (Zisman, 1996).

Mainland coastal vegetation is similar to vegetation found on the cays. Low-relief areas are characterized by mangrove swamp forests, and currently 54,255 ha on the mainland are classified as mangrove (McField et al., 1996). Littoral forest occurs on more elevated sites, often in close association with transitional broadleaf forest or pine savannas. The occurrence of the later two vegetative formations is strongly dependent on soil composition (McField et al., 1996). Water salinities in mainland coastal wetlands range from 0.0 to 35.0 ppt depending on location, time of year, and amount of recent rainfall (Zisman, 1992; S. Platt, pers. obs.).

Climate

The climate of coastal Belize is considered tropical since the average temperature of every month is greater than 18°C. The warmest temperatures occur in April and May, with average daily maximums of 32.8 and 33.1°C respectively (Johnson, 1983; Hartshorn et al., 1984). The coastal zone is exposed to southwest trade winds, averaging 10 to 13 knots, which moderate daily high temperatures (Hartshorn et al., 1984). Rainfall in the coastal zone increases along a north to south gradient with the driest region (1347 mm/year) being Corozal District, Turneffe, and Lighthouse Atolls, and southern Toledo

District the wettest (4526 mm/year). There is a pronounced wet season from June through November, but this may vary annually (Johnson, 1983; Hartshorn et al., 1984).

Two meteorological disturbances, "northers" and cyclones, can greatly alter coastal weather patterns. "Northers" are frontal, cold, wet, northeast air masses which are pushed south from November to February. Local effects are cool temperatures, heavy rains, and rough seas. Cyclones are non-frontal, low pressure, large-scale systems that develop over tropical waters and exhibit well-organized circulation (Hartshorn et al., 1984). Cyclones are classified as tropical disturbances, tropical depressions, tropical storms, or hurricanes depending on wind velocity and sustainability. Hurricanes are the most powerful with sustained winds of 119/km or greater. Effects in coastal areas include dangerous seas, extensive destruction of vegetation, and beach erosion. Hurricane landfall is rare in Belize, and most often occurs in August, September, and October (Hartshorn et al., 1984).

METHODS

Population Surveys

Crocodile surveys were conducted throughout the coastal zone of Belize from July 1996 to October 1997. Nocturnal spotlight surveys were used to census crocodile populations and estimate densities (Magnusson, 1982; Bayliss, 1987; Graham, 1988). Night counts are effective in most habitats, coincide with peak activity periods, and eyeshine reflections are visible at long distances and in situations where animals might otherwise go undetected (O'Brien, 1990). This technique is used in crocodile surveys worldwide involving many species (e.g., Messel et al., 1981; King et al., 1994; Steubing et al., 1994), and other population estimation techniques, such as mark-recapture have confirmed its validity (Bayliss et al., 1986; Hutton and Woolhouse, 1989).

Single spotlight counts were conducted at most locations. Single counts provide an index of relative density because not all crocodiles present are observed during a survey. However, the relationship between the count and actual population size is assumed to remain constant over time, and any change in counts should reflect a proportionate change in the total population (Bayliss, 1987; Graham, 1988). Relative indices are powerful when survey techniques are standardized (Bayliss, 1987). When spotlight counts are replicated, a high degree of precision (low standard error) is generally achieved with a low number of samples (Messel et al., 1981; Bayliss et al., 1986). Optimal allocation of sampling effort should maximize the number of survey routes in order to increase precision (O'Brien, 1990). Standard error decreases dramatically in response to increasing the number of routes, while reduction in standard error due to replication is insignificant (O'Brien, 1990).

Most spotlight surveys were conducted from a 7.5 m skiff equipped with two 60 HP outboard engines. Some surveys were conducted from an aluminum canoe when shallow water or navigational hazards precluded using the larger boat. Crocodiles were located with a 40,000 candlepower Q-beam spotlight and 12-volt headlights. Only 12-volt headlights were used when surveys were conducted by canoe. Survey routes were usually traversed before nightfall, and habitat and navigational features noted. Spotlight surveys began 15 to 30 minutes after sunset. Time of night has not been demonstrated to bias spotlight counts (Messel et al., 1981). Periods of inclement weather were generally avoided (Woodward and Marion, 1978).

The coordinates (latitude and longitude in degrees, minutes, and seconds, or degrees, minutes, and tenths of minutes) of beginning and endpoints of each survey were determined with a handheld Magellan 2000 Global Positioning System (GPS). This unit is rated at an accuracy of 25 m when used under standard conditions without differential correction (Magellan GPS 2000 Users Guide, Magellan Systems Corp., 1995). This level of accuracy was considered acceptable for the purpose of this study. Beginning and endpoints were recorded to allow survey replication by future workers, which is essential for long-term population monitoring programs (King et al., 1993). Distance traveled in each survey was determined using 1:50,000 topographical maps issued by the Ordnance Survey, Southampton, England and obtained from the Department of Lands and Surveys.

Belmopan, Belize. Survey routes were calculated as shoreline distance along coastline and lagoons, or midstream length in linear habitats such as creeks and rivers (King et al.. 1990). Crocodile densities were calculated as the number of crocodiles observed per kilometer of survey route, which allows quantitative comparison with other survey data and provides a means to assess future population trends (Bayliss. 1987).

All crocodiles sighted were approached as closely as possible, identified to species, and total length (TL) estimated. American crocodiles were classified as hatchlings (TL<30 cm), juveniles (TL = 30 - 90 cm), subadults (TL = 90 -180 cm), or adults (TL>180 cm). Morelet's crocodiles were classified similarly, although size limits for subadult (TL = 90 - 150) and adult (TL>150 cm) categories were somewhat less, reflecting a smaller body size at sexual maturity. When crocodiles submerged before TL could be determined they were classified as "eyeshine only" (EO). Counts and size estimates were conducted by the same observer (SGP) on all surveys. The coordinates of each sighting were recorded, and water salinity determined to the nearest 1.0 ppt with an Atago S-10E hand refractometer.

The observed distribution of crocodiles in coastal mainland and island habitats was tested against the null model of random distribution using a chi-square goodness of fit test and a Z-test (Thorbjarnarson, 1988) of the form

$$s_i = \frac{o_i - e_i}{[e_i (1 - e_i) / n]^{0.5}}$$

where

s_i = test statistic for habitat i,
o_i = proportion of crocodiles observed in habitat i,
e_i = proportion of habitat i in survey,
n = total number of crocodiles observed.

Crocodiles were captured whenever possible to confirm size estimates, verify species identifications, and obtain morphometric data, stomach contents, and blood samples for genetic analysis. Smaller individuals (TL ≤ 90 cm) were captured by hand. while a self-locking snare mounted on a pole was used to capture larger crocodiles (Chabreck, 1966). With the exception of recent hatchlings, all captured crocodiles were sexed by opening the cloaca and examining the genitalia (Brazaitis. 1968). Observed sex ratios were tested against a null hypothesis of a 1:1 sex ratio using chi-square analyses (Caughley, 1977).

All place names used in this report correspond to Ordnance Survey topographical maps. At sites where local names did not correspond to names on topographical maps. the local name is given in parentheses.

Morphometric Data and Scale Counts

Morphometric data were collected according to Webb and Messel (1978). The following were recorded from most captured crocodiles: total length, snout-vent length (SVL), head length (HL), head width (HW), snout length, snout width at anterior corner of orbits, snout width at fifth maxillary tooth, snout width at fourth mandibular tooth, mandibular symphasis length and width, and body mass. Rear-foot length was determined according to Platt et al. (1990).

TL and SVL were taken with a steel tape to the nearest 0.1 cm. Head measurements were taken with a dial calipers ($\pm$ 0.1 mm) on smaller animals (HL $\leq$ 150 mm), or a tree calipers ($\pm$ 0.1 cm) on larger (HL $\geq$ 150 mm) crocodiles. Body mass was measured with a spring scales to the nearest 0.1 kg for animals $\leq$ 10.0 kg. Larger crocodiles were weighed to the nearest 1.0 lb. with a spring scale, and this value was converted to kg by dividing by 2.2. Values were rounded to nearest 0.1 kg to avoid false precision.

Scales were counted on most captured crocodiles with TL $\geq$ 40 cm. Nomenclature (Figure 5) follows King and Brazaitis (1971) and Brazaitis (1973). The following were recorded on each crocodile: configuration and number of post-occipital and nuchal scales, number of dorsal scale rows, number of scales in each dorsal scale row, number of single and double caudal scale whorls, and number of right and left ventral scale rows. Additionally, the presence or absence of mandibular teeth protruding through the premaxillary, irregular subcaudal scale groups, Paratrichosoma sp. infection, and scars and injuries were recorded.

Marking

All crocodiles captured during this study were marked either by attaching a self-piercing metal tag to the webbing of the rear foot, or clipping a series of double and single caudal scutes to code for a unique number. While some loss of metal tags has been reported, scute clipping provides a permanent mark as scutes will not regrow (Jennings et al., 1991). Only scutes two to nine in the double and single caudal whorls (count beginning at the union of double and single caudal whorls, and progressing anteriorly for double caudals and posteriorly for single caudals; Figure 6) were used in this marking system.

American crocodiles were assigned a two digit number based on the removal of one single (first number) and one double (second number) caudal scute. Morelet's crocodiles were assigned a four digit code, continuous with 271 crocodiles marked during a previous study (Platt, 1996). The first two numbers in the sequence represent the removal of two single caudal scutes, the third number is a double caudal scute removed from the left side of the whorl, and the fourth number is a double caudal scute removed from the right side of the whorl (Figure 6).

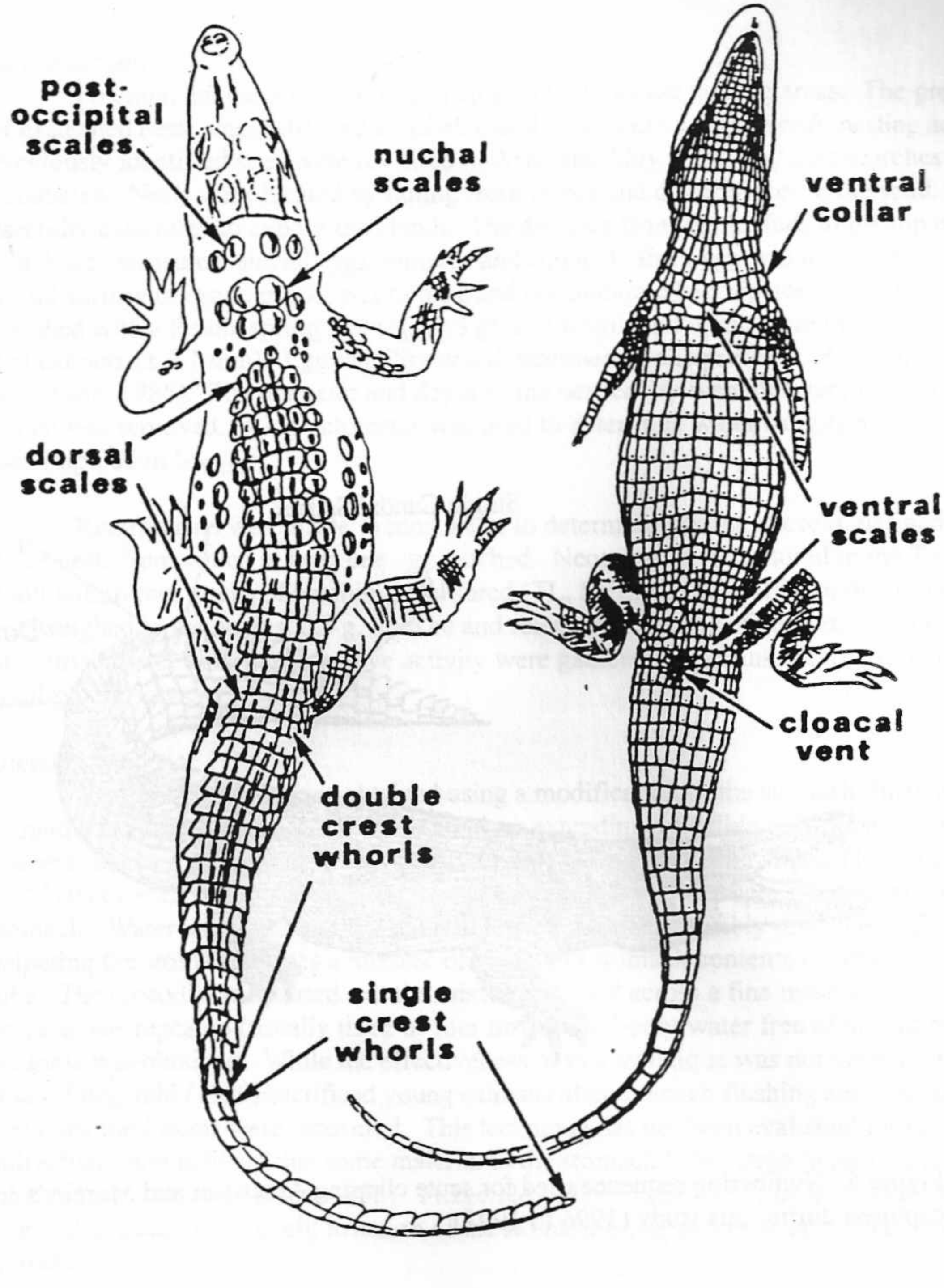


Figure 5. Dorsal (left) and ventral (right) view of a crocodile showing major scale groups (From: Brazaitis, 1973).

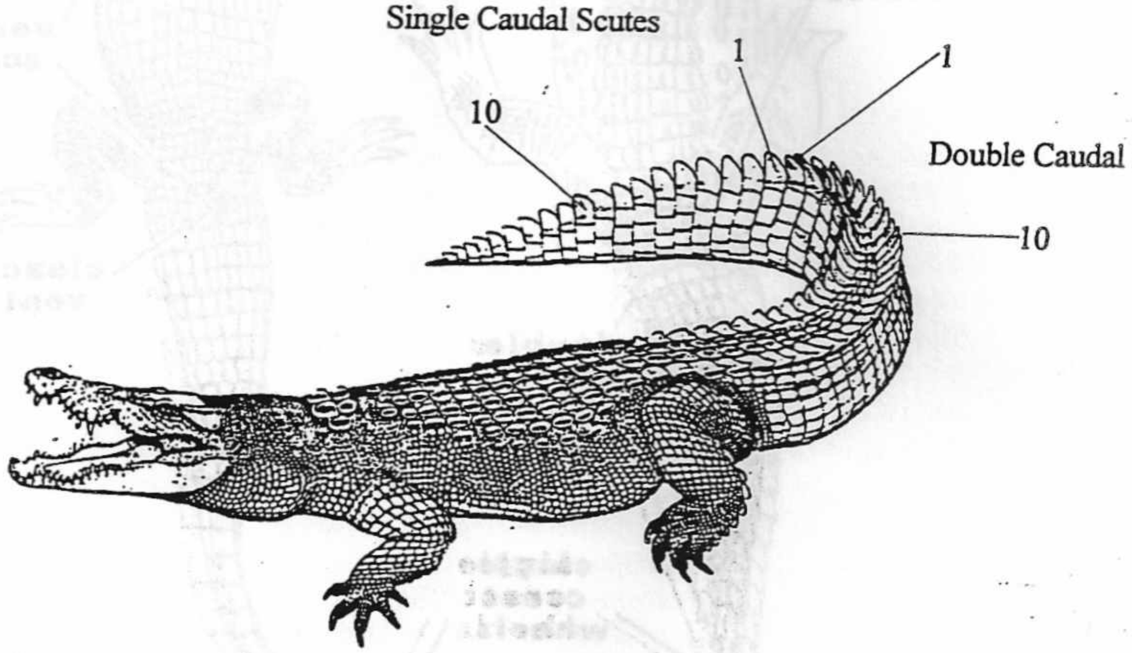


Figure 6. Numbering sequence used for scute clipping American and Morelet's crocodiles captured during this study (1996 to 1997).

Reproduction

Potential habitat was searched in an attempt to locate nesting areas. The presence of excavated nests, eggshells, and eggshell membranes were used to verify nesting activity. Previously identified sites were revisited in April and May 1997, and nest searches conducted. Nests were located by noting fresh tracks and disturbances in the sand, and carefully excavated to expose the clutch. The distance from the surface to the top of the clutch was measured, and all eggs removed and counted. Each egg was numbered on the dorsal surface to insure proper positioning and orientation when replaced. All eggs were weighed with a Pesola spring scales (± 0.5 g), and length and width were measured with dial calipers (± 0.1 mm). Egg viability was determined by the presence of opaque bands (Ferguson, 1985). The diameter and depth of the nest cavity were measured after the clutch was removed. A refractometer was used to determine water salinity at the nest site (see Population Survey).

Return visits were made to most nests to determine nesting success, defined as those nests from which at least one egg hatched. Neonates were captured in the Turneffe Atoll within two weeks of hatching, measured (TL, SVL, HL, and HW) to the nearest 0.1 cm, weighed to the nearest 0.5 g, marked and released at the site of capture. Observations of courtship and other reproductive activity were gathered opportunistically during spotlight surveys.

Dietary Analysis

Stomach contents were obtained using a modification of the stomach flushing technique of Taylor et al. (1978). This involves extending a flexible PVC tube (exterior diameter of tube: hatchlings = 5.5 mm; 30-45 cm TL = 1.4 cm; 45-120 cm TL=1.9 cm; TL>120 cm = 2.1 cm), lubricated with vegetable oil, down the esophagus and into the stomach. Water is poured into the tube until the abdomen is visibly distended. Gently palpating the stomach causes a mixture of water and stomach contents to surge into the tube. The crocodile is inverted and the mixture directed across a fine mesh screen. This process was repeated (usually three or four times) until only water free of any stomach contents was obtained. While the effectiveness of this technique was not verified in this study, Fitzgerald (1989) sacrificed young caimans after stomach flushing and concluded that most food items were recovered. This technique has not been evaluated for larger individuals, and is likely that some material in the stomach is too large to pass through the tube and not recovered (Platt, 1996). Fitzgerald (1989) considered this technique to be safe and noticed only a slight irritation of the stomach lining and esophagus in dissected animals.

Stomach contents were sorted, prey items identified to the lowest possible taxonomic category, and weighed on a Pesola spring scales (± 0.5 g). The frequency of occurrence and percent mass were calculated for each prey category. Non-food items such as gastroliths, vegetable matter, and nematodes were also recorded. Nematodes were preserved in 10% formalin for later identification.

Blood Collection

Blood samples were collected for genetic analyses from all captured crocodiles following the methods of Olson et al. (1975). Blood was drawn from the nuchal sinus using a 20 gauge X 25 mm needle on larger (TL≥60 cm) crocodiles, and a 28 gauge X 13 mm needle on smaller crocodiles. Approximately 0.5 cc of blood was drawn into an unhepranized sterile syringe, and immediately decanted into an equal amount of RT buffer.

SPECIES IDENTIFICATION

Descriptions of C. acutus are provided in King and Brazaitis (1971). Brazaitis (1973), and Smith and Smith (1977). C. acutus occurs sympatrically with C. moreletii in mainland coastal regions of Belize and Mexico (Alvarez del Toro, 1974: Thorbjarnarson. 1989; Platt, 1996), and molecular (Densmore and White, 1991; Forstner et al., 1997). and parasite (Brooks and O'Grady, 1989) data strongly suggest they are closely related. The two species are difficult to distinguish because of morphological similarities. and misidentifications are not uncommon, even among herpetologists (Thorbjarnarson. 1989: Lee, 1995). A summary of morphological characteristics useful for distinguishing C. acutus from C. moreletii are presented in Table 1.

Differences in color have been proposed as a distinguishing characteristic, with C. acutus being somewhat paler than C. moreletii, and having darker crossbands (Schmidt. 1924; Brazaitis, 1973). However, Meerman (1992) reported difficulties in separating animals based on color, and Abercrombie et al. (1980) stated that color was an unreliable character on which to base identification. Likewise, our experience during this study suggests there is considerable variation and overlap in the color of both species. and body coloration is often not readily apparent during spotlight surveys.

Body size is sometimes mentioned as a useful character for distinguishing C. acutus from C. moreletii, with the former being slightly larger (Perez-Higareda et al., 1991). In the past C. acutus attained lengths up to 6.25 m (Alvarez del Toro, 1974). although crocodiles this large are rarely found today (Thorbjarnarson, 1989). However. earlier reports that placed maximum body length of C. moreletii at 2.5 m (Neill. 1971: Brazaitis, 1973) are now considered erroneous, and probably resulted from the selective over-exploitation of large adult crocodiles (Perez-Higareda et al., 1991). The maximum size range for C. moreletii remains ill-defined, but specimens up to 4.1 m have been collected in Mexico (Perez-Higareda et al., 1991). Therefore only extremely large (TL ca. + 4.5 m) crocodiles may be identified on the basis of body size alone, and these are the least frequently observed size class (S. Platt, pers. obs.).

The morphological characters most useful for distinguishing C. acutus from C. moreletii include several head and skull differences, and dorsal and subcaudal scutellation. In general, the head of the American crocodile is more slender than the broad. compact head of Morelet's crocodile (Figure 7; Schmidt, 1924). However, this difference becomes less pronounced as crocodiles mature, and in older American crocodiles the snout-length to snout-width ratio may approach that of Morelet's crocodile (Smith. 1938). Morelet's crocodile has a prominent median preorbital ridge (POR), although less pronounced than the American crocodile (Figure 8; Brazaitis, 1973; Alvarez del Toro, 1974: Thorbjarnarson, 1989). The size and shape of the POR of C. acutus may vary geographically and be sexually dimorphic (Thorbjarnarson. 1989), but these relationships have not been examined in C. moreletii. The configuration of the premaxillary suture differs between the two species, but is visible only on skulls and cannot be used to identify living animals. The suture extends posteriorly in C. acutus, and is transverse in C. moreletii (Figure 8; Schmidt, 1924; Smith, 1938; Ross, 1987; Lee, 1995).

Table 1. Summary of morphological characters distinguishing Morelet's crocodile (Crocodylus moreletii) from the American crocodile (Crocodylus acutus).

Character	Morelet's Crocodile	American Crocodile
GENERAL		
Color	Dark green to black[1]	Gray brown with dark crossbands[1]
Maximum Body Size	Rarely > 4.0 m[9]	To 4.0 m and occasionally larger[3,6,7]
SKULL/HEAD		
Snout Length	1.5 X basal width[1]	1.8 to 2.5 X basal width[1]
Preorbital Ridge	Present but reduced[1,2,3]	Well developed[1,3]
Premaxillary Suture	Transverse[9]	Extends posteriorly[9]
SCUTELLATION		
Nuchals	4 enlarged scales in a square flanked by a single scale on each side[1,8]	4 enlarged scales in a square flanked by a single scale on each side. Highly variable[1]
Dorsals	15 to 17 transverse rows of 4 to 6 scales[1]	14 to 17 (usually 16) transverse rows of 2 to 6, but rarely more than 4 scales[1,4]
Double Caudal Whorls	17 to 20[1]	16 to 17[1]

Table 1 (continued).

Character	Morelet's Crocodile	American Crocodile
Single Caudal Whorls	19[1] (20 to 21 in Belize[8])	15 to 16[1]
Ventral Scales*	29 to 33 transverse rows[1]	26 to 32 transverse rows[1]
Subcaudal Scales	Irregular scales present on ventral and lateral surface[5]	If present, irregular scales on lateral surface only[5]

Source: 1-Brazaitis, 1973; 2-Ross, 1987; 3-Thorbjarnarson, 1989; 4-Ross and Mayer, 1983; 5-Ross and Ross, 1974; 6-Alvarez del Toro, 1974; 7-Schmidt, 1924; 8-S. Platt, unpubl. data; 9-Perez-Higareda et al., 1991.
* Ventral scale rows are counted from the ventral collar to the anterior margin of the cloaca (Brazaitis, 1973).

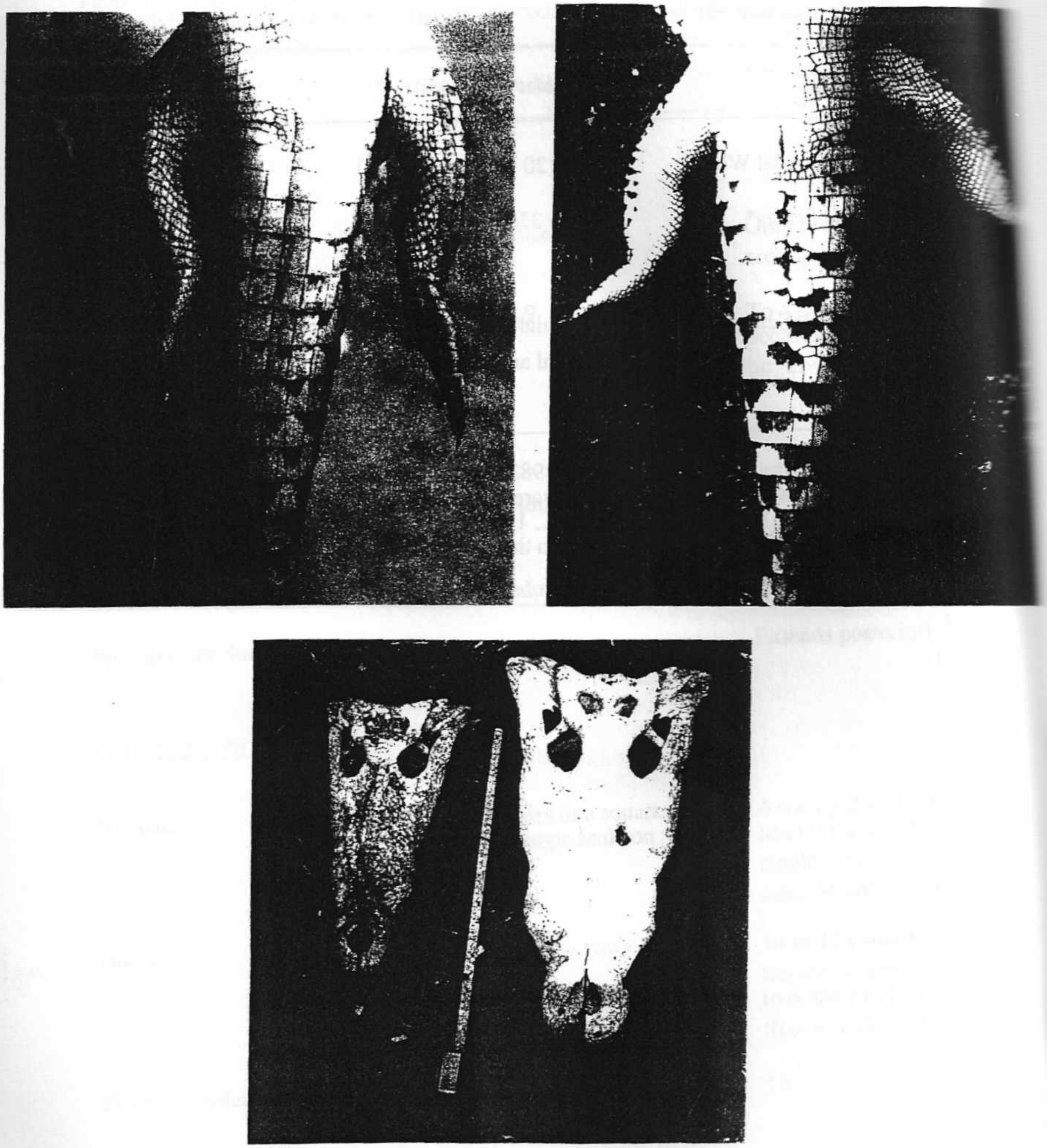


Figure 7. Subcaudal [illegible] crocod[illegible] [illegible] Morelet's crocodile (top right). [illegible] crocodi[illegible] [illegible] and Morelet's crocodile (bottom right) [illegible] [illegible]ginated [illegible] [illegible]on near Gales Point Village.

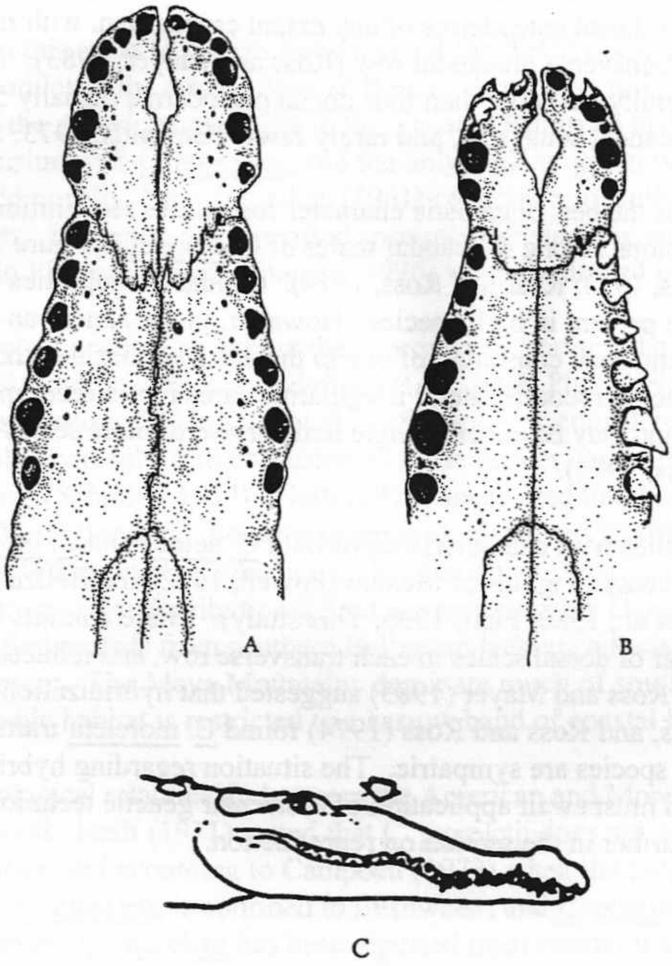


Figure 8. Ventral view of crocodile skulls (above) showing configuration of premaxillary sutures in American crocodile (A) and Morelet's crocodile (B) (From: Lee, 1995). Lateral view of head showing preorbital ridge (C) (From: Brazaitis, 1973). The preorbital ridge is present in both species, although less pronounced in Morelet's crocodile.

Scutellation in C. acutus is highly irregular and variable among individuals resulting in considerable overlap with C. moreletii (King and Brazaitis, 1971; Brazaitis, 1973; Ross and Mayer, 1983). The American crocodile has the most reduced and irregular arrangement of dorsal osteoderms of any extant crocodilian, with rarely more than four scutes in any transverse precaudal row (Ross and Mayer, 1983). In contrast, Morelet's crocodile generally has more than four dorsal osteoderms (usually 5 to 6) in each transverse precaudal scute row, and rarely fewer (Brazaitis, 1973; S. Platt, unpubl. data).

Perhaps the best diagnostic character for species recognition is the presence of irregular intrusions among the caudal scales of C. moreletii (Figure 7; King and Brazaitis, 1971; Brazaitis, 1973; Ross and Ross, 1974). Caudal irregularities in the proximal half of the tail may be present in both species. However, in the American crocodile no more than three are present, each consisting of one to three scales confined to the lateral surface, while in Morelet's crocodile lateral irregularities are always accompanied by ventral irregularities, and may be either a single scale or two or more scales arranged laterally (Ross and Ross, 1974).

Crocodiles with characteristics of both C. acutus and C. moreletii have been reported from coastal regions of Mexico (Powell, 1972) and Belize (Schmidt, 1924; Abercrombie et al., 1980; Platt, 1996; This study). These animals typically exhibit a reduced number of dorsal scales in each transverse row, and reduced or absent caudal irregularities. Ross and Mayer (1983) suggested that hybridization may occur between the two species, and Ross and Ross (1974) found C. moreletii traits in C. acutus only where the two species are sympatric. The situation regarding hybridization remains unresolved and must await application of molecular genetic techniques. Hybridization will be discussed further in the section on reproduction.

RESULTS AND DISCUSSION

POPULATION SURVEYS AND DEMOGRAPHICS

Prior to this study little was known about the distribution of American and Morelet's crocodiles in the coastal zone of Belize. According to Lee (1995) the distribution of the American crocodile in the Yucatan Peninsula and Belize is uncertain owing to confusion with C. moreletii, and the only locality given was the Turneffe Atoll (Figure 9). Additionally, Neill and Allen (1961) collected a juvenile American crocodile near Belize City. However, other verified specimens are lacking and limited surveys (summarized in Platt and Thorbjarnarson, 1996) were conducted prior to our study.

C. moreletii occurs throughout the approximate northern half of Belize, although the southern distributional limit is ill-defined (Lee, 1995; Platt, 1996). Earlier records from Honduras (Gadow, 1905; King et al., 1982) are now considered erroneous (Ross. 1987), and probably result from confusion over the former designation of Belize as British Honduras (Schmidt, 1924). Neill (1971) speculated that Morelet's crocodile may occur in Lake Yoja, Honduras, but after examining specimens and skeletal material collected there, Wilson et al. (1986) concluded that only C. acutus is present. Lee (1995) placed the southern-most distributional limit at approximately Dangriga (Figure 9), and stated that verified records from southern Belize are lacking, although C. moreletii probably is present. The Maya Mountains dominate much of southern Belize and potential crocodile habitat is restricted to a narrow band of coastal lowlands.

The ecological relationship between the American and Morelet's crocodile is poorly understood. Neill (1971) stated that C. moreletii does not occur in saline mangrove habitats, and according to Campbell (1972) when the two species occur sympatrically, C. moreletii is confined to freshwater, and C. acutus to brackish and saline habitats. However, C. moreletii has been reported from coastal mangrove swamps in Belize (Abercrombie et al., 1980; Ouboter 1992; Platt, 1996), although at lower densities in comparison to other habitat types (Platt, 1996).

Spotlight surveys were conducted from July 1996 to October 1997 throughout the coastal zone of Belize (Figure 10). The results are presented in Tables 2 to 4, and localities are listed alphabetically within each region (northern and southern mainland, and cays and atolls). Crocodile sightings are presented in Figure 11 and 12. Survey results from each locality are discussed in detail in Appendix 1. Identification numbers and morphometric data from all captured crocodiles are presented in Appendix 2.

A total of 263 American crocodiles were observed along 956.9 km of survey route (0.27 crocodiles/km; Table 2 and 3). The highest densities recorded were on Cay Caulker (3.40 crocodiles/km), followed by Turneffe Atoll (0.96 crocodiles/km), Long Cay (0.47 crocodiles/km), Hicks Cay (0.36 crocodiles/km), and Ambergris Cay (0.34 crocodiles/km). The high densities noted on Cay Caulker are due to a large concentration of juvenile and subadult crocodiles found at the municipal dump. Low to moderate densities were found

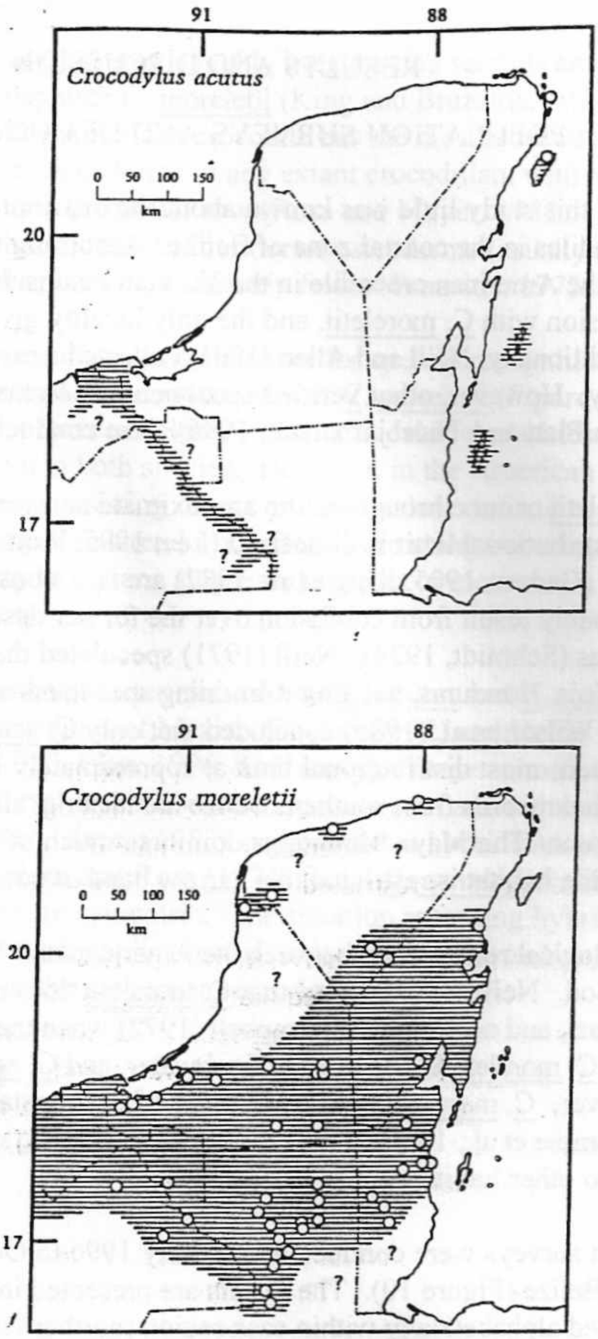


Figure 9. Local distribution of the American crocodile (above) and Morelet's crocodile (below) in the Yucatan Peninsula and Belize. (From: Lee, 1995).

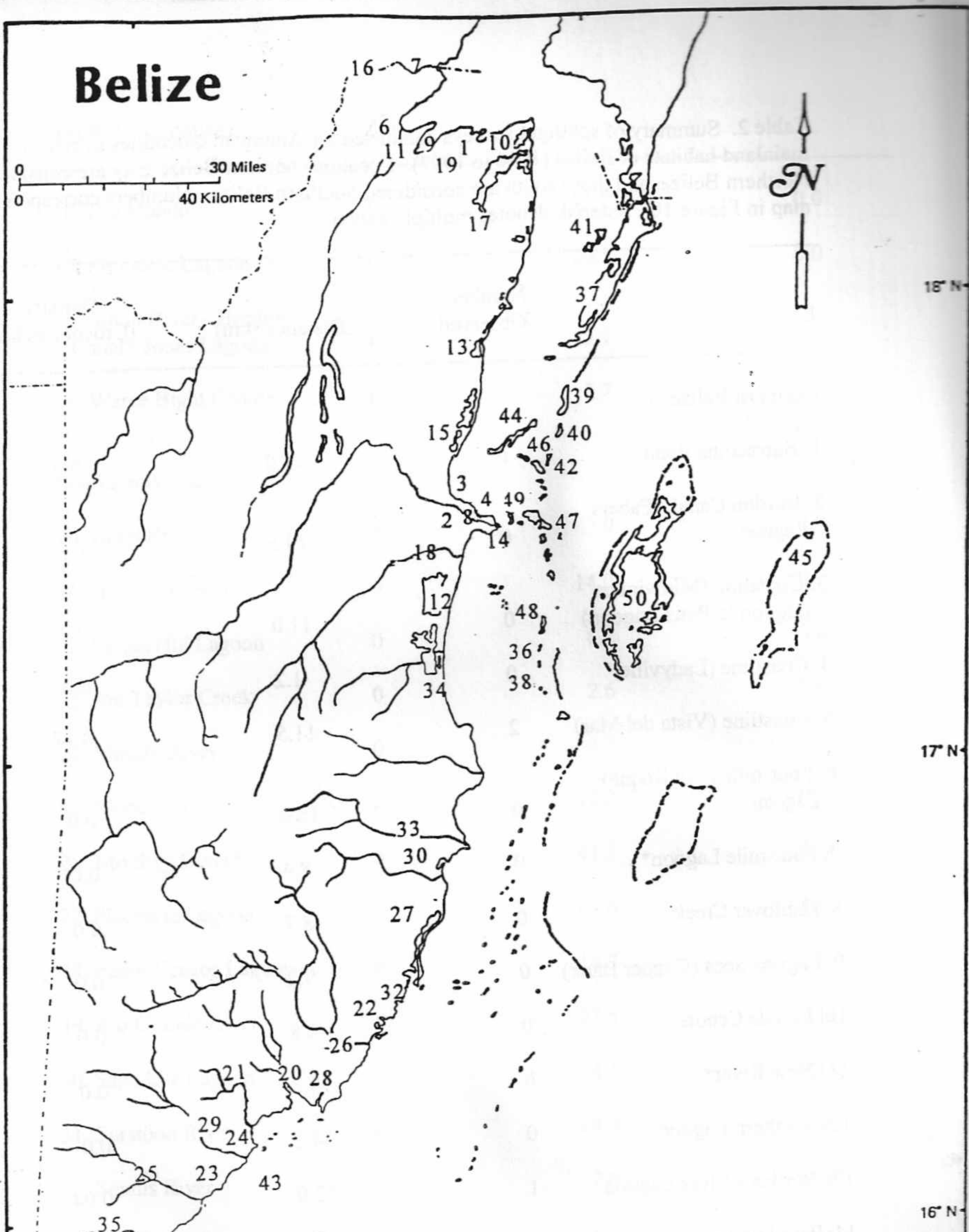


Figure 10. Map of Belize showing approximate location of crocodile surveys conducted in the coastal zone from July 1996 to October 1997. Numbers correspond to Tables 2, 3, and 4.

Table 2. Summary of spotlight surveys conducted for American crocodiles in coastal mainland habitats of Belize (1996 to 1997). Locations north of Belize City are considered Northern Belize, and those south are considered Southern Belize. Numbers correspond to map in Figure 10. Asterisk denotes multiple surveys.

Location	Number Observed	Distance (km)	Density (Crocodiles/km)
Northern Belize			
1. Barracouta Pond	0	7.0	0.0
2. Burdon Canal - Fabers Lagoon	0	19.5	0.0
3. Coastline (Midwinters Lagoon to Potts Lagoon)	0	11.0	0.0
4. Coastline (Ladyville)	0	1.2	0.0
5. Coastline (Vista del Mar)	2	11.5	0.17
6. Four-mile (San Roque) Lagoon	0	15.0	0.0
7. Four-mile Lagoon*	0	8.4	0.0
8. Haulover Creek	0	8.7	0.0
9. Laguna Seca (Copper Bank)	0	9.2	0.0
10. La Isle Cenote	0	0.8	0.0
11. New River*	0	13.2	0.0
12. Northern Lagoon	0	34.2	0.0
13. Northern River Lagoon	1	22.0	0.04
14. Petrojam Lagoon	0	1.2	0.0
15. Potts Creek Lagoon	0	4.2	0.0

Table 2 (continued).

16. Rio Hondo	0	12.7	0.0
17. Shipstern Lagoon	0	10.5	0.0
18. Sibun River - Burdon Canal - Jones Lagoon	0	15.1	0.0
19. Waree Bight Cenote	0	0.7	0.0
Southern Belize			
20. Deep River*	4	43.9	0.09
21. Golden Stream	0	14.0	0.0
22. Indian Hill Lagoon	0	6.2	0.0
23. Joe Taylor Creek	0	2.6	0.0
24. Middle River	0	4.7	0.0
25. Moho River	0	12.2	0.0
26. Monkey River*	0	41.2	0.0
27. Placencia Lagoon	0	68.6	0.0
28. Punta Ycacos Lagoon	0	16.7	0.0
29. Rio Grande River	0	27.5	0.0
30. Sapodilla Lagoon	0	4.1	0.0
31. Sarstoon River	0	49.7	0.0
32. Sennis River	1	7.0	0.40
33. Sitee River*	0	14.7	0.0
34. Southern Lagoon	6	18.7	0.32

Table 3 . Summary of spotlight surveys conducted for American crocodiles on offshore islands and atolls in Belize (1996 to 1997). Numbers correspond to map in Figure 10. Asterisk denotes multiple surveys.

Location	Number Observed	Distance (km)	Density (Crocodiles/km)
36. Alligator Cay	0	7.0	0.0
37. Ambergris Cay*	33	96.9	0.34
38. Bluefield Range	0	1.2	0.0
39. Cay Caulker*	48	14.1	3.40
40. Cay Chapel	0	3.7	0.0
41. Deer Cay	0	8.7	0.0
42. Frenchman's Cay	1	12.0	0.08
43. Gulf of Honduras	0	4.2	0.0
44. Hicks Cay	5	13.7	0.36
45. Lighthouse Atoll	1	5.0	0.20
46. Long Cay*	4	8.4	0.47
47. Maps Cay	3	21.0	0.14
48. Middle Long Cay*	2	27.6	0.07
59. Moho Cay	0	1.3	0.0
50. Turneffe Atoll*	152	156.8	0.96
Total	249	381.3	0.65

Table 4. Morelet's crocodiles observed during spotlight surveys in coastal mainland habitats of Belize (1996 to 1997). Locations north of Belize City are considered Northern Belize, and those south are considered Southern Belize. Numbers correspond to map in Figure 10. Asterisk denotes multiple surveys.

Location	Number Observed	Distance (km)	Density (Crocodiles/km)
Northern Belize			
1. Barracouta Pond	3	7.0	0.42
2. Burdon Canal - Fabers Lagoon	4	19.5	0.20
3. Coastline (Midwinters Lagoon to Potts Lagoon)	2	11.0	0.1
4. Coastline (Ladyville)	0	1.2	0.0
5. Coastline (Vista del Mar)	1	11.5	0.08
6. Four-mile (San Roque) Lagoon	5	15.0	0.66
7. Four-mile Lagoon*	6	8.4	0.71
8. Haulover Creek	2	8.7	0.22
9. Laguna Seca (Copper Bank)	2	9.2	0.21
10. La Isla Cenote	0	0.8	0.0
11. New River*	34	13.2	2.50
12. Northern Lagoon	1	34.2	0.05
13. Northern River/ Lagoon	2	22.0	0.09
14. Petrojam Lagoon	1	1.2	0.83
15. Potts Creek Lagoon	0	4.2	0.0

Table 5. Comparisons of estimated densities of American crocodiles in coastal mainland and island habitats of Belize.

Habitat	Number of Crocodiles	Kilometers Surveyed	Density (per km)	Z score
Coastal Mainland	14	575.6	0.02	-17.16**
Islands	249	381.3	0.65	17.19**

**P < 0.001

Table 6. Population densities of C. acutus reported in the literature.

Location	Density (Crocodiles/km)	Habitat	Source
Belize	0.02	Offshore Islands	This Study
Belize	0.65	Mainland	This Study
Costa Rica	2.9 - 4.5	River	Sanchez et al., 1997
Haiti	6.3	Lake	Thorbjarnarson, 1988
Honduras	0.51	River	Klien, 1977
Honduras	0.34	Coastal / River	King et al., 1990
Mexico (Chiapas)	0.6 - 2.1	Coastal	Martinez-Ibarra et al., 1997
Mexico (Sinaloa)	6.94	Coastal	Ojeda et al., 1997
USA (Florida)	0.21/hr*	Coastal	Mazzotti, 1983
Venezuela	2.52 - 7.13	River	Artega and Sanchez, 1996

*Densities presented as crocodiles observed per hour of survey.

A total of 127 Morelet's crocodiles were observed and 576.5 km of mainland coastal habitat surveyed (Table 4), including mangrove swamps, river mouths, saline lagoons, and coastline. An overall density of 0.22 Morelet's crocodiles/km was calculated. This is considered a conservative value as crocodiles which could not be identified to species ("eye shine only" or EO) were not included. Given the apparent rarity of C. acutus on the mainland, it is probable that most EOs were C. moreletii. If the 15 EO's are added to the 127 C. moreletii observed, then the revised density estimate is 0.24 crocodiles/ km.

Survey data from Platt (1996) were used to make comparisons of C. moreletii densities between inland and coastal habitats. A chi-square goodness-of-fit test indicated C. moreletii was not randomly distributed between habitats ($\chi^2 = 1227.3$; $p < 0.001$), and according to z-test statistics, C. moreletii was significantly less abundant in coastal habitats than would be expected in a null model of random distribution (Table 7). Furthermore, a chi-square goodness-of-fit test indicated C. moreletii was not randomly distributed between coastal habitats in northern versus southern Belize ($\chi^2 = 99.4$; $p < 0.001$), and according to z-test statistics, C. moreletii was significantly more abundant in the north compared to the south (Table 8).

C. moreletii abundance in coastal habitats is characterized by low to moderate densities (Table 4). The highest densities were found in the lower reaches of the New River (2.5 crocodiles/km), and the Bladen River (2.2 crocodiles/km), although the latter figure is based on a relatively short stretch of river. Lower (<1.0 crocodiles/km) densities were found at most other coastal locations, and high densities were not found at any site. Densities of 15 to 20+ C. moreletii/km have been reported from some inland freshwater lagoons (Platt, 1996). There was no evidence for the occurrence of C. moreletii on any offshore cays, and early reports of C. moreletii on Lighthouse Atoll (Stoddart, 1962) are erroneous and result from confusion with C. acutus.

Morelet's crocodiles were found at ten locations (Figure 13; Table 9) south of the distributional limit of Lee (1995) during this study. Specimens were captured in Placencia Lagoon, and Monkey, Sitee, and Bladen Rivers. Additional C. moreletii were observed during spotlight surveys of Sennis, Deep, Temash, and Sarstoon Rivers, and during the day at Paynes Creek. Nesting activity was found at Monkey, Swasey, Bladen, Temash, and Sennis Rivers, and Paynes Creek (Appendix 7). These records extend the known distribution of Morelet's crocodile to the Guatemalan border, approximately 130 km south of the currently recognized distributional limit (Lee, 1995). Survey results indicate C. moreletii is rare in much of southern Belize; densities were generally low, and Morelet's crocodile was absent at many sites (Table 4). The highest densities were found in the Monkey-Bladen-Swasey River system, where crocodiles were found in the main river channel and adjacent oxbow lakes.

Only C. moreletii were found in most surveys of mainland coastal habitats, and occurred sympatrically with C. acutus. C. moreletii is generally considered a freshwater species (Taplin, 1988), but in this study were found in salinities as high as 22.0 ppt.

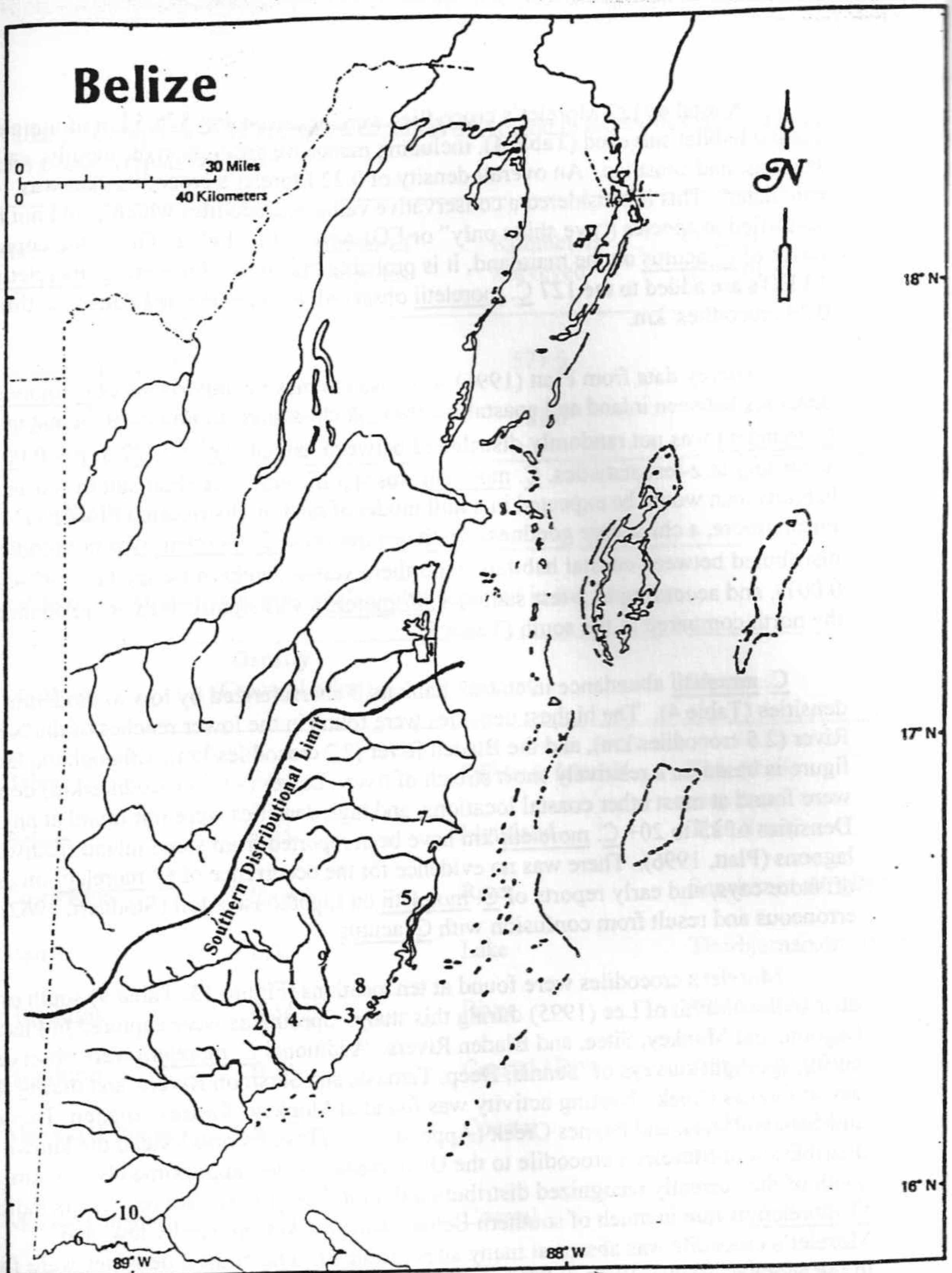


Figure 13. The approximate southern distributional limit of Morelet's crocodile in Belize (Lee, 1995), and extra-limital locations where Morelet's crocodiles were recorded (1996 to 1997) during this study. Numbers correspond to Table 9.

Table 9. Distributional records of Morelet's crocodile in southern Belize. Numbers correspond to map in Figure 13.

Location	Remarks
1. Bladen River	Multiple sightings, captures, and nesting.
2. Deep River	Multiple sightings.
3. Monkey River	Multiple sightings, captures, and nesting.
4. Paynes Creek	Sighting, nesting.
5. Placencia Lagoon	Single capture.
6. Sarstoon River	Multiple sightings.
7. Sitee River	Multiple sightings and captures.
8. Sennis River	Single sighting and nesting.
9. Swasey River	Nesting.
10. Temash River	Multiple sightings and old nest.

These results are in contrast to Neill (1971) who stated that C. moreletii does not occur in saline habitats. Likewise, according to Campbell (1972) C. moreletii is confined to freshwater, and C. acutus to brackish and saline habitats when both are present in coastal regions.

The patterns of abundance between the two species are poorly understood, but may reflect past hunting pressure. Both species were over-exploited, and following population depletion, C. moreletii may have recovered more rapidly and dispersed into habitats formerly occupied by C. acutus (Platt, 1996). It is not known if C. moreletii is inhibiting the recovery of C. acutus in these areas. Similar models have been proposed to explain patterns of abundance between Caiman crocodilus and Crocodylus intermedius (Magnusson, 1982; Thorbjarnarson and Hernandez, 1992), and Caiman crocodilus and C. acutus (Thorbjarnarson, 1989; Sigler, 1996).

Size Class Distribution

A total of 287 American crocodiles were observed during daylight reconnaissance and spotlight surveys. Of these, 95 (33.1%) were classified as EO, and 194 were approached closely enough to estimate size. Size classes are presented in Table 10 and Figure 14. A chi-square analysis was used to compare size-class distributions within each habitat against a null model of equal distribution. Cay habitats did not differ significantly from the null model, but significant differences were found in mainland habitats and the Turneffe Atoll. Subadults were more abundant than expected in mainland habitats, and juveniles were less abundant than expected in the Turneffe Atoll. Juveniles were also under-represented (5.9%) in a previous survey of Turneffe Atoll (Platt and Thorbjarnarson, 1996).

Only 17 (8.7%) of crocodiles for which size could be determined in this study had an estimated total length greater than 240 cm. The two largest crocodiles were a 325 cm individual encountered near Blackbird Cay, and a 301 cm crocodile captured on Ambergris Cay. The estimated total length of the majority (75.7%) ranged from 180 to 240 cm. C. acutus is known to attain maximum total lengths of 6.25 m (Alvarez del Toro, 1974) to 7.0 m (Schmidt, 1924), although today individuals over 4.0 m are rare (Thorbjarnarson, 1989). Observations made in Belize indicate C. acutus may attain a smaller body size than reported for other populations. It is unknown whether this is due to genetic and environmental factors, or past over-exploitation which removed most large adults.

Sex Ratio

A total of 123 American crocodiles were captured during this study (Figure 15; Appendix 2), and sex was determined for 83 individuals. Thirty-seven hatchlings and three small juveniles could not be confidently sexed. An overall sex ratio and comparison of sex ratios between habitats is presented in Table 11.

Table 10. American crocodile size classes compared by habitat. Total number of crocodiles followed by frequency (%) within each habitat in parentheses.

Habitat	Juveniles	Subadults	Adults	χ^2
Mainland	2 (13.3)	11 (73.3)	2 (13.3)	10.8*
Cays	21 (35.0)	20 (33.3)	19 (31.6)	0.10 NS
Turneffe Atoll	24 (20.1)	45 (37.8)	50 (42.0)	9.6*
Total	47 (24.2)	76 (39.1)	71 (36.5)	

* $P < 0.05$
NS Not significant

Table 11. Sex ratios of 83 American crocodiles captured in coastal habitats of Belize (1996 to 1997). Sex ratio presented as female : male.

Habitat	Females	Males	Sex Ratio	χ^2
Mainland	1	5	1 : 5	2.6 NS
Cays	3	19	1 : 6.3	12.1*
Turneffe Atoll	32	23	1 : 0.7	0.92 NS
Total	36	47	1 : 1.3	2.09 NS

NS Not significant
* $p < 0.01$
** $p < 0.001$

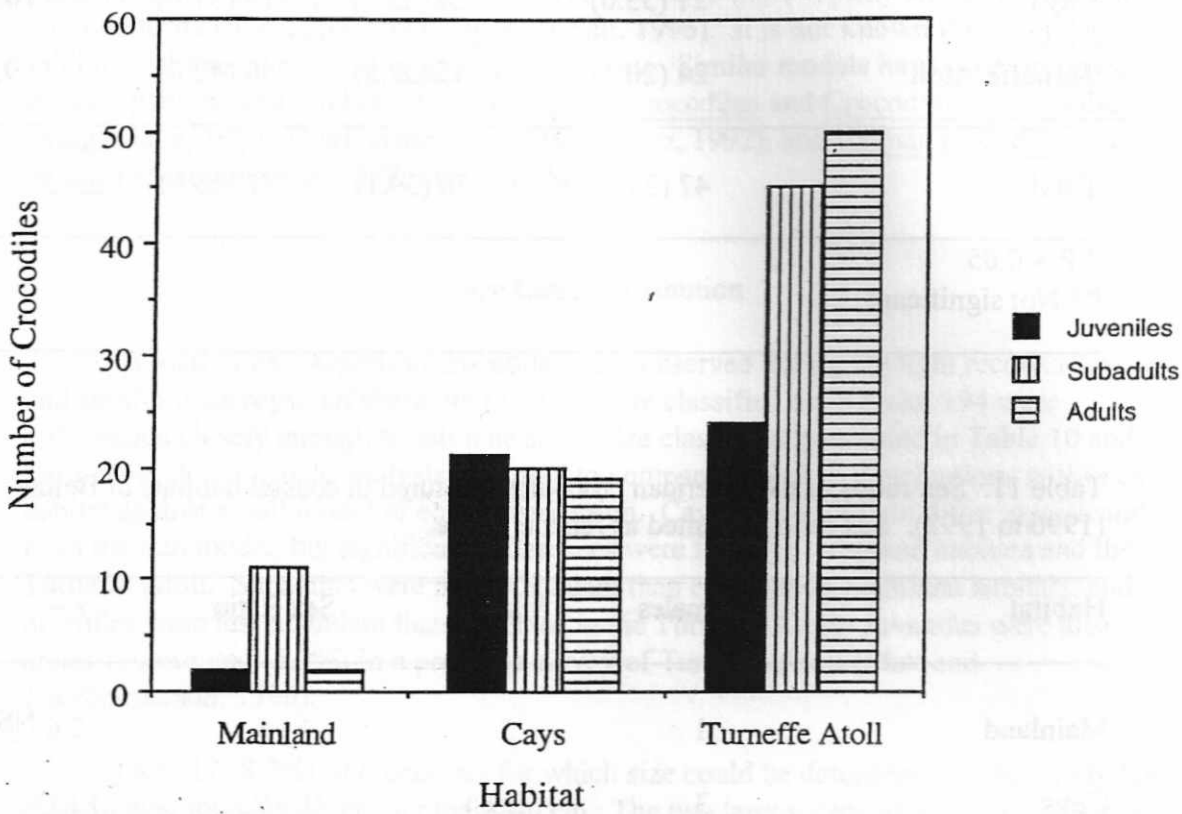


Figure 14. Size class distribution of 194 American crocodiles observed during surveys of coastal habitats in Belize (July 1996 to October 1997). Crocodiles were classified as juveniles (TL = 30.1 to 90.0 cm), subadults (TL = 90.1 to 180.0 cm), or adults (TL>180.0 cm).

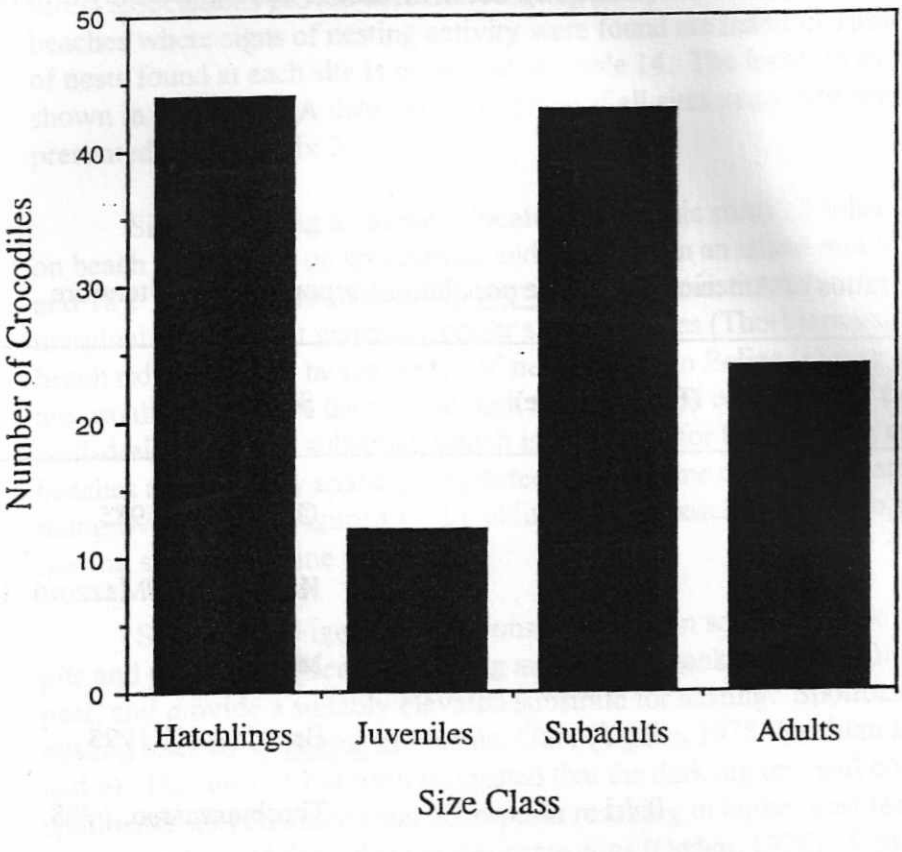


Figure 15. Size class distribution of 123 American crocodiles captured in the coastal zone of Belize from July 1996 to October 1997. Crocodiles were classified as hatchlings (TL≤30 cm), juveniles (TL = 30.1 to 90.0 cm), subadults (TL = 90.1 to 180.0 cm). or adults (TL>180.0 cm).

The resulting overall sex ratio, and the sex ratio for mainland habitats was male biased, but not significantly different from parity. The sex ratio for the cays was male biased and significantly different from 1:1. Mainland populations may also be different from 1:1, but the small sample size lacked sufficient statistical power to detect differences. The sex ratio of the Turneffe Atoll population was slightly female biased. but likewise not significantly different from 1:1. Most other C. acutus populations also exhibit a female biased sex ratio (Table 12), but in no case is this significantly different from 1:1.

Table 12. Sex ratios of American crocodile populations reported in the literature.

Location	Sex Ratio (Female:Male)	Source
Florida, USA	1:0.7	Gaby et al., 1985
	1:0.4	Kushlan and Mazzotti. 1989
	1:1.2	Moler, 1991
	1:0.5	Brandt et al., 1995
Haiti	0.7:1	Thorbjarnarson, 1988
Honduras	0.7:1	Klien, 1977
	1:0.6	Thorbjarnarson, 1989

REPRODUCTION

Nesting Habitat

Searches for nesting beaches were conducted throughout the study, often in conjunction with population surveys. Suitable habitat was usually, but not always found on the eastern (windward) shoreline of cays where elevations were greatest. Indicator plant species such as Thrinax radiata, coconut palms (Cocos nucifera), and cay littoral forest associations proved useful in locating potential nesting habitat. Coordinates of all beaches where signs of nesting activity were found are listed in Table 13, and the number of nests found at each site is presented in Table 14. The location of nesting beaches is shown in Figure 16. A detailed description of all sites examined during this study is presented in Appendix 3.

Sixteen nesting areas were located during this study (Tables 13 and 14): ten sites on beach ridges, four on spoilbanks, and one each on an island and low beach (Figures 17 and 18). Other studies indicate C. acutus is opportunistic and will nest in a variety of marginal habitats, but generally prefer sandy beaches (Thorbjarnarson, 1989). Elevated beach ridges seem to be the preferred nesting sites in Belize (Figure 17). These beaches are usually well above the normal high tide level, and composed of coarse sand providing a well-drained, porous substrate, which is important for hole nesting crocodilians. Nesting beaches are generally sparsely vegetated, and in some cases associated with shallow mangrove lagoons (Figure 17). In addition, these beaches may also serve as important nesting sites for marine turtles.

Spoilbanks (Figure 18) are constructed when soil is dredged from canals or borrow pits and placed in adjacent low-lying areas. Spoilbanks are typically composed of organic peat, and provide a suitably elevated substrate for nesting. Spoilbanks are widely used as nesting sites by C. acutus in Florida, USA (Ogden, 1978; Kushlan and Mazzotti, 1989a and b). However, it has been suggested that the dark organic soil composing most spoilbanks may increase solar absorption resulting in higher nest temperatures that might alter sex ratios (Moler, 1991) or desiccate eggs (Ogden, 1978). Furthermore, Lutz and Dunbar-Cooper (1984) concluded that sand is a more suitable substrate than organic matter, as fine particles of the latter may restrict gaseous diffusion to the egg. However, it should be noted that in the current study and others (Ogden, 1978; Moler, 1991), clutches deposited in organic substrates hatched successfully.

A single nest site was found on a low beach along the leeward shoreline of Blackbird Cay (Figure 18). This site was only slightly elevated above the normal high tide level, composed of fine sand and organic matter, and the surrounding soils were waterlogged. It is significant that the only mound nests found in Belize were at this site, and may represent attempts by females to compensate for a lack of elevation. Crocodilian eggs are intolerant of flooding, and submergence for more than 12 hours results in embryo death (Joanen et al., 1977).

Table 13. Description and location of American crocodile nesting areas identified in the coastal zone of Belize (1994 to 1997). Inclusion was based on the presence of an active nest or eggshells found at the site. Numbers in parentheses correspond to Figure 16.

Location	Description	Latitude (N)	Longitude (W)
Ambergris Cay			
Journeys End (1)	Beach Ridge	17° 58' 02"	87° 55' 47"
Santa Cruz Lagoon (2)	Island	18° 05' 14"	87° 54' 51"
San Pedro (WASA) (3)	Spoilbank	17° 53.72'	87° 58.75'
Belize City (4)	Spoilbank	17° 30' 50"	88° 12' 20"
Cay Caulker (5)	Spoilbank	17° 44' 10"	88° 01' 54"
Lighthouse Atoll			
Northern Cay (6)	Beach Ridge	17° 27' 11"	87° 29' 57"
Long Cay (7)	Beach Ridge	17° 37' 46"	88° 03' 55"
	Beach Ridge	17° 37' 33'	88° 04' 08"
Maps Cay (8)	Beach Ridge	17° 29.84'	88° 05.23'
Southern Lagoon (9)	Beach Ridge	17° 15' 17"	88° 20' 46"
Turneffe Atoll			
Blackbird Cay (10, 11)	Beach Ridge	17° 18' 57"	87° 47' 58"
	Beach Ridge	17° 20' 36"	87° 47' 56"
	Beach Ridge	17° 20' 25"	87° 47' 45"
	Low Beach	17° 25' 37"	87° 49' 21"
Northern Cay (12)	Beach Ridge	17° 29' 35"	87° 47' 08"
Deadmans Cay (13)	Beach Ridge	17° 13' 05"	87° 51' 44"

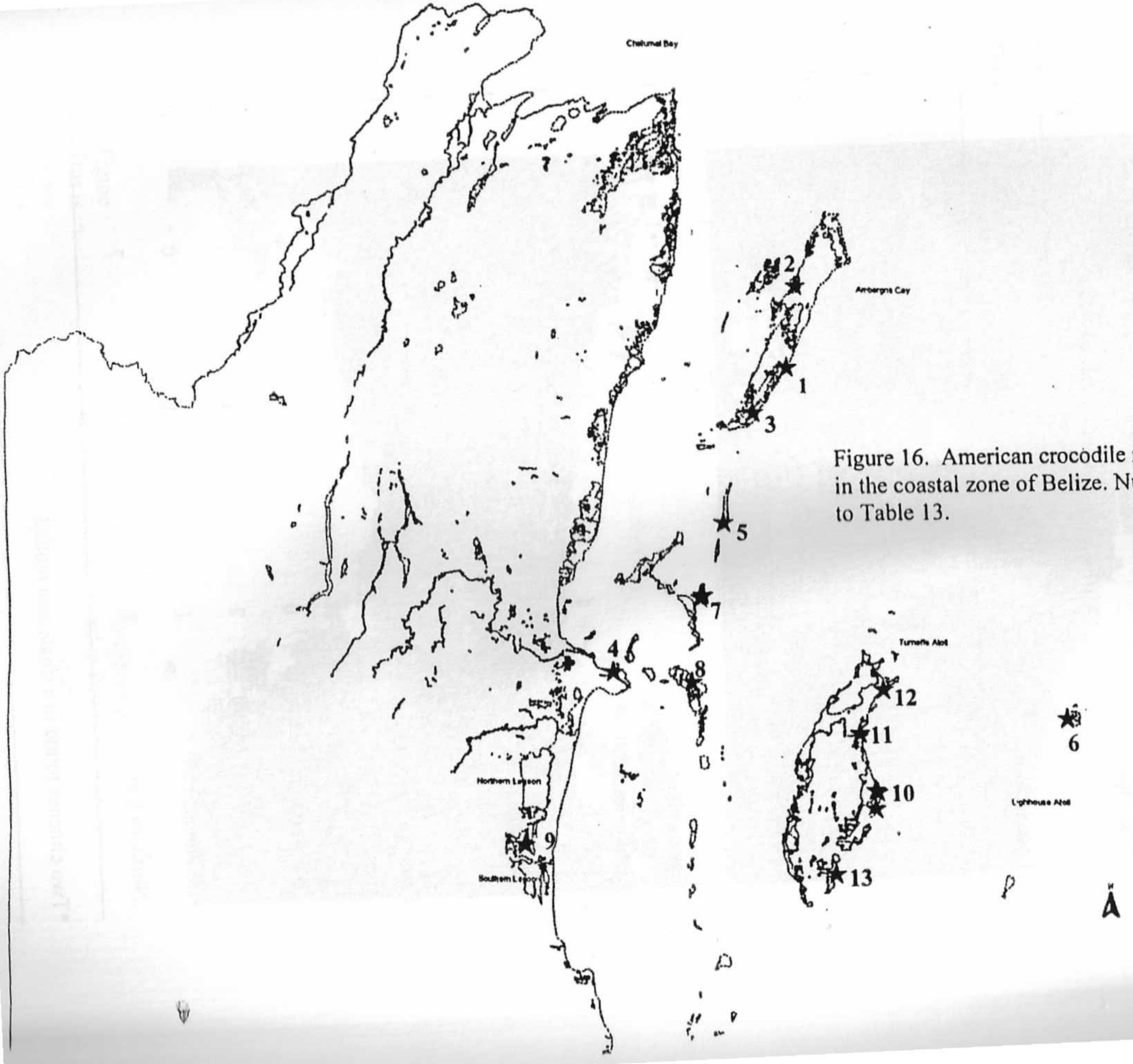


Figure 16. American crocodile nesting sites (star) in the coastal zone of Belize. Numbers correspond to Table 13.

Table 14. Number of American crocodile nests found each year at nesting beaches in Belize. Inclusion was based on the presence on the presence of an active nest or eggshells found at the site.

	Number of Nests			
Location	1994	1995	1996	1997
Ambergris Cay				
Journeys End		--	--	1
San Pedro	--	--	2	0
Santa Cruz Lagoon	--	1	0	--
Belize City	--	--	1	1
Cay Caulker	--	1	1	1
Lighthouse Atoll				
Northern Cay	--	--	--	1
Long Cay	--	--	2	1
Maps Cay	1	--	0	1
Southern Lagoon	--	--	1	1
Turneffe Atoll				
Blackbird Cay (east)	0	--	5	3
Blackbird Cay (west)	2	1	1	2*
Deadmans Cay	1	1	0	0
Northern Cay	8	?	7	10

*Two clutches found in a single nest mound.

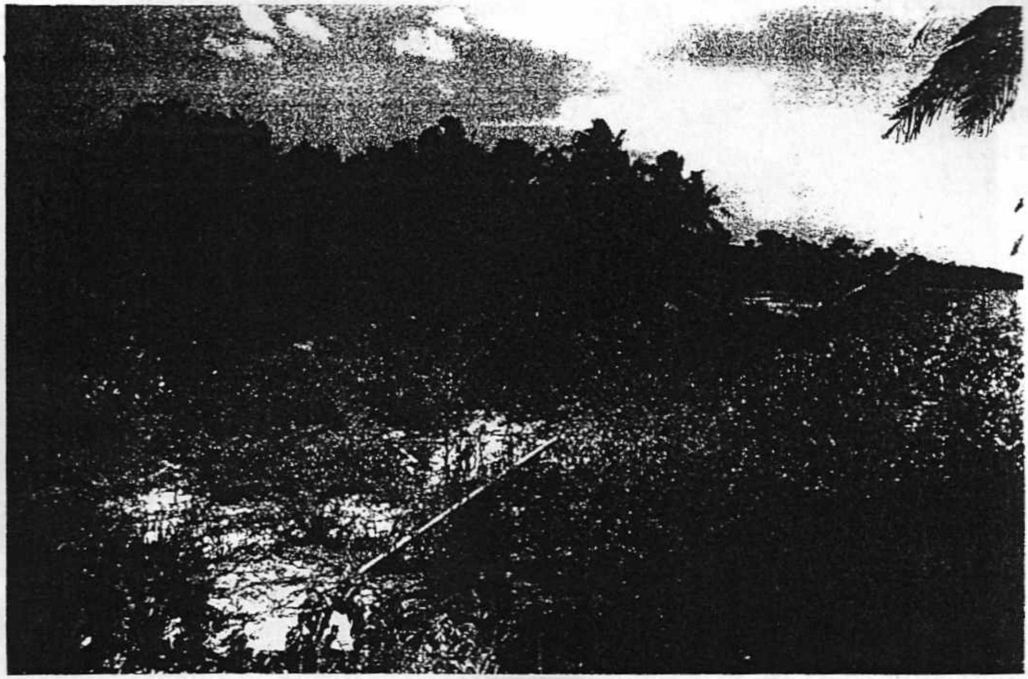


Figure [illegible] [illegible] crocodile nesting beach on Northern Cay [illegible] Turneffe [illegible]
This is the [illegible] significant nesting site yet identified in Belize [illegible] shallow [illegible]
lagoon ad[illegible] beach provides ideal nursery habitat [illegible]
(below)

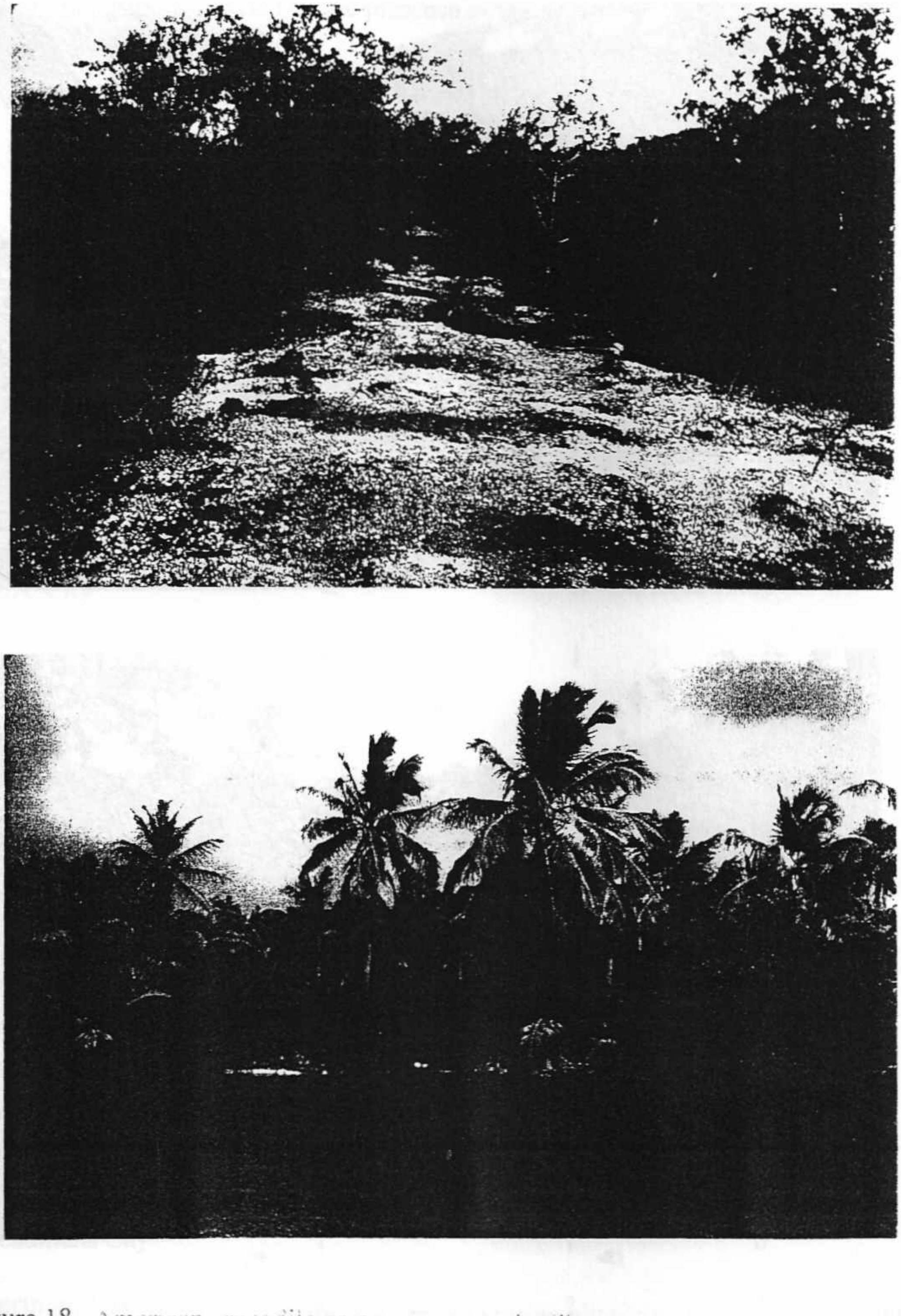


Figure 18. American crocodile nesting habitat: Spoilbanks [illegible] campus [illegible] University College of Belize, Belize City (above) and [illegible] beach [illegible] Blackbird [illegible]

Shallow mangrove lagoons (Figure 17) occur adjacent to nesting beaches on Northern Cay, Turneffe Atoll and Long Cay, and a freshwater pond is found at a nest site on Northern Cay, Lighthouse Atoll. These lagoons are thought to provide important nursery habitat for hatchlings as they are rich in prey, offer abundant cover, shelter from wave action, and provide a source of fresh or brackish water. Hatchlings cannot maintain body mass in seawater (35 ppt; Dunson, 1970), and access to fresh or brackish water (≤10 ppt) is important for osmoregulation (Mazzotti et al., 1986). Juvenile survival is typically high where nursery habitat is available (Kushlan and Mazzotti, 1989a).

Colonial nesting (more than one nest at a site) occurred at five of 16 nesting sites (Table 14). Colonial (sometimes referred to as "communal") nesting has been reported in other C. acutus populations (Thorbjarnarson, 1989), and is believed to occur when suitable nesting habitat is limiting (Thorbjarnarson, 1989). Nesting habitat is limiting in Belize due to both natural and anthropogenic factors. Elevated beaches generally occur only on the eastern (windward) shores of cays, and are lacking on many cays, especially those inside the barrier reef. Additionally, fishing camps and tourist resorts are usually constructed on these beaches, further reducing habitat available for nesting. The preservation of known and potential nesting habitat is therefore essential to ensure the continued viability of American crocodile populations in Belize (see Conservation Recommendations).

Minimum Reproductive Size

The size at which female C. acutus become sexually mature is highly variable between populations, and may reflect environmental or genetic differences in growth rates, and/or age at sexual maturity (Thorbjarnarson, 1989). Reported size at first reproduction ranges from 2.1 to 3.0 m (Table 15). However, the value in coastal Belize may be much lower. Blood samples collected from two females in February 1997 contained large amounts of visible fat indicating vitellogenesis was occurring. The females measured only 188.5 cm (#625) and 210 cm (#610), suggesting females in Belize reach sexual maturity at a size smaller than reported for other populations. The small clutches found in Belize are also suggestive of small female body size (see below). Males probably become sexually mature at a similar size, but may be excluded from breeding by larger, dominant individuals (Thorbjarnarson, 1989).

Courtship

The breeding system of the American crocodile is polygynous, and one male generally copulates with several females. During the breeding season males defend territories, excluding other males, but allowing females to enter (Lang, 1987). Courtship and mating are exclusively aquatic activities, and involve a complex repertoire of behaviors (Thorbjarnarson, 1989). Presumed courtship activity was observed during February 1997 in the Turneffe Atoll when groups of adult crocodiles were observed in shallow water near Calabash Cay, along the eastern shoreline of Blackbird Cay, and at the nesting area on Northern Cay.

Table 15. Minimum reproductive size reported for female American crocodiles.

Location	Total Length (m)	Source
Belize	1.8 to 2.1?	This Study
Columbia	2.3	Medem, 1981 as cited in Thorbjarnarson, 1989.
Cuba	2.7 to 3.0	Varona, 1987.
Florida, USA	2.25	Kushlan and Mazzotti, 1989a.
	2.13 to 2.74*	LeBuff, 1957.
Haiti	2.2 to 2.3	Thorbjarnarson, 1988.
Honduras	2.4	Klien, 1977 as cited in Thorbjarnarson, 1989.
Mexico	2.8	Alvarez del Toro, 1974.

* Length presented as "seven to nine feet". It is uncertain if crocodiles were actually measured.

Nesting

Crocodile tracks and shallow, exploratory holes were found on nesting beaches in the Turneffe Atoll during late March and early April 1997. Thirteen clutches were found from 4 April to 25 June 1997 (Appendix 4). Oviposition dates as estimated from egg band width, ranged from 29 March to 5 May 1997 (Appendix 4) with a mean date of 14 April ± 10.8 days. This coincides with the last half of the dry season, and is similar to nesting periods elsewhere in the Caribbean (Schmidt, 1924; Alvarez del Toro, 1974; Thorbjarnarson, 1989). While mating behavior was not observed in this study, oviposition typically occurs 20 to 30 days after ovulation (Astheimer et al., 1989). Thus, in Belize courtship and mating probably commence in February and peak in March, a period coinciding with our observations of groups of adult crocodiles in February 1997.

Nesting beaches appear to be reused annually. Nesting occurred in multiple years at ten of 11 sites for which more than one year of data is available (Table 14), although it could not be determined if these were the same or different females. Nest site reuse among C. acutus is common, especially where nesting habitat is scarce (Thorbjarnarson, 1989). The largest concentration of nests was found on Northern Cay, Turneffe Atoll where seven to 10 clutches were deposited annually (Table 14). Nests were generally positioned two to three meters apart. Two hole nests and one mound nest contained each contained two clutches.

Fifty-five nests were examined from 1994 to 1997. These included two mound nests and 53 hole nests. The two mound nests were found on a low beach along the western shore of Blackbird Cay. The first was found in 1994, and reused in 1995 and 1996. In 1997, a second mound was constructed about 3.0 m away from the original mound, and contained two clutches of eggs readily distinguished by a notable discrepancy in egg size and the extent of opaque banding. The two clutches were deposited adjacent to each other, and the majority of eggs in both appeared viable and hatched successfully. Each mound was a well defined pile of sand and leaves, measuring approximately 200 X 160 cm wide and 30 cm high. Similar mound nests have been reported only among American crocodile populations in Florida, USA (Ogden, 1978; Kushlan and Mazzotti, 1989a). The construction of mound nests may be an adaptive response to nesting in low-lying areas where the probability of flooding is high (Thorbjarnarson, 1989). The remaining nests examined in this study were classified as hole nests, although some were slightly mounded (<10 cm). The mean dimensions of 12 hole nests are presented in Table 16. According to Kushlan and Mazzottii (1989a) a continuum exists between mound and hole nests.

Fourteen clutches were found during this study (Appendix 4 and 5). One clutch was found in 1996 (Clutch #1), and thirteen in 1997 (Clutch #2-14). Clutch and egg parameters are summarized in Table 16. Mean clutch size was 22.3 $\pm$ 6.0 (range = 17 to 22; n = 14). This value is within the range found in other studies, but is among the lowest reported for the American crocodile (Table 17). Likewise, in comparison to other studies (Table 18), mean egg dimensions and mass found in Belize are also among the lowest reported.

Clutch mass is probably the best indicator of female reproductive output. Unfortunately, clutch mass has not been widely reported by previous workers, but comparisons with existing data indicate clutch mass found in Belize is considerably less than noted elsewhere (Table 19). The relationship of clutch and egg mass, with female body size is highly variable, both inter- and intraspecifically among crocodilians, but in general these parameters increase with increasing female body size (Thorbjarnarson, 1996). Thus, the small clutch and egg size found in this study are probably the result of the small female body size in the population.

Egg viability was determined by the presence of opaque bands on the eggshell, and unbanded eggs may result from infertility or early embryonic death (Ferguson, 1985). During this study, one nest contained rotten eggs and bands could not be distinguished, and three nests were found within 12 hours of oviposition before bands became evident (usually 24 hours after laying; Ferguson, 1985; S. Platt, pers. obs.). Levels of egg

Table 16. Nest dimensions and clutch characteristics of the American crocodile in Belize (1996 to 1997).

Parameter	Mean ± 1 SD	Range	n
Nest Characteristics			
Depth to Top of Clutch (cm)	23.3 ± 6.3	17 - 32	14
Depth to Bottom of Clutch (cm)	32.8 ± 5.4	22 - 40	14
Width of Hole (cm)	26.0 ± 8.6	20 - 35	12
Distance to Water (m)	8.5 ± 4.1	3.0 - 16.7	14
Clutch Characteristics			
Clutch Size	22.3 ± 6.0	12 - 32	14
Egg Length (mm)	70.5 ± 4.3	60.6 - 88.3	304
Egg Width (mm)	44.1 ± 1.6	39.2 - 50.0	304
Egg Mass (g)	85.6 ± 9.7	61.5 - 111.0	280
Clutch Mass (kg)	1.8 ± 0.8	0.9 - 3.1	13
Non-viable Eggs (%)	46.5 ± 41.7	0.0 - 86.6	8

Table 17. Clutch size (mean, range, and sample size) reported for the American crocodile. NA = not available.

Location	Mean	Range	n	Source
Belize	22.3	12 to 32	14	This Study
Haiti	22.5	17 to 28	14	Thorbjarnarson, 1989
Honduras	22	NA	1	Schmidt, 1924
Florida, USA	44*	19 to 81*	20	Ogden, 1978
	38	15 to 56	46	Kushlan and Mazzotti, 1989a
Cuba	NA	20 to 75	NA	Varona, 1987
Mexico	NA	30 to 60	NA	Alvarez del Toro, 1974

* According to Kushlan and Mazzotti (1989a) this value was inflated by counting multiple clutches in the same nest as single clutches.

Table 18. Length, width, and mass reported for American crocodile eggs. Means given if available, otherwise range is presented. NA = not available.

Location	Width (mm)	Length (mm)	Mass (g)	Source
Belize	44.1	70.5	85.6	This Study
Cuba	42 - 47	73 - 81	NA	Barbour and Ramsden, 1919
Florida, USA	NA	NA	91.3	Lutz and Dunbar-Cooper, 1984
Haiti	45.4	76.5	97.0	Thorbjarnarson, 1989
Honduras	42 - 42.5	70 - 76	NA	Schmidt, 1924
Mexico	54.0	80.0	NA	Alvarez del Toro, 1974
Panama	52.0	79.0	NA	Breder, 1946
Not Given	NA	NA	103.4	Duval, 1977 as cited in Thorbjarnarson, 1989

viability could be determined for 10 clutches. These nests contained 229 eggs of which 43 were non-banded (18.7%). However, 26 of the non-viable eggs were recovered at a single nest on Cay Caulker, and non-viability may have resulted from exposure to environmental pollutants. If this clutch is removed from the analysis, then an adjusted value of 8.5% is calculated. This is similar to the 10% and 9.9% levels of non-viability reported from Florida (Kushlan and Mazzotti, 1989a), and Haiti (Thorbjarnarson, 1988), respectively. Stress resulting from environmental or social factors (Ferguson, 1985; Platt, 1996) and diet (Hunt, 1980; Joanen and McNease, 1987) appear to influence levels of egg viability, which in some crocodilians exhibits considerable annual variation (Platt, 1996).

Approximate hatching dates were determined for two nests with known oviposition dates on Northern Cay, Turneffe Atoll. When inspected on 25 June 1997, damp sand in the holes indicated nests had been excavated within the previous six to 12 hours and the hatchlings removed. Estimated incubation periods were 78 and 81 days. Other clutches hatched from late June to mid-July, although the exact hatching dates were unknown and incubation periods could only be approximated. This is in accordance with the results of our previous study (Platt and Thorbjarnarson, 1996), and reports from elsewhere (see review in Thorbjarnarson, 1989). Hatchling emergence in Belize coincides with the beginning of the wet season, and June is the month of greatest rainfall (Johnson, 1983).

The reproductive chronology of C. acutus in Belize thus appears to follow the general Caribbean climatic pattern. Courtship and mating occurs during February and March, followed by nesting from late March to early May. Eggs incubate for a period of approximately 78 to 90 days, and hatchlings emerge in late June and early July, at the onset of the wet season. Hatchling emergence closely coincides with highest rainfall and lowest water salinities of the year. Hatchlings probably depend on rainfall events for rehydration, and according to Moler (1991) the temporal distribution of rainfall is as important as the amount of rain. Rainfall exerts a strong influence over growth rates, and hence survival of hatchlings (Moler, 1991).

Table 19. Clutch mass reported for the American crocodile.

Location	Clutch Mass (kg)	n	Source
Belize	1.8	14	This Study
Florida, USA	5.2	1	Lutz and Dunbar-Cooper, 1984
	4.0*	20	Ogden, 1978
	3.4*	46	Kushlan and Mazzotti, 1989a
Haiti	2.18	14	Thorbjarnarson, 1989

*Clutch mass not reported in original paper. Calculated by multiplying the reported mean clutch size by a mean egg mass of 91.3 g (Lutz and Dunbar-Cooper, 1984).

Nesting Success

Previous studies (Ogden, 1978; Kushlan and Mazzotti, 1989a) have attempted to estimate nesting (hatching) success by counting the number of eggshells at nest sites and subtracting the number of unhatched eggs from initial clutch size. However, this method has serious limitations and yields an underestimate of hatching success (Kushlan and Mazzotti, 1989a) as females often consume unhatched eggs during nest excavation (Kushlan and Simon, 1981). In this study, relatively few eggshells or unhatched eggs were found. For example, only 17 eggshells and no unhatched eggs were found during multiple visits to Northern Cay, Turneffe Atoll, while 60+ hatchlings were counted in the adjacent nursery lagoon. Thus, for the purposes of this study, a successful nest was defined as one that produced at least one viable offspring.

Successful nests were recognized by piped eggshell membranes and signs indicating the nest had been excavated by a female. Eggs that pip successfully are easily recognized as the membrane is usually intact save for one distal end. Nest excavation by the female leaves an enlarged hole with a characteristic apron of splayed sand. Conversely, at nests that had been raided by predators, shredded eggshell membranes were found, and the sand apron in front of the hole was absent (S. Platt, pers. obs.).

Nesting success appears to be high among C. acutus in Belize. Eight of ten (80.0%) clutches for which the fate is known were successful. The two exceptions were a clutch of eggs that apparently desiccated and another that was composed almost solely of non-viable eggs. Additionally, of 41 other nests examined (including Platt and Thorbjarnarson, 1996) only two were lost to raccoon (Procyon lotor) predation.

Most clutch mortality is attributed to a combination of flooding and nest predation, with minor losses from other causes such as unsuitable thermal regimes or desiccation (see review in Platt, 1996). Flooding does not appear to be a major source of mortality among C. acutus nests in Belize as most are on substrates not subject to inundation. Raccoons are a major nest predator wherever they occur with crocodilians (Platt, 1996), and are found throughout the Turneffe Atoll and on many cays (Platt and Thorbjarnarson, 1996; Zisman, 1992). However, egg losses to raccoons appear to be minor. An examination of raccoon scats in the Turneffe Atoll indicate various crabs comprise the bulk of the diet (S. Platt, pers. obs.). Crabs are abundant in mangrove habitats, and Fleming et al. (1976) found that raccoon predation of American alligator (Alligator mississippiensis) nests was dependent on the availability of alternate foods, with predation being lowest when other foods such as crawfish, were most abundant.

While nest defense by female American crocodiles was not observed during this study, fresh tracks were occasionally found and large adults seen near nests, and it is likely that females were guarding nests from predators. Female American crocodiles have been reported to defend nests from a variety of predators (Alvarez del Toro, 1974; Dugan et al., 1981; Varona, 1987; Paez and Bock, 1988), and while aggressive behavior towards human investigators is used as an index of nest defense in many studies. females may defend nests against small mammalian predators, but selectively avoid humans (Wilkinson, 1983).

Post-Hatching Observations

Twenty hatchlings approximately one-week old (identified by an open umbilical scar) were captured on 10 July 1997 at the nursery lagoon on Northern Cay. Turneffe Atoll (Appendix 2). Morphometric data is presented in Table 20. These values are similar to the data of Brandt et al. (1995; TL = 26.5 $\pm$ 1.9 cm. SVL = 13.4 $\pm$ 1.0 cm. mass = 59.4 $\pm$ 9.9 g, n = 785) and Lutz Dunbar-Cooper (1984; mass = 59.2 $\pm$ 1.2 g. other attributes not reported) from Florida, USA. The latter noted that hatchling mass was 0.64 $\pm$ 0.01 g of initial egg mass, and an almost identical value has been found for a wide range of bird species (Lutz and Dunbar-Cooper, 1984). This is due to water loss from the egg during incubation, and is thought to be indicative of a common evolutionary lineage between birds and crocodilians (Lutz and Dunbar-Cooper, 1984). Interestingly. if the mean body mass of week old hatchling C. acutus is divided by mean egg mass found in this study, a value of 0.68 is calculated, very close to the figure given by Lutz and Dunbar-Cooper (1984). A similar value was also found for C. moreletii in Belize (Platt and Rainwater, unpubl. data).

Maternal care of neonates appears minimal among C. acutus in Belize. Females excavated all successful nests, and based on an interpretation of sign, transported neonates to water. Adults were present in the nursery lagoon on Northern Cay. Turneffe Atoll shortly after hatchling emergence in August 1996, and June and July 1997. and did respond to hatchling distress calls during capture operations. However, no other evidence of maternal care was noted during this study. At other sites single hatchlings and juveniles were encountered at widely separated locations, suggesting true pod formation does not occur among neonate C. acutus in Belize. Other studies also indicate an extended period of maternal care is lacking in the American crocodile (Rodda, 1984; Thorbjarnarson. 1988; Kushlan and Mazzottii, 1989a; Moler 1991).

The timing of hatchling dispersal in Belize was found to be variable. No hatchlings could be found at the nursery lagoon on Northern Cay, Turneffe Atoll in November 1996, while at a similar site on Long Cay, juveniles that probably hatched in 1996 (based on TL; see Growth) were still present in February 1997. The large number of hatchlings at Northern Cay may have led to a rapid depletion of available food resources prompting an early dispersal. At Long Cay (2 nests in 1996). hatchling numbers may have never been high enough to deplete resources and juveniles remained near natal beaches. A similar resource depletion model has been proposed to explain home range dispersion patterns of C. acutus (Rodda, 1984). and daily movement away from a communal retreat by hatchling American alligators (Dietz and Hines. 1980). Hatchlings were never found near sites that lacked nursery habitat. and dispersal from these sites probably occurred immediately after hatching (Kushlan and Mazzottii. 1989a).

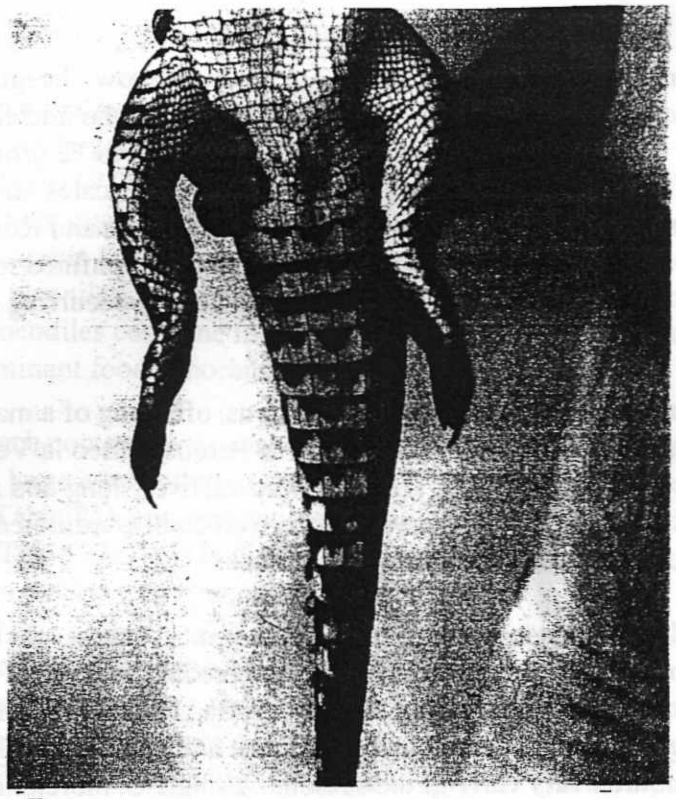
Table 20. Morphometric attributes of 20 American crocodile hatchlings, approximately one-week old, captured on 10 July 1997 in the nursery lagoon on Northern Cay, Turneffe Atoll.

Attribute	Mean + 1SD	Range
Total Length (cm)	27.9 ± 1.2	26.2 - 31.0
Snout-vent Length (cm)	13.2 ± 0.5	12.4 - 14.5
Head Width (mm)	22.0 ± 0.6	20.9 - 22.9
Head Length (mm)	42.4 ± 1.6	39.7 - 44.9
Mass (g)	58.5 ± 0.4	46.0 - 67.0

Hybridization

Hybridization between American and Morelet's crocodiles has long been postulated (Ross and Mayer, 1983). Crocodiles with characteristics of both species have been reported from the coastal regions of Mexico (Powell, 1972) and Belize (Schmidt, 1924; Abercrombie et al., 1980; Platt, 1996). These individuals typically exhibit a reduced number of dorsal scales in each transverse row, and reduced or absent subcaudal scale irregularities. In an examination of C. acutus museum specimens collected from throughout the range of the species, Ross and Ross (1974) found irregular scale groups on the lateral surface of the tail, only where C. acutus was sympatric with C. moreletii (Belize through Chiapas, Mexico), or where the population may have been influenced by feral C. moreletii (west coast of Mexico). The dorsal armor of the suspected hybrids resembled both parent species (Ross and Ross, 1974).

During this study several crocodiles were collected that exhibited traits of both C. acutus and C. moreletii. Three crocodiles which most closely resembled C. moreletii were captured in Monkey River (#102, #104, and #2-3-9-4). These individuals had typical C. moreletii dorsal scutellation and head shape, but the lateral and ventral surfaces of the tail completely lacked irregular scale groups. The ventral scutellation of the tail was symmetrical and identical in appearance to C. acutus (Figure 19). Another C. moreletii (#101) captured in Placencia Lagoon exhibited coloration similar to C. acutus, and had only 2 groups of irregular subcaudal scales, but a normal number of dorsal scales. A group of four juvenile C. moreletii (#117, #158, #162, #175) were captured in a small oxbow along the Bladen River. The juveniles were similar in size, and probably from the same clutch. The dorsal scutellation was highly variable, with one exhibiting normal C. moreletii scutellation, two exhibiting a reduced number of dorsal scales, and a single



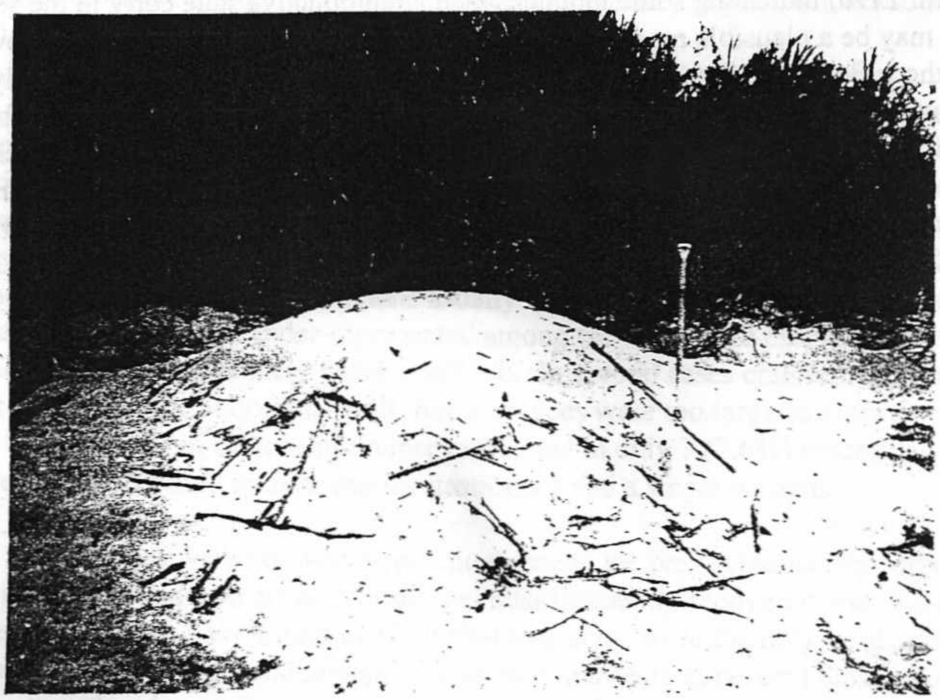


Figure 19. Subcaudal scutellation of a Morelet's crocodile collected from Monkey River in southern Belize (above). Note the complete absence of irregular scale groups, which is suggestive of hybridization with the American crocodile. Morelet's crocodile nest along the Swasey River (below). Boat paddle measures approximately 150 cm long.

individual had no more than four scales in any transverse row. Irregular subcaudal scale groups were present on all four crocodiles, but confined to the mid-line of the tail, and numbered only two to four, rather than the more typical 8 to 12 groups of C. moreletii. Finally a juvenile C. acutus (#4-8) which had two irregular scales on the ventral surface of the tail was captured on Ambergris Cay. According to Ross and Ross (1974), when irregular scales are found on the tail of C. acutus, they are confined to the lateral surface only. Whether any of these crocodiles represent naturally occurring hybrids remains unresolved.

Three known C. acutus X moreletii hybrids, offspring of a male American and a female Morelet's crocodile, were examined at the Parque Museo la Venta, Villahermosa, Tabasco, Mexico in August 1997. The head was relatively long and narrow, and appeared similar to a typical C. acutus. However, all three crocodiles exhibited normal-appearing irregular scale groups on the basilateral tail surfaces.

If hybridization is to occur in the wild, there must exist a mechanism for gene flow between the two species. In northern Belize, the breeding seasons of the American and Morelet's crocodiles apparently only slightly overlap (Platt, 1996). It is possible though, that a male C. acutus might occasionally inseminate a female C. moreletii which reaches reproductive condition very early in the season. A single C. moreletii clutch believed to have been deposited in mid-May, was found in northern Belize during a previous study (Platt, 1996) indicating some females reach a reproductive state early in the season, and this may be a plausible model for at least a low level of hybridization. However, in southern Belize, the breeding season of the two species occurs simultaneously (Appendix 7), and it is significant that this is the region where most of the suspected hybrids originate. In the absence of temporal differences, spatial segregation or behavioral mechanisms must exist to prevent a complete breakdown of inter-species barriers. Blood samples collected from American and Morelet's crocodiles, and suspected hybrids will be used to determine if hybridization is occurring among these populations.

FOOD HABITS

Few studies have specifically addressed food habits of the American crocodile. Most reports are largely anecdotal or based on the examination of a few stomachs (e.g., Alvarez del Toro, 1974; Medem, 1981; Schmidt, 1924), and Thorbjarnarson (1988) provides the only quantitative assessment of diet. Available information suggests the American crocodile follows the typical ontogenetic dietary shift described in other crocodilians; juveniles and hatchlings feed primarily on invertebrates, and with increasing body size, crocodiles consume increasingly larger amounts of vertebrate prey, with fish being the dominant food (Thorbjarnarson, 1989).

Stomach contents were examined from 104 crocodiles, ranging in size from hatchlings to large adults, during this study. The results are presented by frequency of occurrence (Table 21), and percent mass (Table 22). A list of all prey taxa recovered is presented in Table 23. This is the only study to examine the food habits of American crocodiles in a marine environment.

Invertebrates were the most important prey based on both frequency of occurrence and percent mass, for all size classes of crocodiles. Insect remains occurred in 31 (39.8%) stomachs and were usually recovered as highly macerated bits of chitin and flesh, which could not be readily identified to species. However, at least three orders were represented among identifiable remains. All insects are believed to have been consumed directly, and there was no evidence of secondary ingestion (Jackson et al., 1974).

Crustaceans (crabs and shrimp) were found in 72 (69.2%) stomachs, were consumed by all size classes, and represent the most important prey category for American crocodiles living in coastal habitats of Belize. Crabs were found in 64 (61.5%) stomachs, and six species were identified including terrestrial (Cardisoma guanhumi, Ucides cordatus), arboreal (Aratus pisonii, Goniopsis sp.), and aquatic (Uca minax, Callinectes sp.) species. Crab remains usually consisted of claws, legs, and pieces of carapace. Crabs may be under-represented among the larger size classes, as recovery by stomach flushing occasionally proved difficult. In several cases crab remains could be palpated through the abdominal wall, but the pieces were too large to enter the stomach tube. Shrimp were of minor importance and found in only 7 (7.6%) crocodiles. Other invertebrates recovered include marine gastropods and a single octopus.

Vertebrates were not well represented among the prey remains recovered during this study. Fish and bird remains were the most frequently recovered and constituted the greatest mass. Fish were found in 10 (9.6%) stomachs, were the only vertebrate prey consumed by hatchlings, and ranked second next to insects in percent mass. Rapid digestion rendered most fish unidentifiable to genus, but one recently consumed Gambusia sp. was recovered. Another crocodile was captured with a snapper (Lutjanus sp.) in its jaws. This fish was included in the list of prey taxa, and the analysis of diet by percent occurrence, but not in percent mass. Consumption of fish by smaller size classes may be

Table 21. Frequency of occurrence (%) of prey taxa and non-food items recovered from 104 American crocodiles collected in Belize (1996 to 1997). Presented by size class with sample size in parentheses.

	Size Class			
	<50 cm	50 - 90 cm	90 - 180 cm	>180 cm
Prey Category	(32)	(15)	(40)	(17)
Insects	50.0	60.5	15.0	0.0
Mollusca	0.0	6.6	2.5	5.8
Crustacea				
Crab	25.0	66.0	77.5	88.2
Shrimp	0.0	0.0	17.5	5.8
Isopoda	9.3	0.0	0.0	0.0
Osteichthyes	6.2	0.0	15.0	11.7
Amphibia	0.0	0.0	15.0	11.7
Reptilia	0.0	6.6	2.5	0.0
Aves	0.0	0.0	7.5	11.7
Mammalia	0.0	13.3	0.0	0.0
Non-food Items				
Gastroliths	0.0	0.0	27.5	17.6
Vegetation	0.0	6.6	0.0	23.5
Nematodes	6.2	20.0	50.0	17.6

Table 22. Percent mass of prey taxa recovered from 104 American crocodiles collected in Belize (1996 to 1997). Presented by size class with sample size in parentheses.

	Size Class			
	<50 cm	50 - 90 cm	90 - 180 cm	>180 cm
Prey Category	(32)	(15)	(40)	(17)
Insects	46.2	66.1	1.3	0.0
Mollusca	0.0	1.0	0.4	2.0
Crustacea				
Crab	19.1	31.0	83.1	65.2
Shrimp	0.0	0.0	5.9	0.1
Isopoda	6.5	0.0	0.0	0.0
Osteichthyes	28.0	0.0	4.1	15.3
Amphibia	0.0	0.0	0.4	0.0
Reptilia	0.0	1.0	0.1	0.0
Aves	0.0	0.0	4.3	16.6
Mammalia	0.0	1.0	0.0	0.0

Table 23. Prey taxa identified in stomach contents of 104 American crocodiles collected in Belize (1996 to 1997).

Class Insecta	Class Amphibia
Coleoptera	*Rana* sp.
Odonata	Class Reptilia
Orthroptera	*Rhinoclemmys areolata*
Class Gastropoda	*Ctenosaura similis*
Cerithium sp.	Class Aves
Class Crustacea	*Phalacrocorax* sp.
Decapoda	
Aratus pisonii	
Callinectes sp.	
Cardisoma guanhumi	
Goniopsis sp.	
Palaemonidae	
Uca minax	
Ucides cordatus	
Isopoda	
Class Osteichthyes	
Gambusia sp.	
Lutjanus sp.	

an important source of dietary water and important in osmoregulation (Ellis, 1981; Dunson, 1982). Bird remains, mostly cormorant feathers, were recovered from five (4.8%) stomachs.

Other vertebrate remains included mammals (unidentified balls of hair), a lizard (Ctenosaura similis), and a turtle (Rhinoclemmys areolata). The latter was recovered from a subadult crocodile captured in Northern Lagoon, Turneffe Atoll. The remains were fresh and included a foreleg and shreds of skin. It is believed the turtle originated in the atoll. The nearest known Rhinoclemmys populations are on the coast of mainland Belize, about 40 km away, and given the rapid digestion of flesh and bone in the crocodilian stomach, the undigested state of the remains strongly suggest the turtle was consumed locally. R. areolata has not been previously reported from the atoll (Lee, 1995), and this finding constitutes a significant range extension. The remains (CUSC #1382) were deposited in the Vertebrate Collection, Clemson University, Clemson, South Carolina, USA.

Significant differences were noted in patterns of prey consumption between size classes. Hatchling crocodiles consumed primarily insects, fiddler crabs (Uca minax), and small fish. Because of a high surface to mass ratio, hatchlings are especially vulnerable to dehydration under saline conditions (Taplin, 1988) and fish consumption is probably extremely important from an osmoregulatory standpoint. The food habits of hatchling crocodilians are not well described, but other reports suggest a similar reliance on insects and small invertebrates (Delany, 1990; Fischer et al., 1991, Platt, 1996). Neonates C. acutus begin feeding seven to ten days after hatching.

Larger (TL = 50 to 90 cm) juveniles fed primarily on insects and crabs, and subadults and adults consumed increasing amounts of crabs, and vertebrate prey. Insects were of negligible importance to subadults, and not found in stomachs of adults. The frequency of occurrence of crabs steadily increased with increasing body size, and they appear to be the most important food for larger size classes. However, percent mass of crabs declined slightly among adult crocodiles. This may have resulted from a diversification of the diet to include more vertebrate prey, but it may also reflect the difficulty experienced in recovering crab remains by stomach flushing. Birds and fish were the most important vertebrate prey for subadult and adult crocodiles. However, in contrast to other studies (Thorbjarnarson, 1989), fish were not the dominant prey of adult C. acutus in Belize.

Gastroliths were recovered from 14 (7.4%) crocodiles, and generally consisted of pieces of coral or pumice. Gastroliths were only recovered from crocodiles >90 cm TL, and are believed to facilitate the breakdown of ingested prey in a manner similar to grit in the avian gizzard (Sokol, 1971). Plant material is probably ingested incidental to prey capture and has no nutritional value (Coulson and Hernandez, 1983).

Foraging crocodiles were most frequently encountered in calm, shallow water habitats such as turtle grass beds, mangrove swamps, and sandy shoals. These areas offer an abundance of fish and invertebrates, and constitute important foraging habitats. In the Turneffe Atoll, the presence of marine gastropods and octopus among stomach contents, and heavily abraded ventral scutes noted on some captured crocodiles and thought to result from crawling over coral, strongly suggest that additional foraging activity occurs along sheltered portions of the barrier reef. While spotlight surveys were not conducted because of the danger involved, several fishermen reported encountering crocodiles along the reef. Furthermore, in the Turneffe Atoll the reef crest is only 100 to 200 m from many areas where crocodiles were frequently observed during spotlight surveys.

Crocodiles were also often found in the vicinity of fishing camps where entrails and other refuse were being discarded in the water. Crocodiles are readily attracted by this waste, and while it may represent a potentially important food source, improper disposal practices increase the likelihood of crocodile/human conflicts.

GROWTH RATES

Published values for C. acutus growth rates are mainly from animals less than two years old, and indicate growth is rapid during this period (Thorbjarnarson, 1989). Growth rates are typically greatest during the first few months after hatching, and decline as animals grow older. Rapid growth early in life reduces the period in which juveniles are vulnerable to predation and osmotic stress. The little available data for older crocodiles suggests that growth rates continue to decline throughout life. Growth rates also exhibit considerable temporal and individual variation, especially among larger animals (Thorbjarnarson, 1989). Growth rate data is summarized in Table 24.

The limited duration of this study precluded gathering long-term growth data, but hatchling growth rates were approximated. Three juveniles (mean TL = 43.5 $\pm$ 0.81 cm) captured in a nursery lagoon on Long Cay on 19 February 1997, were assumed to have hatched in July 1996 based on total length and the presence of a discernible umbilical scar. Assuming a hatching date of 1 July 1996 (see Reproduction) and a mean hatchling length of 27.9 cm, total length had increased by 15.6 cm over a period of 233 days (0.066 cm/day). If this growth rate is sustained, hatchlings would reach an approximate length of 52.0 cm at one year of age. However, crocodiles may be substantially smaller due to stressful environmental conditions, particularly during the dry season when juveniles are exposed to elevated water salinity and temperature.

Another crocodile (#7-3) was initially captured on 24 November 1996, and recaptured on 27 February 1997. Total length increased by 3.0 cm (114.5 to 117.5 cm) over an interval of 95 days (0.03 cm/day). It is not known if this is a representative growth rate for larger C. acutus in Belize. However, if a hatchling reaches a total length of 52.0 cm at the end of year 1, given a growth rate of 0.03 cm/day thereafter, it will require an additional 11.3 years to reach sexual maturity (TL ca. 180 to 210 cm for females: see Reproduction). These growth rates are the lowest reported for any population of C. acutus, but should be interpreted with extreme caution as they are based on a sample size of only four crocodiles.

The slow growth rates of American crocodiles in Belize is probably manifested in the small adult body size noted in this study. Slow growth rates among neonates could also result in lowered survival by increasing the period hatchlings remain at a size vulnerable to predation and osmotic stress. Mazzottii (1983) found that once hatchlings reach a mass of 200 g (TL ca. 42 to 43 cm) they are much less susceptible to osmotic stress. In Florida, USA this size may be attained in three to four months of hatching, but in Belize this may take nearly a year. The reasons for the diminished growth rates in Belize are unclear, but it is possible there is a high metabolic cost associated with living in a marine environment, and consequently individuals must invest additional energy into osmoregulation at the expense of growth.

Table 24. Growth rates reported for the American crocodile.

Age Class	Location	Growth Rate (cm/day)	Source
Hatchlings	Belize	0.066	This Study
	Florida, USA	0.112	Kushlan and Mazzottii. 1989a
	Florida, USA	0.117 - 0.157	Moler. 1991
	Haiti	0.111 - 0.135	Thorbjarnarson. 1988
1 - 2 Years	Haiti	0.05 - 0.06	Thorbjarnarson. 1988
>2 Years	Jamaica	0.05	Thorbjarnarson. 1989
	Florida, USA	0.08	Moler. 1991

SALINITY RELATIONS

A summary of water salinity data from 283 non-hatchling crocodile sightings and captures is presented in Table 25. Salinities were lowest at mainland sites owing to the influence of run-off from nearby rivers and creeks, and considerably higher on offshore cays and atolls. The highest mean salinity was found in the Turneffe Atoll where mean salinity approached seawater (35 ppt). However, water salinities recorded in inland lagoons in the Turneffe Atoll were considerably lower, but highly variable. The most saline conditions where crocodiles were found was 47.0 ppt in the nursery lagoon on Northern Cay, Turneffe Atoll (June 1997), and 45.0 ppt in Laguna Cantena, Ambergris Cay (May 1997). The mean salinities recorded in this study are somewhat higher than those found in Florida, USA (Table 26). The highest salinities where crocodiles were encountered in Florida ranged from 35 to 40 ppt in cooling canals at Turkey Point Power Plant (Gaby et al., 1985; Mazzotti et al., 1986).

Hatchling crocodiles were found only at three sites during this study: the nursery lagoon on Northern Cay, Turneffe Atoll, a mangrove swamp and borrow pit at the WASA Facility, Ambergris Cay, and a small, man-made pond on Northern Cay, Lighthouse Atoll (Table 27). Salinity at these sites ranged from freshwater (0.0 ppt) to 34 ppt. The nursery lagoon on Northern Cay was visited periodically throughout the study, and salinity appeared to be strongly influenced by rainfall events (Figure 20). Salinity was lowest after heavy rains in the summer of 1996, peaked in June 1997 following an exceptionally severe dry season (June 1997), and began to decline during the wet season of 1997. Hatchlings were observed in the nursery lagoon only during August 1996, and July and August 1997. Hatchling C. acutus have been reported from a wide range of water salinities (Mazzotti et al., 1986), but at high salinities lose mass rapidly. Optimal salinity is probably ≤10 ppt (Mazzotti et al., 1986). Thus it appears that C. acutus hatchlings in Belize may be subject to prolonged periods of osmotic stress during periods of elevated water salinity, which may result in decreased growth and survival.

The elevated salinities found in this study are interesting because the American crocodile is considered an estuarine rather than a true marine species (Taplin, 1988; Kushlan and Mazzotti, 1989a). American crocodiles lose weight in sea water as an inverse function of total body volume (Ellis, 1981). This problem is particularly acute among smaller size classes which have a high surface to body mass ratio (Taplin, 1988), and under laboratory conditions hatchling C. acutus are incapable of maintaining mass in seawater (Dunson, 1970; Evans and Ellis, 1977; Ellis, 1981). All members of the order Crocodylia posses extra-renal salt excreting glands on the tongue, but field and laboratory studies do not support a significant secretory role for these glands in C. acutus under saline conditions (Taplin, 1988). Rather, osmoregulation is accomplished by a variety of behavioral mechanisms. Foremost seems to be drinking brackish or freshwater made available by rainfall (Mazzotti et al., 1986; Kushlan and Mazzotti, 1989a). A positive water flux may also be maintained by consuming vertebrate prey (Ellis, 1981; Dunson, 1982), and avoiding hypersaline conditions through utilization of humid, terrestrial microhabitats (Ellis, 1981).

Table 25. Water salinities recorded during observations of American crocodiles in coastal habitats of Belize (1996 to 1997). These values do not include observations of hatchlings.

Habitat	Mean ± 1SD (ppt)	Range (ppt)	n
Coastal Mainland	3.2 ± 2.2	0.0 - 6.0	14
Cays	28.2 ± 7.2	10.0 - 45.0	85
Turneffe Atoll			
Inland Lagoons	14.3 ± 14.7	0.0 - 47.0	26
All Other Areas	33.7 ± 3.2	18.0 - 36.0	158

Table 26. Water salinities reported for American crocodile populations in Florida. USA. NA = not available.

Source	Mean ± 1SD (ppt)	Range (ppt)	n
Kushlan and Mazzotti, 1989a			
Overall	13.8 ± 10.0	0.0 - 35.0	111
Spring and Summer	17.8 ± 9.5	0.0 - 35.0	53
Winter and Fall	9.8 ± 8.8	0.0 - 31.0	58
Gaby et al., 1985	NA	0.0 - 40.0	?

Table 27. Water salinity recorded at sites where hatchling American crocodiles were observed in Belize (1996 to 1997).

Location	Date	Number of Hatchlings	Salinity (ppt)
Ambergris Cay			
Borrow Pit	4 Oct. 1996	1	26
Mangroves	4 Oct. 1996	1	34
Lighthouse Atoll			
Northern Cay	23 Aug. 1996	1	0
Turneffe Atoll			
Northern Cay	21 Aug. 1996	60+	10
	10 July 1997	100+	34
	22 Aug. 1997	10+	30

Osmoregulatory strategies employed by American crocodiles inhabiting marine environments in Belize remain largely unknown. It is unlikely that prey consumption represents a significant source of freshwater for adult crocodiles, as the diet is composed mainly of crabs, and marine invertebrates are isotonic with respect to their environment (Grigg et al., 1980). However, the large mass of fish recovered from hatchlings (see Food Habits) strongly suggests that vertebrate prey represent an important source of dietary water for the size classes most vulnerable to osmotic stress. Rainfall probably provides a significant source of freshwater, especially during the wet season. Crocodiles were observed in a rain-filled slough (0.0 ppt) on Blackbird Cay during November 1996, and a well worn trail to the sea indicated crocodiles were regularly moving into the slough. However, during the dry season there is a paucity of surface water on these islands and what is available is hypersaline (+35 ppt).

Lingual salt glands may play a significant excretory role among American crocodiles inhabiting marine environments. Taplin (1988) cautions that no measurements of Na^- influx or salt gland function have been carried out with C. acutus recently captured in a marine environment. Earlier conclusions were based on experimental animals of uncertain geographic origin obtained from crocodile farms (Evans and Ellis, 1977; Dunson, 1982). Experiments performed on C. porosus shortly after capture in saline habitats, clearly demonstrated the role of salt glands in salt excretion in that species. The excretory role of salt glands in C. acutus living under marine conditions is an area that warrants further investigation.

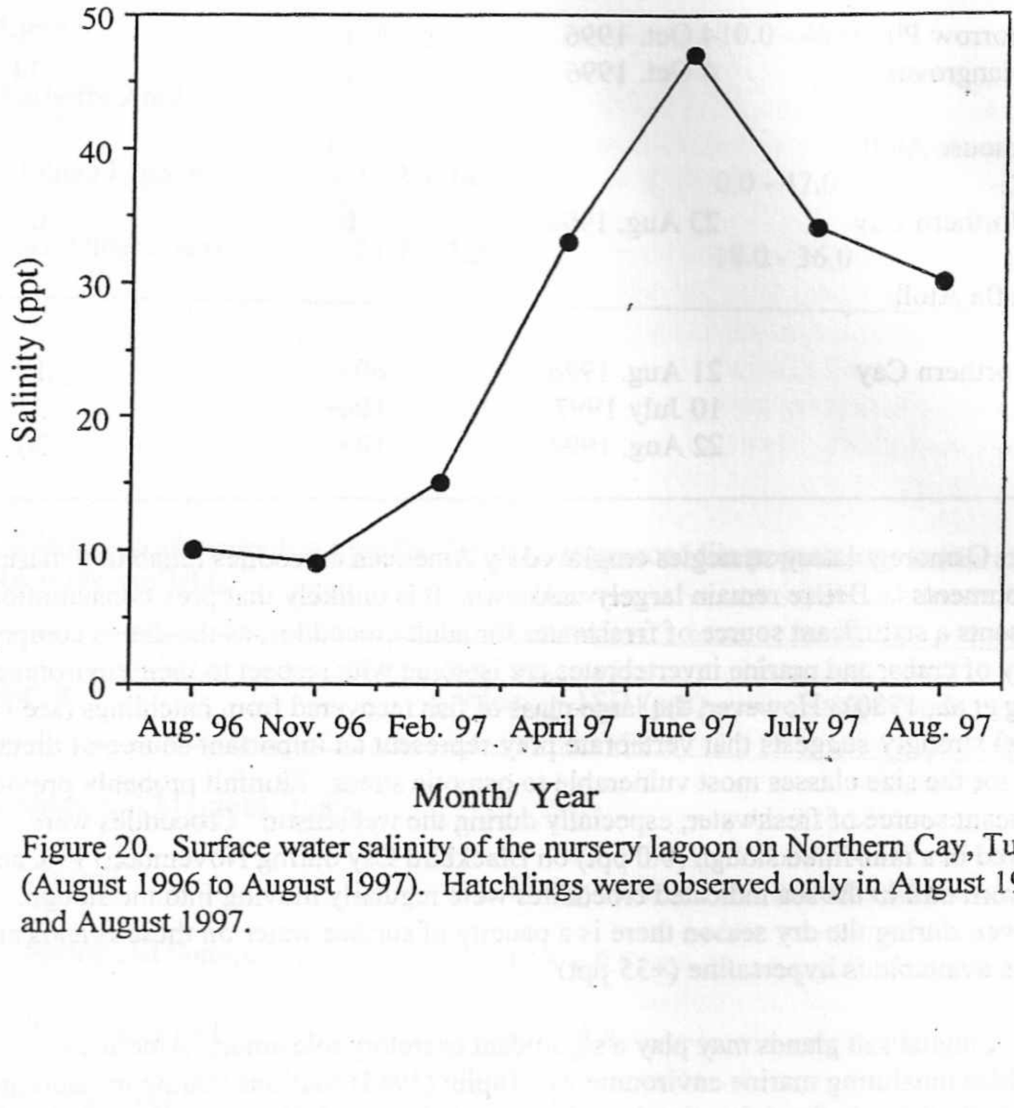


Figure 20. Surface water salinity of the nursery lagoon on Northern Cay, Turneffe Atoll (August 1996 to August 1997). Hatchlings were observed only in August 1996, and July and August 1997.

PARATRICHOSOMA INFECTION AND INJURIES

Paratrichosoma sp. are parasitic nematodes which burrow through the epidermal layers, leaving visible tunnels on the ventral scutes (Ashford and Muller, 1978). The adults deposit eggs, and larvae mature in the tunnels. Transmission from one host to the next is not well understood (Ashford and Muller, 1978). Paratrichosoma infection has been noted in at least seven species of crocodilians, including C. acutus and C. moreletii (King and Brazaitis, 1971, Ashford and Muller, 1978). The parasite was first described by Solger (1877) from C. americanus in Mexico, and it is unclear whether this is a reference to C. acutus or C. moreletii. Infection can considerably lower the commercial value of crocodilian skins (King and Brazaitis, 1971).

Twenty-three (18.6%) American crocodiles captured during this study had evidence of Paratrichosoma infection (Table 28). Infection was most prevalent among larger size classes, and highest among subadults. It is unclear why infection is highest among intermediate sized animals, and the etiology of infection is poorly known (Ashford and Muller, 1978). No infection was found among crocodiles <60 cm TL. Contrary to Ashford and Muller (1978), who concluded the parasite is rare or absent among crocodiles in saline habitats, most (95.1%) of the American crocodiles examined in this study originated in marine habitats where water salinity approached full-strength seawater water (35 ppt). Much higher levels of Paratrichosoma infection were reported among C. johnstonii (Webb and Manolis, 1983), and C. porosus (Webb and Messel, 1977) inhabiting freshwater habitats.

Twenty-nine (23.5%) American crocodiles captured in this study showed evidence of recent or past injuries. The incidence increased from 0.0% among small juveniles to 58.3% of adults (Table 28). Injuries generally consisted of extensive scarring or open wounds on the ventral and lateral surfaces of the tail, and the ventral and dorsal surfaces of the head. Some injuries were noted in the thoracic and abdominal regions, and occasionally missing digits or limbs were encountered. The incidence of injuries found among C. acutus in Belize is higher than the 2.6% reported from Haiti (Thorbjarnarson, 1988), or the 14.1% from Jamaica (Garrick, unpubl. data cited in Thorbjarnarson, 1989). Most injuries are probably the result of aggressive intraspecific encounters (Cott, 1961; Webb and Manolis, 1983).

BLOOD COLLECTION

Blood samples were collected from 180 crocodiles during this study. These include 85 samples from American crocodiles (9 from mainland populations, 23 from offshore populations, and 53 from the Turneffe Atoll), and 95 from Morelet's crocodiles (48 from inland populations and 47 from coastal populations). Genetic analyses of these samples will be conducted by Dr. George Amato, Wildlife Conservation Society, Bronx, New York, USA.

Table 28. The incidence of Paratrichosoma sp. infection and injuries among 123 American crocodiles captured in Belize (1996 to 1997).

Size Class (n)	Paratrichosoma Infection (%)	Injuries (%)
<60 cm	0.0	0.0
60 - 90 cm	25.0	33.3
90 - 180 cm	34.8	25.5
>180 cm	20.8	58.3

A POPULATION MODEL FOR THE AMERICAN CROCODILE IN THE COASTAL ZONE OF BELIZE

Chabreck (1966) proposed the following model to estimate the size of crocodilian populations:

E = N / (P X A X F) where

E = percent of females nesting.
N = total number of nests.
P = total population size,
A = percent of population which is sexually mature.
F = percent of females among mature crocodiles.

The variables A, F, and N can be estimated from nest counts, and demographic data obtained in spotlight counts. For purposes of this model only crocodiles greater than 210 cm TL are considered sexually mature; however females may be capable of reproducing at an even smaller body size (see Reproduction). Based on the spotlight counts. 24.5% of the population is considered sexually mature (A). Thirty-six of 83 crocodiles captured were females. Thus the percent of females (F) among mature crocodiles in the Turneffe Atoll is estimated to be 43.3%. Fifteen C. acutus nests were found in the Turneffe Atoll in 1997 (N). It is believed that all nests in the Turneffe Atoll were accounted for in 1997.

Estimates of reproductive effort (E) are available only from Everglades National Park (Mazzotti, 1983 as cited in Thorbjarnarson, 1989), and Etang Saumatre. Haiti (Thorbjarnarson, 1988), where 72 and 63.8% receptively, of females are estimated to nest each year. Estimates of E are unavailable for Belize populations, so the figure from Haiti (63.8%) was used because of population similarities in clutch parameters and size of nesting females.

Solving for P yields an estimated population size in the Turneffe Atoll of 232 non-hatchling crocodiles. Thus there are probably 200 to 300 non-hatchling crocodiles in the atoll, with perhaps 20 to 30 breeding females. This is considerably less than the estimate of 500 to 600 proposed by Perkins (1983). However, our estimate must be interpreted with caution for several reasons. First, the percent of females nesting each year is probably a population specific parameter, and the value from Haiti might be unrealistic for Belize. Second, the number of clutches deposited in the Turneffe Atoll may vary annually. Third, significant numbers of juveniles may have been concealed in the mangroves and therefore not detected during spotlight surveys. Increasing the number of juveniles counted during surveys would cause a proportional decrease in A. resulting in a greater value for P.

Using estimates of population size for the Turneffe Atoll. and the area of mangrove habitat in the coastal zone. it is possible to obtain a crude approximation of the country-wide population of C. acutus (Table 29). According to McField et al. (1996) there are 8.771 ha of mangrove habitat in the Turneffe Atoll. Assuming a population of

250 non-hatchling crocodiles in the atoll, a density of 0.028 crocodiles/ha is calculated. If it is assumed that similar densities are present on offshore cays, then the 12.913 ha of mangrove on the cays is calculated to support an additional 370 crocodiles. Because our survey data indicate American crocodiles are extremely rare on the mainland, density values from Turneffe Atoll are considered inappropriate. To account for these extremely low mainland densities, a value of 0.005 crocodiles/ha was used in the calculation. Thus, the 54.255 ha of mangroves on the mainland is expected to support 272 crocodiles, which should be considered a very liberal estimate. Based on demographic data, many of these are probably subadults. Summing the values for the Turneffe Atoll, coastal cays, and mainland gives a country-wide population estimate of only 892 crocodiles, considerably less than the estimate of 10.000 to 20,000 originally proposed by Perkins (1983).

The American crocodile population in the Turneffe Atoll may function as a regionally important source population. Large juvenile and subadult crocodiles enter a dispersal phase when they begin to come into territorial conflict with adults, and this phase is an integral part of C. acutus population dynamics (Thorbjarnarson, 1989). Crocodiles may move long distances during this phase, and Moler (1991) has reported the recovery of tagged juveniles 12 to 112 km from the initial point of capture. The scarcity of juvenile crocodiles in the Turneffe Atoll may be related to dispersal events, as the atoll is only 15 to 20 km from the chain of offshore cays inside the barrier reef; well within the dispersal capabilities of juveniles. Given the large number of adults in the atoll and the highest concentration of nesting activity in the coastal zone, it is probable that the Turneffe Atoll population plays an important role in regional metapopulation dynamics.

A similar metapopulation model may explain the distribution of the American crocodile along the Atlantic coast of Mexico. C. acutus is present along the eastern shore of the Yucatan Peninsula, on both the mainland and offshore islands, including Banco Chinchorro Atoll, but absent from the western side of the Yucatan and most of the Gulf Coast of Mexico (Lee, 1995; Marco Lazcano, pers. comm.). Morelet's crocodile occurs throughout this region, but is confined to the mainland (Lee, 1995). Morelet's crocodile appears capable of tolerating saline conditions, and while the interaction between the two species is poorly understood, this distributional pattern suggests C. moreletii may exclude C. acutus from many mainland habitats. The offshore islands and Banco Chinchorro probably serve as source populations for C. acutus on the mainland of eastern Yucatan, while the absence of suitable offshore refuges on the western side of the peninsula has precluded the establishment of C. acutus populations in this region.

Table 29. Population estimates of the American crocodile in the coastal zone of Belize.

Location	Density (Crocodiles/ha)	Mangrove Habitat (ha)*	Estimated Population
Turneffe Atoll	0.028	8,771	~250
Cays	0.028	12,913	~370
Mainland	0.005	54,255	~272
Total		75,939	892

*Data from McField et al., 1996.

Population Recruitment

The short duration of this study did not allow a quantitative assessment of age-specific survival or population recruitment. Crocodilians typically exhibit Type I survivorship curves with most mortality occurring early in life (Smith, 1980). Once individuals reach adult size, age-specific survival remains relatively constant until senescence. Survivorship may also vary temporally and spatially.

Estimates of age-specific survival are available for two American crocodile populations in Florida, USA (Table 30). At North Key Largo, first year survival among cohorts ranged from 6.8 to 42%, with a pooled estimate of 20.4%. Survival increased thereafter with increasing age, and beyond age five is very high (Moler, 1991). Age specific survival rates were considerably lower at Turkey Point Power Plant, and the authors speculate that some crocodiles assumed to have died may have dispersed from the site (Brandt et al., 1995). Survival rates can be difficult to determine in field studies because it is often impossible to distinguish between emigration and mortality (Moler, 1991).

Population recruitment in the Turneffe Atoll was estimated using the survivorship data from North Key Largo. The following assumptions were made based on the results of our study:

1. The number of clutches deposited in the atoll each year is 15.
2. The total number of eggs produced was calculated by multiplying the number of nests by a mean clutch size of 22.5. The resulting value is 335.

3. Egg viability is 91.5 % and all viable eggs hatch. Thus, the initial cohort consists of 305 hatchlings.

The resulting survivorship of this cohort is calculated in Table 31. An estimated 5 to 10 individuals from the initial cohort will survive to reach adulthood based on this model. As the sex ratio in the Turneffe Atoll is 1:1, half of these are expected to be females. If the population of adult crocodiles is assumed to be 97 based on the preceding population model and size class distribution data, this represents an annual increase of 5.1 to 10.3%. A value of approximately 9% was calculated for C. acutus populations in Florida (Brandt et al., 1995). The reader is cautioned however, that this model is probably over simplistic.

Table 30. Age-specific survivorship of C. acutus from the Turkey Point Power Plant (Brandt et al., 1995) and North Key Largo (Moler, 1991), Florida, USA. Values represent mean survivorship from multiple cohorts. Percent survival is the percent of the original cohort surviving to a given age. NA = not available.

	% Survival	
Year	Turkey Point	North Key Largo
1	8.5	20.4
2	5.0	64.9
3	5.9	65.2
4	4.3	71.4
5	NA	75.0
6	NA	91.7
7	NA	71.4
8	NA	80.0
9	NA	100.0
10	NA	75.0

Table 31. Estimated survivorship of an initial cohort of 305 hatchling American crocodiles in the Turneffe Atoll. Percent survival is based on Moler (1991).

Year	% Survival	Number Surviving
1	20.4	62.2
2	64.9	40.3
3	65.2	36.3
4	71.4	18.7
5	75.0	14.0
6	91.7	12.9
7	71.4	9.2
8	80.0	7.4
9	100.0	7.4
10	75.0	5.4

CONSERVATION

The American crocodile was afforded legal protection under the Wildlife Protection Act of 1981 (Marin, 1981; Klemm and Navid, 1989) after many years of over-exploitation by commercial skin hunters. While no surveys were conducted during the 1960's and 1970's there is general agreement among early writers that C. acutus was extremely rare and confined to scattered localities (Neill and Allen, 1961; Powell, 1971; King et al., 1982; Perkins, 1983; Ross, 1997). Most crocodilian populations are resilient to over-exploitation and respond well to protection (Bayliss, 1987). However, the results of our survey indicate that population densities of C. acutus remain low on most offshore cays and atolls, and the species is extremely rare on the mainland.

There is little evidence to indicate C. acutus populations have recovered significantly from past over-exploitation. While the species occurs widely in the coastal zone, densities are among the lowest reported. Furthermore, crocodiles in marine habitats tend to disperse widely (Moler, 1991), and many occurrences outside of the Turneffe Atoll may represent transient individuals rather than members of an established population. Indeed, the sex ratio of crocodiles captured in cay and mainland habitats was male biased, and males typically exhibit the greatest dispersal tendencies. Additionally, the low number of juveniles noted during spotlight surveys is strongly suggestive of decreased population recruitment.

The largest population in Belize is found on the Turneffe Atoll (Figure 11 and 12), and this population appears to play a vital role in regional metapopulation dynamics. The status of this population remains tenuous, as the atoll is inhabited by only 200 to 300 non-hatchling crocodiles, with perhaps 20 to 30 breeding females. Reproduction is dependent on two major sites (Tables 13 and 14), which remain unprotected and vulnerable to development. Based on density estimates from the Turneffe Atoll, the country-wide population is thought to number less than 1000 individuals. Thus American crocodile populations throughout Belize remain vulnerable, and unless appropriate conservation measures are taken, the species could be locally extinct early in the next century.

Despite legal protection, several threats remain to the continued survival of the American crocodile in Belize. Although attacks on humans are extremely rare, and are solely attributed to C. moreletii (Marlin et al., 1995), both species are generally perceived as a threat to humans and livestock, and opportunistic killing of crocodiles does occur. Most crocodiles are killed when in the vicinity of human habitations, a problem exacerbated by careless waste disposal practices at fishing camps, which tend to attract crocodiles to these sites. We found some evidence of opportunistic killing, and many fishermen interviewed had shot crocodiles in the past, or professed a willingness to do so in the event crocodiles were seen near their camps. We found no evidence, however, of any commercial poaching, and the discovery of several skins at a fishing camp by Coral Cay Conservation personnel (Gail Bradley-Miller, pers. comm.) appears to be an isolated incident. However, even the occasional shooting of crocodiles may constitute a significant source of mortality in a small population.

A far greater source of mortality appears to be monofilament gill nets used by fishermen. Both C. acutus and C. moreletii are vulnerable, and the majority of skulls we examined during this study were obtained from crocodiles which drowned in fishing nets (Appendix 6). Monofilament nets attached to beach traps seem to be particularly effective in capturing crocodiles. While it is impossible to quantify this mortality, the number of reports we received suggest it is commonplace. Given the low densities in the coastal zone, the loss of even a few crocodiles, especially adult females can have a significant negative impact on populations. Furthermore, the widespread use of gill nets in southern Belize is inhibiting the local recovery of both species.

The greatest threat to the continued viability of C. acutus populations seems to be habitat destruction, especially the development of nesting beaches and associated nursery habitat. Mangrove swamps and turtle grass beds are important foraging habitats for crocodiles and remain widespread in coastal Belize (McField et al., 1996). However, some turtle grass beds have been lost to dredging and water pollution, and mangroves are being cleared on a localized, but rapidly increasing scale (Zismam, 1992; McField et al., 1996; S. Platt, pers. obs.). Existing legislation prohibits mangrove clearance without a permit, but laws are not rigorously enforced (Zisman, 1992; McField et al., 1996). The loss of foraging habitat however, does not constitute a threat to the species, at least in the foreseeable future.

On the other hand, beach ridges, where most nesting occurs, are extremely limited in extent, and under increasing pressure for development. As beaches are often the only elevated ground on cays otherwise at or slightly below sea level, they are highly sought as sites for fishing camps and tourist resorts. Consequently, these ridges and associated plant communities are considered the most critically endangered habitat in the coastal zone (McField et al., 1996). Furthermore, nursery lagoons and freshwater pools found adjacent to the beach ridges are critical for the survival of hatchling and juvenile crocodiles. These pools are a vital source of freshwater, without which young crocodiles may be subject to severe osmotic stress and a corresponding reduction in survival. The preservation of beach ridges and nursery habitat is therefore crucial to long-term population viability, and is the single most important element of any American crocodile conservation strategy in Belize

CONSERVATION RECOMMENDATIONS

The current low population densities found in the coastal zone, and the loss of nesting and nursery habitat warrant continued protection and classification of the American crocodile as an endangered species in Belize. Together with marine turtles, and the West Indian Manatee (Trichechus manatus), the American crocodile should be considered a flagship species essential to the protection of critical coastal zone habitats. Failure to address conservation issues will result in the decline and eventual extirpation of C. acutus populations in Belize. The objective of the following recommendations is to ensure the continued survival and enhance the recovery of American crocodile populations in Belize. Recommendations are listed in order of importance believed necessary to achieve these goals.

I. Preservation of known and potential nesting habitat.

This is the single most important measure necessary to ensure the long-term survival of American crocodile populations in Belize. Viable crocodile populations cannot be maintained without adequate protection of nesting beaches. In the absence of beach protection, crocodiles will be deprived of suitable nesting habitat and recruitment will drastically decline and perhaps cease. It is also critical to protect brackish lagoons and freshwater pools associated with nesting areas. These wetlands provide vital nursery habitat for hatchlings, and are an essential source of freshwater for size classes most susceptible to osmotic stress. Without access to nursery habitat, hatchling survival is expected to be low, and recruitment may not balance mortality.

Furthermore, nesting beaches are invariably associated with cay littoral forest, the most endangered coastal habitat in Belize (McField et al., 1996), and also frequently used as nesting sites by marine turtles. Therefore, protection of crocodile nesting habitat will benefit marine turtles and ensure the preservation of significant areas of cay littoral forest. Every effort should thus be made to extend maximum protection to these nesting sites. The following is a list of critical sites which warrant the most stringent protection. These sites are prioritized and the numbers in parentheses correspond to Table 13 and Figure 16.

Turneffe Atoll

The largest C. acutus population and the majority of population recruitment in Belize occurs in the Turneffe Atoll. Protection of nesting habitat in Turneffe Atoll is critical given the importance of this population in regional metapopulation dynamics.

1. Northern Cay (12)

This is the most significant nesting beach yet identified in Belize and preservation is essential to maintain viable populations in the Turneffe Atoll, and perhaps the entire coastal zone. Up to 10 nests are deposited here annually, and the presence of optimal nursery habitat insures high rates of hatchling survival. This beach is within the boundaries of the proposed Turneffe Atoll National Park and maximum protection should be afforded to this site. An extensive nursery lagoon located adjacent to this beach must also be protected.

2. Blackbird Cay

The beach on the eastern shoreline (10) is considered critical nesting habitat. This area is privately owned, but every effort should be made to include this beach in the proposed National Park, restrict future development through zoning, or obtain a conservation easement from the landowner(s). This beach also provides nesting habitat for marine turtles (S. Platt, pers. obs.), and encompasses one of the largest contiguous tracts of cay littoral forest in the coastal zone. The nesting site on the western shore of the cay (11) should be included as a satellite parcel in the proposed national park.

3. Other sites in the Turneffe Atoll

The former nesting site on Deadmans Cay should be protected against development as it is likely nesting crocodiles will utilize this site in the future. The beaches along the eastern shore of Deadmans and Calabash Cay represent potential nesting habitat, and at least 75% of this area should be protected from future development. Like Blackbird Cay, these beaches offer nesting habitat to marine turtles and encompass significant stands of cay littoral forest.

Cays and Mainland

4. Long Cay (7)

This site is the most significant nesting beach outside of the Turneffe Atoll. The site is in close proximity to extensive shoals and turtle grass beds, and there is a sheltered mangrove lagoon located adjacent to the beach providing excellent nursery habitat. Juvenile survival is expected to be high at this site. An infrequently used fishing camp is located at one beach while the a significant stand of cay littoral forest is present at the other.

5. Other Sites

Nest sites located at UCB (4), and the WASA Facilities, San Pedro (3) are already on public property and can be readily protected by the responsible GOB entities. The Maps Cay (8) and Southern Lagoon (9) sites do not appear to be in immediate danger of development. Nonetheless, since each site is very small (< 0.10 ha) both could be designated and protected at little cost. There is an active program of community conservation based on manatee and crocodile watching at Gales Point, and alerting the village to the presence of the Southern Lagoon site would probably ensure protection.

As additional nesting sites are found, every effort should be made to protect them through zoning or incorporation into the existing framework of protected areas. Also, it is imperative to evaluate coastal areas being considered for development with regards to potential crocodile nesting habitat, before the relevant permits are issued.

II. Long-term monitoring program.

A long-term (10+ years) population monitoring program, based on nest counts and spotlight surveys is essential to detect future population trends and evaluate the success of conservation strategies. Protection of nesting beaches should be tightly coupled with an annual survey of nesting beaches. An increase in the number of nests produced each year can be assumed to indicate an increase in crocodile populations. Nest counts are inexpensive and can be accomplished within two to three days, and therefore demand only a minimal investment of time and labor. Counts should be conducted during the last two weeks of July, immediately after hatchling emergence, when excavated nests are readily detectable. The number of nests and eggshells found at each site should be tallied.

Nest monitoring is recommended for the following sites which are listed in order of priority (numbers in parentheses correspond to Table 13 and Figure 16):

1. Northern Cay, Turneffe Atoll (12).
2. Blackbird Cay, Turneffe Atoll (10, 11).
3. Ambergris Cay (2, 3).
4. Long Cay (7).
5. Cay Caulker (5).
6. Belize City (4).
8. Maps Cay (8).

Additionally, Deadmans Cay (13) and the beaches along the eastern shore of Turneffe Atoll (Appendix 3) should be monitored for future nesting activity. Efforts should also be made to investigate other potential nesting habitat in hopes of locating additional sites. Reconnaissance can be conducted opportunistically during the course of other fieldwork. If further sites are located, appropriate protection should be instituted.

In addition to nest counts, population trends should be monitored with spotlight surveys which are inexpensive, easy to conduct, and provided standardized methodology is employed, are readily comparable to baseline data resulting from this study. Spotlight surveys are recommended for population monitoring at the following sites (numbers in parentheses correspond to site accounts listed in Appendix 1):

Turneffe Atoll

1. Northern Lagoon (6).
2. Northern Lagoon to Crikozeen Creek (7).
3. Cay Bokel to Tarpon Creek (1).
4. Blackbird Cay - western shore (3).
5. Blackbird Cay - eastern shore (4).
6. Calabash Cay (4).

Ambergris Cay

1. San Pedro Lagoon (3).
2. Western Shoreline (4).
3. WASA Facility (5).
4. BCNP - Laguna Cantena (9).
5. BCNP - Western Shore of Ambergris Cay (8).
6. BCNP - Santa Cruz Lagoon (7).

A mark-recapture program at BCNP would also prove a valuable supplement to nest monitoring and spotlight surveys. Technical assistance and data analysis could be provided by Wildlife Conservation Society biologists.

III. Restrict the use of monofilament gill nets

The drowning of crocodiles in monofilament gill nets represents a significant source of mortality in areas where crocodile densities are low. The use of monofilament nets attached to fish traps in Bacalar Chico National Park should be banned. Monofilament nets should also be prohibited in the proposed Turneffe Atoll National Park, and all other protected areas in the coastal zone. Banning gill nets and replacing them with wire mesh on fish traps will eliminate the incidental drowning of crocodiles, brown pelicans, and cormorants.

Additionally, the widespread use of gill nets in southern Belize is inhibiting the recovery of C. acutus in this region. Nets placed across rivers often completely obstruct the channel, and although this practice is illegal, existing laws are not being enforced. In addition to drowning crocodiles, these nets may deny manatees upstream passage to critical refuge habitats (Larry Saulnier, US Peace Corps, pers. comm.). Laws prohibiting this practice need to be rigorously enforced.

IV. Crocodiles should be promoted as an ecotourism attraction

Ecotourism can provide local income and employment, and justify the maintenance of wildlife on an economic basis competitive with more exploitative forms of resource use (Munro and Holdgate, 1991). Tourism is the fastest growing industry in Belize, and estimated to be the largest source of foreign exchange. The industry is expected to remain the most viable economic sector, in terms of foreign exchange earnings, employment, and opportunities for Belizean entrepreneurs. Therefore the government of Belize has listed the tourism sector, and specifically small-scale ecotourism, as a preferred option in the 1994 to 1998 Development Plan (McField et al., 1996).

Crocodiles have considerable ecotourism potential as they are readily located at night and become habituated to the presence of tourists (Platt, 1996). Additionally, most tourists are enthusiastic about the prospect of encountering large crocodiles at close-range, and crocodiles usually are the most sought after species on wildlife viewing trips (S. Platt, pers. obs.). Crocodile watching should be actively promoted as a form of non-consumptive wildlife use. Tour operators in Orange Walk, Burrell Boom, Indian Church, Monkey River, and Gales Point already advertise C. moreletii as a featured species on boat trips, but C. acutus has been largely overlooked. Potential opportunities for C. acutus-based ecotourism exist, especially in San Pedro where large crocodiles are easily found in San Pedro Lagoon, a short boat ride from town. Meetings should be held with tour operators in San Pedro, Cay Caulker, and elsewhere along the coast to make them aware of these potential opportunities. Members of the community whose livelihood depends on the continued survival of American crocodiles can be expected to support and enhance future conservation efforts.

V. Public Education

A public education campaign should be conducted, emphasizing that crocodiles are not a threat to humans, and killing is unnecessary and illegal under Belizean law. Public education must also stress the need for proper disposal of fish and lobster offal to avoid attracting crocodiles into the vicinity of habitations. There is also an urgent need to conduct workshops with local police, who are often unaware of existing conservation legislation concerning crocodiles and other wildlife.

LITERATURE CITED

Abercrombie, C. L., D. Davidson, C. A. Hope and D. E. Scott. 1980. Status of Morelet's crocodile (Crocodylus moreletii) in Belize. Biol. Conser. 17:103-113.

Abercrombie, C. L., D. Davidson, C. A. Hope, D. E. Scott, and J. E. Lane. 1982. Investigations into the status of Morelet's crocodile (Crocodylus moreletii) in Belize, 1980. Pp. 11-30. In: Crocodiles. Proc. 5th Working Meeting of Croc. Spec. Group,IUCN- The World Conser. Union, Morges, Switzerland.

Alvarez del Toro, M. 1974. Los Crocodylia de Mexico (estudio comparativo). Inst. Mexico Rec. Nat. Renov. 70 pp.

Artega, A. and C. Sanchez. 1996. Conservation and management of Crocodylus acutus in the low basin of the Yaracuy River, Venezuela. Pp. 154-161. In: Crocodiles. Proc. of 13th Working meeting of Croc. Spec. Group., IUCN, Gland. Switzerland.

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

Astheimer, L. B., S. C. Manolis, and C. R. Grau. 1989. Egg formation in crocodiles: Avian affinities in yolk deposition. Copeia 1989: 221-224.

Barbour, T. and C. T. Ramsden. 1919. The herpetology of Cuba. Mem. Mus. Comp. Zool., Harvard Univ. 47: 71-213.

Bayliss, P. 1987. Survey methods and monitoring within crocodile management programmes. In: Wildlife management: Crocodiles and alligators. Pp. 157-175. In: Webb, G J. W., S. C. Manolis, and P. J. Whitehead (eds.). Surrey Beatty and Sons Pty. Ltd., Sydney.

Bayliss, P., G. J. W. Webb, P. J. Whitehead, K. Dempsey, and A. Smith. 1986. Estimating the abundance of saltwater crocodiles, Crocodylus porosus Schneider, in tidal wetlands of the Northern Territory: a mark-recapture experiment to correct spotlight counts to absolute numbers, and the calibration of helicopter and spotlight counts. Aust. Wildl. Res. 13: 309-320.

Brandt, L. A., F. J. Mazzotti, J. R. Wilcox, P. D. Barker, Jr., G. L. Hasty, Jr., and J. Wasilewski. 1995. Status of the American crocodile (Crocodylus acutus) at a power plant in Florida, USA. Herpetol. Nat. Hist. 3: 29-36.

Brazaitis, P. 1973. The identification of living crocodilians. Zoologica 58: 59-88.

Brazaitis, P. J. 1968. The determination of sex in living crocodilians. Brit. J. Herpetol. 4:54-58.

Breder, C. M. 1946. Amphibians and reptiles of the Rio Chucunague drainage. Darien. Panama, with notes on their life histories and habits. Bull. Amer. Mus. Nat. Hist. 86: 429-431.

Brooks, D. R. and R. T. O'Grady. 1989. Crocodilians and their helminth parasites: Macroevolutionary considerations. Amer. Zool. 29: 873-883.

Campbell, H. W. 1972. Ecological or phylogenetic interpretations of crocodilian nesting habits. Nature 238: 404-405.

Casas-Andreu, G. and A. Rogel-Bahena. 1986. Observaciones sobre los nidos y las nidadas de Crocodylus moreletii en Mexico. Anales del Instituto de Ciencias del Mar y Limnologia, Universidad Nacional Autonoma de Mexico. 12: 232-330.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley & Sons. London.

Cayetano, E. 1995. Belize coastal marine resource study: An assessment of the vulnerability of Belizes coastline to sea level rise. Unpubl. Report to Belize Center for Environmental Studies, Belize City.

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

Charnock-Wilson, J. 1970. Manatees and crocodiles. Oryx 10: 236-238.

Cott, H. B. 1961. Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (Crocodylus niloticus) in Uganda and northern Rhodesia. Trans. Zool. Soc. London 29: 211-357.

Coulson, R. A. and T. Hernandez. 1983. Alligator metabolism: Studies on chemical reactions in vivo. Pergamon Press, London. 182 pp.

Davenport, J., D. J. Grove, J. Cannon, T. R. Ellis, and R. Stables. 1990. Food capture. appetite, digestion rate and efficiency in hatchling and juvenile Crocodylus porosus. J. Zool. (London). 220: 569-592.

Delany, M. F. 1990. Late summer food habits of juvenile American alligators. J. Herpetol. 24:418-421.

Densmore, L. D. and P. S. White. 1991. The systematics and evolution of the Crocodilia as suggested by restriction endonuclease analysis of mitochondrial and nuclear ribosomal DNA. Copeia 1991: 602-615.

Dietz, D. C., and T. C. Hines. 1980. Alligator nesting in north-central Florida. Copeia 1980: 249-258.

Dugan, B. A., A. S. Rand, G. M. Burghardt, and B. C. Bock. 1981. Interactions between nesting crocodiles and iguanas. J. Herpetol. 15: 409-414.

Dunson, W. A. 1970. Salinity relations of crocodiles in Florida Bay. Copeia 1970: 374-385.

Duval, J. 1977. La primera reproduction de los cocodriles Americanos en el ZOODOM. ZOODOM 2: 12-15.

Ellis, T. M. 1981. Tolerance of seawater by the American crocodile, Crocodylus acutus. J. Herpetol. 23: 1-7.

Evans, D. H. and T. M. Ellis. 1977. Sodium balance in hatchling American crocodiles. Crocodylus acutus. Comp. Biochem. Physiol. 58A: 159-162.

Ferguson, M. W. J. 1985. Reproductive biology and embryology of the crocodilians. Pp. 329-491. In: Biology of the Reptilia. Vol. 14. Gans, C. and F. Billet (eds.). John Wiley and Sons, New York.

Fischer, R. V., F. J. Mazzotti, J. D. Congdon, and R. E. Gatten, Jr. 1991. Post-hatching yolk reserves: Parental investment in American alligators from Louisiana. J. Herpetol. 25: 253-256.

Fitzgerald, L. A. 1989. An evaluation of stomach flushing techniques for crocodilians. J. Herpetol. 23:170-172.

Fleming, D. M., A. W. Palmisano, and T. Joanen. 1976. Food habits of coastal marsh raccoons with observations of alligator nest predation. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 30: 348-357.

Forstner, J. M., M. R. J. Forstner, D. E. Starkey, E. E. Louis, T. M. Guerra, S. M. Tanksley, and S. K. Davis. 1997. Phylogenetic relationships of the New World Crocodylus and the application of nuclear and mitochondrial markers for identifying hybrids in the captive population of Cuban crocodile (Crocodylus rhombifer). Pp. 78. In: Proc. Fourth regional meeting, IUCN Croc. Spec. Group. Villahermosa, Tabasco, Mexico. (Abstract Only).

Frost, M. D. 1977. Wildlife management in Belize: Program status and problems. Wildl. Soc. Bull. 5: 48-51.

Gaby, R., M. P. McMahon, F. J. Mazzotti, W. N. Gillies, and J. R. Wilcox. 1985. Ecology of a population of Crocodylus acutus at a power plant site in Florida. J. Herpetol. 19: 189-198.

Gadow, H. 1905. Distribution of Mexican amphibians and reptiles. Proc. Zool. Soc. London. 2: 209.

Graham, A. D. 1988. Methods of surveying and monitoring crocodiles. Pp. 74-101. In: Proc. SADCC workshop on crocodile management and utilization. Hutton. J. M.. J. N. B. Maphande, A. D. Graham, and H. H. Roth (eds.). Dept. National parks and Wildlife, Kasungu, Malawi.

Grigg, G. C., L. E. Taplin, P. Harlow, and J. Wright. 1980. Survival and growth of hatchling Crocodylus porosus in saltwater without access to fresh drinking water. Oecologia 47: 264-266.

Groombridge, B. 1987. The distribution and status of world crocodilians. Pp 9-21. In: Wildlife Management: Crocodiles and alligators. Webb, G. J. W., S. C. Manolis and P. J. Whitehead (eds.). Surrey Beatty and Sons Pty. Ltd., Sydney.

Hartshorn, G., L. Nicolait, L. Hartshorn, G. Bevier, R. Brightman, J. Cal, A. Cawich. W. Davidson, R. DuBois, C. Dyer, J. Gibson, W. Hawley, J. Leonard. R. Nicolait. D. Weyer, H. White, and C. Wright. 1984. Belize country profile: A field study. USAID, and Robert Nicolait and Assoc., Ltd., Belize City, Belize.

Hope, C. A. and C. L. Abercrombie. 1986. Hunters, hides, dollars and dependency: Economics of wildlife exploitation in Belize. Pp. 143-152. In: Crocodiles. Proc. of 7th Working meeting of Croc. Spec. Group., IUCN, Gland, Switzerland.

Hunt, R. H. 1980. Propagation of Morelet's crocodile. Pp. 161-165. In: Reproductive Biology and Diseases of Captive Reptiles. Murphy, J. B. and J. T. Collins (eds.). SSAR Contrib. to Herpetol., No. 1.

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 of Ngezi, Zimbabwe, and the use of spotlight counts to monitor crocodile abundance. J. Appl. Ecol. 26: 381-395.

Jackson, J. F., H. W. Campbell, and K. E. Campbell. 1974. The feeding habits of crocodilians: Validity of the evidence from stomach contents. J. Herpetol. 8: 378-381.

Jennings, M. J., D. N. David, and K. M. Portier. 1991. Effects of marking techniques on growth and survivorship of hatchling alligators. Wildl. Soc. Bull 19: 204-207.

Joanen, T. and L. McNease. 1987. Alligator farming research in Louisiana. Pp. 329-340. In: Wildlife management: Crocodiles and alligators. Webb, G. J. W.. S. C. Manolis and P. J. Whitehead (eds.). Surrey Beatty and Sons Pty. Ltd., Sydney.

Joanen T., L. McNease, and G. Perry. 1977. Effects of simulated flooding on alligator eggs. Proc. Ann. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31: 33-35.

Johnson, W. C. 1983. The physical setting: Northern Belize and Pulltrouser Swamp. Pp. 8-20. In: Pulltrouser Swamp: Ancient Maya habitat, agriculture, and settlement in northern Belize. Turner, B. L. and P. D. Harrison (eds.). Univ. Texas Press, Austin.

King, R. B., I. C. Baillie, T. M. B. Abell, J. R. Dunsmore, D. A. Gray, J. H. Pratt, H. R. Versey, A. C. S. Wright and S. A. Zisman. 1992. Land resource assessment of northern Belize. Natural Resource Institute, Overseas Development Administration, United Kingdom. Bull. 43. Vol. 1 and 2.

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

King, F. W., H. W. Campbell, and P. E. Moler. 1982. Review of the status of the American crocodile. Pp. 84-98. In: Crocodiles. Proc. 5th Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union, Morges, Switzerland.

King, F. W., M. Espinal, and L. C. A. Cerrato. 1990. Distribution and status of the crocodilians of Honduras. Pp. 313-354. In: Crocodiles. Proc. 10th Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union, Gland, Switzerland.

King, F. W., J. P. Ross, and L. D. Gutierrez. 1994. Survey of the status of the crocodilians of Nicaragua. Pp. 121-161. In: Crocodiles. Vol. 2. Proc. 12th Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union, Gland, Switzerland.

King, F. W., J. P. Ross, J. V. M. Molina, and D. Gutierrez. 1993. Survey of the crocodilians of Nicaragua. Unpubl. Report to Instituto Nicaraguense de Recursos Naturales Y Del Ambiente and the Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Gainesville, Florida.

Klemm, C. and D. Navid. 1989. Crocodilians and the law. Pp. 80-100. In: Crocodiles: their ecology, management, and conservation. IUCN-The World Conservation Union Publ., Gland, Switzerland.

Klien, E. H. 1977. A status evaluation of the crocodilians of eastern Honduras. Unpubl. Manuscript.

Kushlan, J. A. 1988. Conservation and management of the American crocodile. Environ. Manage. 12: 777-790.

Kushlan, J. A. and F. J. Mazzotti. 1989a. Population biology of the American crocodile. J. Herpetol. 23: 7-21.

Kushlan, J. A. and F. J. Mazzotti. 1989b. Historic and present distribution of the American crocodile in Florida. J. Herpetol. 15: 187-192.

Kushlan, J. A. and J. C. Simon. 1981. Egg manipulation by the American alligator. J. Herpetol. 15: 451-454.

LeBuff, C. R. 1957. Observations on captive and wild North American crocodilians. Herpetologica 13: 25-28.

Lee, J. C. 1995. The amphibians and reptiles of the Yucatan Peninsula. Cornell Univ. Press, Ithaca and London.

Lutz, P. L. and A. Dunbar-Cooper. 1984. The nest environment of the American crocodile (Crocodylus acutus). Copeia 1984: 153-161.

Magnusson, W. E. 1982. Techniques of surveying for crocodiles. Pp. 389-403. In: Crocodiles. Proc. 5th Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union, Morges, Switzerland.

Marin, F. 1981. Wildlife Protection Act 1981. No. 4. Ministry of Natural Resources. Government Printing Office, Belmopan.

Marlin, J., K. Marlin, and S. G. Platt. 1995. A documented case of an attack by Morelet's crocodile (Crocodylus moreletii) on man. Bull. Chicago Herp. Soc. 30: 165-167.

Martinez-Ibarra, J. A., E. Naranjo-Pinera, K. Nelson, and R. Rodiles-Hernandez. 1997. Estado de las poblaciones de cocodrilianos (Crocodylus acutus, Caiman crocodilius) en una zona Pesquera de la Reserva de la Biosfera "La Encrucijada". Chiapas, Mexico. Pp. 105-112. In: Proc. Fourth regional meeting, IUCN Croc. Spec. Group, Villahermosa, Tabasco, Mexico.

Mazzotti, F. J. 1983. The ecology of Crocodylus acutus in Florida. Ph.D. Dissertation. Pennsylvania State University, University Park, Pennsylvania.

Mazzotti, F. J., B. Bohnsack, M. P. McMahon, and J. R. Wilcox. 1986. Field and laboratory observations on the effects of high temperature and salinity on hatchling Crocodylus acutus. Herpetologica 42: 191-196.

McField, M, S. Wells, and J. Gibson. 1996. State of the Coastal Zone report. Belize. 1995. Coastal Zone Management Programme, and United Nations Development Programme and Global Environmental Facility. Project No. Bze/92/G31.

Medem, F. 1981. Los Crocodylia de Sur America. Vol. 1. Los Crocodylia de Colombia. Bogota: Ed. Carrera 7a Ltd.

Meerman, J. C. 1992. The status of crocodiles in the eastern Corozal District. Occas. Papers of the Belize Nat. Hist. Soc. 1: 1-5.

Meerman, J. C. 1993. Survey of Cay Caulker: Insects and reptiles. Unpubl. Report to Forest Dept., Belmopan, Belize.

Meerman, J. C. and T. Boomsma. 1993. Burdon Canal Nature Reserve Survey. Unpubl. Rep. to Belize Forestry Dept.

Messel, H., G. C. Vorlicek, A. G. Wells, and W. J. Green. 1981. Surveys of tidal river systems in the Northern Territory of Australia and their crocodile populations. Monograph No. 1. Pergamon Press, Sydney.

Minty, C., M. Murray, and S. Zisman. 1995. Turneffe terrestrial resource reconnaissance. Unpubl. Report to Coral Cay Conservation and University College of Belize, Belize City.

Moler, P. E. 1991. American crocodile recovery plan implementation: American crocodile population dynamics. Final Report to Florida Freshwater Fish and Game Commission. Study No. 7532.

Munro, D. A. and M. Holdgate. 1991. Caring for the earth: A strategy for sustainable living. IUCN/UNEP/WWF, Gland, Switzerland.

Neill, W. T. 1971. The last of the ruling reptiles: Alligators, crocodiles, and their kin. Columbia Univ. Press, New York.

Neill, W. T. and R. Allen. 1961. Further studies on the herpetology of British Honduras. Herpetologica 17: 37-51.

O'Brien, T. G. 1990. A comparison of 3 survey methods for estimating relative abundance of rare crocodilians. Pp. 91-108. In: Crocodiles. Proc. 10th Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union. Gland. Switzerland.

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

Ojeda, F. J. L., P. B. Mendoza, and P. L. A. Ramos. 1997. Evaluacion poblacional y lagunos aspectos ecoloicos de Crocodylus acutus en la Laguno de Chiricahueto. Pp. 90-104. In: Proc. Fourth regional meeting, IUCN Croc. Spec. Group. Villahermosa, Tabasco, Mexico.

Olson, G. A., J. R. Hessler, and R. E. Faith. 1975. Technics for blood collection and intravascular infusion of reptiles. Lab. Animal Sci. 25: 783-786.

Ouboter, P. E. 1992. Status and conservation of crocodilians in northeastern Belize. Pp. 18-29. In: Crocodiles. Proc. 11th Working Meeting of Croc. Spec. Group. IUCN-The World Conser. Union. Gland, Switzerland.

Paez, V. P. and B. C. Bock. 1988. Crocodylus acutus: Nest defense. Herpetol. Rev. 19: 83.

Perez-Higareda, G. 1980. Notes on nesting of Crocodylus moreleti in southern Veracruz. Mexico. Bull. Maryland Herp. Soc. 16: 52-53.

Perez-Higareda, G., A. Rangel-Rangel, and H. M. Smith. 1991. Maximum sizes of Morelet's and American crocodiles. Bull. Maryland Herp. Soc. 27: 34-37.

Perkins, J. S. 1983. The Belize barrier reef ecosystem: An assessment of its resources. conservation status, and management. Unpubl. Report to New York Zoological Society and Yale School of Forestry and Environmental Studies.

Platt, S. G. 1996. The ecology and status of Morelet's crocodile in Belize. Ph.D. Dissertation, Clemson University, Clemson, South Carolina.

Platt, S. G., C. G. Brantley, R. S. Cropanzano, and R. W. Hastings. 1990. A method for determining the size of nesting female alligators. Wildl. Soc. Bull. 18: 296-298.

Platt, S. G. and J. B. Thorbjarnarson. 1996. Preliminary assessment of the status of the American crocodile (Crocodylus acutus) in the coastal zone of Belize. Pp. 184-206. In: Crocodiles. Proc. of 13th Working meeting of Croc. Spec. Group.. IUCN, Gland, Switzerland.

Powell, J. 1971. The status of crocodilians in the United States, Mexico, Central America, and the West Indies. Pp. 72-82. In: Crocodiles. Proc. First Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union. Morges. Switzerland.

Powell, J. 1972. The Morelet's crocodile: An unknown quantity. Animal Kingdom 1972 (2): 21-26.

Powell, J. 1973. Crocodilians of Central America, including Mexico and the West Indies: Developments since 1971. Pp. 27-31. In: Crocodiles. Proc. 2nd Working Meeting of Croc. Spec. Group, IUCN- The World Conser. Union. IUCN NS Suppl. Paper 41. Morges, Switzerland.

Rebelo, G. H. and W. E. Magnusson. 1983. An analysis of the effect of hunting on Caiman crocodilus and Melansuchus niger based on the sizes of confiscated skins. Biol. Conserv. 26: 95-104.

Rodda, G. H. 1984. Movements of juvenile American crocodiles in Gatun Lake, Panama. Herpetologica 40: 444-451.

Ross, C. A. 1987. Crocodylus moreletii. Cat. Amer. Amphib. and Rept. 407.1-407.3

Ross, F. D. 1997. A geographically divided historical review of items about Crocodylus acutus, Crocodylus moreletii, and Crocodylus rhombifer in Volumes 1 to 9 (June 1971 to December 1990) of the I. U. C. N. Crocodile Specialist Group Newsletter: with notes about citing items, and an expedition investigating Central American Crocodylus. Pp. 150-181. In: Proc. Fourth regional meeting, IUCN Croc. Spec. Group, Villahermosa, Tabasco, Mexico.

Ross, F. D. and G. C. Mayer. 1983. On the dorsal armor of the Crocodilia. Pp. 305-331. In: Advances in herpetology and evolutionary biology. Rhodin. A. G. J. and K. Miyata (eds.). Museum Comp. Zool., Cambridge.

Ross, C. A. and F. D. Ross. 1974. Caudal scalation of Central American Crocodylus. Proc. Biol. Soc. Washington 87: 231-234.

Sanchez, J. J., J. R. Bolanos, and L. Piedra. 1997. Tamano estructura y distribucion de la poplacion de Crocodylus acutus (Crocodylia: Crocodilidae) en los Rios Tempisque y Bebedero, Costa Rica. Pp. 131-136. In: Proc. Fourth regional meeting, IUCN Croc. Spec. Group, Villahermosa, Tabasco, Mexico.

Schmidt, K. P. 1924. Notes on Central American crocodiles. Fieldiana 12: 79-92.

Sigler, L. 1996. Caiman situation in Chiapas, Mexico. Pp 151-152. In: Crocodiles. Proc. of 13th Working meeting of Croc. Spec. Group., IUCN, Gland, Switzerland.

Sokol, O. 1971. Lithophagy and geophagy in reptiles. J. Herpetol. 5: 67-71.

Solger, B. 1877. Uber eine neue species von Trichosoma R. Archiv. fur Naturgeschichte 43: 19-23.

Smith, H. M. 1938. Notes on reptiles and amphibians from Yucatan and Campeche, Mexico. Occas. Pap. Mus. Zool., Univ. Michigan 338: 1-22.

Smith, H. M. and R. B. Smith. 1977. Synopsis of the herpetofauna of Mexico. Vol. 5. Guide to the Mexican Amphisbaenians and crocodilians. John Johnson. North Bennington, Vermont.

Smith, R. L. Ecology and field biology. Harper and Row, Publ., New York.

Stoddart, D. R. 1962. Three Caribbean atolls: Turneffe Islands, Lighthouse Reef. and Glovers Reef, British Honduras. Atoll Res. Bull. 87.

Stuebing, R. B., G. Ismail, and L. H. Ching. 1994. The distribution and abundance of the Indo-pacific crocodile Crocodylus porosus in the Klias River. Sabah. East Malaysia. Biol. Conserv. 69: 1-7.

Taplin, L. E. 1988. Osmoregulation in crocodilians. Biol. Rev. 63: 333-377.

Taylor, J. A., G. J. W. Webb and W. E. Magnusson. 1978. Methods of obtaining stomach contents from live crocodiles (Reptilia, Crocodilidae). J. Herpetol. 12:415-417.

Thorbjarnarson, J. B. 1988. The status and ecology of the American crocodile in Haiti. Bull. Florida State Mus., Biol. Sci. 33: 1-86.

Thorbjarnarson, J. 1989. Ecology of the American crocodile (Crocodylus acutus). Pp. 228-258. In: Crocodiles: Their ecology, management, and conservation. IUCN-The World Conservation Union Publ., Gland, Switzerland.

Thorbjarnarson, J. 1992. Crocodiles: An action plan for their conservation. Messel. H., F. W. King, and J. P. Ross (eds.). IUCN/SSC Croc. Spec. Group Publ.. Gland. Switzerland.

Thorbjarnarson, J. B. 1996. Reproductive characteristics of the order Crocodylia. Herpetologica 52: 8-24.

Thorbjarnarson, J. and G. Hernandez. 1992. Recent investigations of the status and distribution of the Orinoco crocodile Crocodylus intermedius in Venezuela. Biol. Conser. 62: 179-188.

Varona, L. S. 1987. The status of Crocodylus acutus in Cuba. Carib. J. Sci. 23: 256-259.

Webb, G. J. W. and S. C. Manolis. 1983. Crocodylus johnstoni in the McKinlay River area, N. T. V. Abnormalities and injuries. Aust. Wildl. Res. 10: 407-420.

Webb, G. J. W. and H. Messel. 1977. Abnormalities and injuries in the estuarine crocodile, Crocodylus porosus. Aust. Wildl. Res. 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.

Appendix 1. Results of population surveys conducted in the coastal zone of Belize (July 1996 to October 1997). Sites are listed alphabetically by region (mainland, cays, and atolls).

MAINLAND

Agua Caliente Swamp
Survey Route: Begin at 16° 10' 41" N; 88° 57' 23" W. Follow creek to 16° 10' 22" N; 88° 58' 27" W.
Distance = 2.6 km.

This swamp consists of a seasonally flooded forest and wetland community found nowhere else in Belize (Zisman, 1996). A spotlight survey was conducted by canoe on 11 June 1997. Water levels were at an annual minimum just prior to the onset of the wet season. Low water levels at this time are expected to concentrate crocodiles into the remaining water bodies. During the wet season, water levels are three to five meters above the dry season level making surveys impractical. No crocodiles were observed during the survey, and according to local residents crocodiles were present in the swamp in the past (>10 years ago), but were never common, and are now extinct. Based on habitat, these were likely Morelet's crocodiles, although this site is well south of the distributional limits presented in Lee (1995).

Barracouta Pond
Survey Route: Begin at boat landing (18° 19' 07" N; 88° 17' 16" W). Circumnavigate lagoon and return to starting point.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	3	7.0	0.42
EO	1	7.0	0.14
Total	4	7.0	1.75

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
0	1	2	1	1

A spotlight survey was conducted on 10 May 1997. Water salinity was 10.0 ppt and lagoon levels were below normal due to drought. Ouboter (1992) reported finding

American crocodiles in this lagoon, but in the present survey only Morelet's crocodiles were encountered.

Bladen River

Survey Route: Begin at junction of Bladen and Swasey Rivers (16° 23' 57" N: 88° 33' 29" W). Proceed upstream to 16° 24' 01" N; 88° 33' 58" W.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	0.9	2.2

This survey was conducted by canoe on 22 May 1997. One juvenile C. moreletii (TL = 37.7 cm) was captured, and another sighted (TL ca. 60 cm). Additionally, on 18 April 1997 a spotlight survey was conducted in an oxbow along the Bladen River at the Belize Foundation for Research and Environmental Education. Six crocodiles were observed and three (TL from 36.5 to 45.2 cm) were captured. Groups of irregular subcaudal scutes were present, but greatly reduced an all C. moreletii captured along the upstream sections of the Bladen River. These Morelet's crocodiles were found approximately 80 km south of the distributional limit presented by Lee (1995). Voucher photographs will be deposited in the Vertebrate Collection, Clemson University, Clemson, South Carolina, USA.

Burdon Canal - Fabers Lagoon

Survey Route: Begin at Burdon Canal/ Northern Lagoon (17° 23.61' N; 88° 18.65' W). Follow canal to Fabers Lagoon, circumnavigate lagoon and return to canal. Follow canal to Haulover Creek (17° 30.51' N; 88° 13.46' W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	4	19.5	0.20
EO	2	19.5	0.10
Total	6	19.5	0.30

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
0	2	2	0	2

Burdon Canal is a man-made navigation canal linking Haulover Creek/ Belize River with the Sibun River. The canal traverses extensive mangrove swamps, and a portion of these swamps are included in the Burdon Canal Nature Reserve (Zisman, 1996). Mangrove clearance and filling have occurred in other parts of this wetland system (Zisman, 1992; S. Platt, pers. obs.).

A spotlight survey was conducted on 12 August 1996. Water salinities were 0.0 ppt owing to an influx of freshwater following heavy rains. At other times water salinities do not exceed 5.0 ppt because of the influence of the Belize River. Crocodiles that could be identified were C. moreletii and it is likely that the EO's were also this species. In addition to this survey, C. moreletii have been reported from Burdon Canal by Meerman and Boomsma (1993) and Platt (1996). There are no recent C. acutus records from Burdon Canal, but Neill and Allen (1961) reported the collection of a juvenile from this swamp. The current status of C. acutus in this area remains uncertain.

Chopal Pond

This freshwater lagoon is located within the Shipstern Nature Reserve, approximately 3 km east of Shipstern Lagoon. A daylight reconnaissance was made on 8 May 1997. With the exception of a small pool, the pond was almost completely dry, and four juvenile C. moreletii were observed. One week prior to our visit, 37 juvenile C. moreletii were counted here (Steve Nichols, pers. comm.). The crocodiles apparently dispersed overland during the interim period. Additionally, a C. moreletii nest mound from 1996, and two bank dens were found along the shore. No evidence of C. acutus was found at this site.

Coastline: Midwinter Lagoon to Potts Creek Lagoon.

Survey Route: Begin at mouth of Midwinter Lagoon (17° 42' 59" N; 88° 14' 13" W). Follow coastline south to mouth of Potts Creek Lagoon (17° 38' 32" N; 88° 17' 16" W). Midwinters Lagoon is too shallow to navigate except by canoe.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	11.0	0.18

Spotlight survey was conducted on 17 July 1997. Water salinity was 22.0 ppt. Both crocodiles (TL ca. 150 and 210 cm) were encountered feeding at the mouth of Potts Creek Lagoon.

Coastline: University College of Belize to Moho Cay Boat Landing

This short segment (ca. 300 m) of coastline was searched on numerous occasions when returning from offshore surveys, and two crocodiles were captured. On 14 January 1997 an American crocodile (TL = 93.0 cm) was captured while basking on an exposed mudflat on UCB property, and a C. moreletii (TL = 150.0 cm) was captured at almost the same location on 27 January 1997. Water salinities at the time of each capture were 8.0 ppt and 15.0 ppt, respectively. On 5 March 1997, a C. moreletii (TL ca. 120 cm) was observed basking on the bank of St. Johns Canal (water salinity = 15.0 ppt). These observations confirm the presence of both species within the environs of Belize City.

Coastline: Vista del Mar to University College of Belize

Survey Route: Begin at canal mouth in Vista del Mar Community (17° 33' 42" N: 88° 16' 44" W). Follow coastline south towards Belize City. Enter canals at 17° 31' 01" N: 88° 13' 20" W, 17° 31' 04" N; 88° 13' 27" W, and 17° 31' 11" N; 88° 13' 48" W. Each canal is surrounded by residential development and extends about 500 m inland. Return to Caribbean Sea and follow coastline to UCB boat landing (17° 31' 05" N; 88° 12' 14" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	2	11.5	0.17
C. moreletii	1	11.5	0.08
Total	3	11.5	0.26

One C. acutus (TL ca. 210 cm) and one C. moreletii (TL ca. 180 cm) were observed in the canals during a spotlight survey on 14 January 1997, and another C. acutus (TL = 93.0 cm) was captured near UCB. A large amount of floating garbage was noted in the canals, and this may be attracting crocodiles. Water salinities were 4.0 ppt in the canals and along the coast.

Corozal

Nuisance crocodiles are frequently reported in Chetumal Bay at Corozal, but it is uncertain which species are present. Water salinities may be as high as 25.0 ppt, but are significantly depressed during the wet season when freshwater is discharged into this semi-landlocked bay by the New River and Rio Hondo. This salinity range is within the limits tolerated by C. moreletii (S. Platt, pers. obs.). so either species could be present. During a visit in July 1996, local residents stated that a large crocodile had just been shot in Chetumal Bay, but attempts to locate the carcass proved unsuccessful.

Deep River

Survey Routes

8 November 1996: Begin upstream at 16° 21' 55" N; 88° 41' 15" W. Follow river downstream to river mouth (16° 17' 01" N; 88° 39' 03" W).

12 February 1997: Begin upstream at 16° 22' 08' N; 88° 41' 22" W. Proceed downstream to river mouth (16° 17' 01" N; 88° 39' 03" W).

10 June 1997: Begin at river mouth (16° 17' 01" N; 88° 39' 03" W). Proceed upstream to mouth of Mushcamp Creek (16° 18' 03" N; 88° 39' 55" W). Follow creek until no longer navigable (16° 19' 11" N; 88° 38' 06" W). Return downstream to starting point.

Deep River drains a network of forest, savanna, and upland habitats. Extensive mangrove swamps are found at the river mouth. Water salinities at the river mouth ranged from 4.0 ppt in November 1996 to 6.0 ppt in June 1997. Water salinities upstream were consistently 0.0 ppt.

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	8 Nov. 96	3	15.8	0.18
	12 Feb. 97	0	21.4	0.0
	10 June 97	1	6.7	0.14
C. moreletii	8 Nov. 96	0	15.8	0.0
	12 Feb. 97	2	21.4	0.93
	10 June 97	1	6.7	0.14
Unidentified Species	8 Nov. 96	1	15.8	0.06
	12 Feb. 97	1	21.4	0.04
	10 June 97	0	6.7	0.0
Total		9	43.9	0.20

Size Distribution

Species	Juveniles	Subadults	Adults
C. acutus	2	2	3
C. moreletii	0	0	3
Unidentified	0	1	1

Three spotlight surveys were conducted in Deep River and nine crocodiles were encountered. Four C. acutus were identified, including one which was captured. All were found in the mangrove swamps at the river mouth. Three C. moreletii were observed: two along the upper reaches and one in Mushcamp Creek. The later crocodile was sighted in red mangrove about 200 m from an American crocodile. These C. moreletii sightings are approximately 90 km south of the distributional limits presented by Lee (1995).

Four-mile Lagoon (San Roque Lagoon)
Survey Route: Begin where channel from New River enters lagoon (18° 20.52' N: 88° 25.16'W). Circumnavigate lagoon and return to starting point.

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	3 July 96	5	7.5	0.66

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO<1.8m
0	2	3	0	0

This lagoon is part of the New River delta, and should not be confused with the nearby Four-mile Lagoon on the Rio Hondo. Four-mile Lagoon has been designated as critical habitat for the West Indian manatee (Zisman, 1996). This survey was conducted by canoe as the lagoon is too shallow to allow the passage of a larger boat. Water salinity was 0.0 ppt.

Four-mile Lagoon
Survey Route: Begin at boat landing (18° 20.73' N; 88° 22.95' W). Circumnavigate lagoon and return to starting point.

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	4 July 96	3	8.4	0.35
	5 Sept. 97	3	8.4	0.35
Total		6	16.8	0.35

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO<1.8m
0	2	2	1	1

This lagoon is located along the Rio Hondo approximately 6.5 km upstream from Chetumal Bay. Salinity during both surveys was 0.0 ppt.

Golden Stream

Survey Route: Begin upstream at 16° 17' 26" N; 88° 44' 37" W. Proceed downstream to river mouth (16° 13' 39" N; 88° 44' 05" W).
Distance = 14 km.

A spotlight survey was conducted on 4 June 1997. No crocodiles were encountered along the survey route. Golden Stream was heavily hunted during the period of exploitation. John Sprang, owner of Village Farm situated between Golden Stream and Middle River, reported sighting only about one crocodile/year. He attributes the scarcity of crocodiles to the widespread use of monofilament gill nets.

Haulover Creek

Survey Route: Begin at Belize River/Haulover Creek (17° 32' 09" N; 88° 14' 34" W). Follow Haulover Creek into Belize City until reaching Belcan Bridge (17° 30' 12" N: 88° 11' 52" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	8.75	0.22

A spotlight survey was conducted on 14 January 1997. Water salinities ranged from 1.0 ppt in the Belize River to 8.0 ppt at Belcan Bridge. One C. moreletii (TL = 39.0 cm) was captured at the Belcan Bridge. The other C. moreletii (TL ca. 150 cm) was observed among red mangroves along Haulover Creek. No C. acutus were found at this location. C. moreletii was previously reported from Haulover Creek by Platt (1996).

Indian Hill Lagoon

Survey Route: Begin at lagoon mouth (16° 25.06' N; 88° 26.59' W). Circumnavigate lagoon and return to starting point.
Distance = 6.2 km.

No crocodiles were encountered during a spotlight survey on 6 November 1996. However, personnel at an aquaculture facility adjacent to the lagoon stated that crocodiles are occasionally found in shrimp ponds and assumed to originate in Indian Hill Lagoon. Either species could be present.

Joe Taylor Creek

Survey Route: Begin at creek mouth (16° 06' 28" N; 88° 47' 54" W) and proceed upstream to a point where creek is no longer navigable (16° 07' 02" N: 88° 48' 25" W).

Distance = 2.6 km.

No crocodiles were observed during a spotlight survey on 5 June 1997. However, crocodiles are occasionally reported in this creek by local residents (Larry Saulnier, US Peace Corps, pers. comm.). Furthermore, a hole nest containing crocodile eggs was unearthed during the construction of a building at the creek mouth (Brian Holland, P. G. Dolomite, pers. comm.). Based on the description, this was likely a C. acutus nest. The site has since been developed and is no longer available.

Ladyville

Survey Route: Begin at canal mouth (17° 33' 37" N; 88° 16' 53" W). Follow canal to terminus (17° 33' 07" N; 88° 17' 10" W) and illuminate each spur canal.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	1	1.2	0.83

Spotlight survey conducted on 17 July 1997 and a single C. moreletii (TL ca. 120 cm) was observed. This canal drains an extensive mangrove swamp and passes through a recently constructed housing development where crocodiles are commonly observed by local residents. Water salinity was 10.0 ppt.

Laguna Seca (Copper Bank)

Survey Route: Begin in Chetumal Bay at mouth of lagoon (18° 19' 54" N; 88° 20' 29" W). Circumnavigate lagoon and return to starting point. Sections of the shoreline are difficult to approach owing to shallow water.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	9.2	0.21

A spotlight survey was conducted on 25 October 1997, and two C. moreletii (TL ca. 150 and 210 cm) were observed. No C. acutus were found. Water salinities in the lagoon were 0.0 ppt.

La Isle Cenote

Survey Route: Begin at boat landing (18° 20' 07" N; 88° 07' 45" W). Circumnavigate lagoon and return to starting point.

Distance=0.8 km.

No crocodiles ere observed during a spotlight survey conducted on 4 October 1997. Heavy rains prior to the survey caused widespread flooding and crocodiles probably dispersed into the surrounding forest. Crocodiles of an undetermined species have occasionally been observed here by Paul Walker (Wild Treks, Inc., pers. comm), and a Morelet's crocodile examined in the Steve Nichols collection originated at this site. Additionally, Nichols has examined several other C. moreletii captured by villagers in this cenote (Steve Nichols, pers. comm.).

Middle River
Survey Route: Begin upstream at 16° 14' 51" N; 88° 45' 45" W. Proceed downstream to river mouth (16° 13' 17" N; 88° 44' 36" W).
Distance = 4.7 km.

Spotlight survey conducted on 4 June 1997. No crocodiles observed. See comments under Golden Stream.

Moho River
Survey Route: Begin upstream at 16° 04' 32" N; 88° 51' 01" W. Proceed downstream to river mouth (16° 03' 31" N; 88° 51' 01" W).
Distance = 12.2 km.
A spotlight survey conducted on 2 June 1997 found no crocodiles.

Monkey River
Survey Route
9 November 1996 and 10 February 1997: Begin at junction of Bladen and Swasey Rivers (16° 23' 57" N; 88° 33' 29" W). Follow river downstream to mouth (16° 21' 56" N: 88° 29' 06" W).
15 April 1997: Low water levels prevented passage upstream to previous starting point. Survey began at 16° 23' 21" N; 88° 29' 06" W. Follow river downstream to mouth (16° 21' 56" N; 88° 29' 06" W).

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	9 Nov. 96	4	14.8	0.27
	10 Feb. 97	8	14.8	0.54
	15 April 97	1	11.6	0.08
Total		13	41.2	0.31

In addition to crocodiles sighted during spotlight surveys, two C. moreletii were observed basking during a daylight reconnaissance on 10 February 1997, and are included in the size distribution below.

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
0	6	3	4	2

Water salinity during all surveys was 0.0 ppt. During the November 96 survey the water level was approximately 200 cm above normal, and the strong current severely hampered survey operations. The greatest number of crocodiles were observed during February 97, and the fewest crocodiles were sighted in April 97 when water levels were the lowest. It is likely that crocodiles vacated the main channel at this time, and sought refuge in adjacent oxbow lakes.

Five crocodiles were captured during surveys of Monkey River. Two of these appeared to be typical Morelet's crocodiles (#2-3-9-3 and #621) with groups of irregular scales present on the lateral and basal surface of the tail. These crocodiles were found approximately 75 km south of the distributional limit presented by Lee (1995). Voucher photographs (CUSC #1381) were deposited in the Vertebrate Collection, Clemson University, Clemson, South Carolina, USA. The three other crocodiles (#2-3-9-4, #102, and #104) appeared to be C. moreletii, but exhibited a reduced number of dorsal scales in each scale row and a complete absence of irregular subcaudal scales. These characteristics are suggestive of possible hybridization between C. acutus and C. moreletii. No American crocodiles were found in Monkey River.

New River

Survey Route: (Coordinates given in UTM).
2 July 1996: Begin at mouth of Four-mile (San Roque) Lagoon (50012801). Proceed downstream to mouth of New River (53702885).
6 December 1996: Begin at river mouth (53702885) and proceed upstream to Pueblo Nuevo (50012635).

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2 July 96	15	6.0	2.5
	6 Dec. 96	19	7.2	2.6
Total		34	13.2	2.5

Size Distribution

Hatchlings	Juveniles	Subadults	Adults
0	12	6	6

The New River is the largest river system in northern Belize, and extensive mangrove swamps are found at the river mouth near Chetumal Bay (Hartshorn et al., 1984). Water salinities were 0.0 ppt, even at the river mouth, during both surveys.

Northern Lagoon

Survey Route: Begin where Burdon Canal enters Northern Lagoon (17° 23' 02" N; 88° 19' 42" W). Follow eastern shore until reaching Main (Radigan) Creek (17° 18' 25" N; 88° 19' 20" W). Follow creek to Southern Lagoon (17° 16' 07" N; 88° 19' 31" W). Retrace route back to Northern Lagoon and follow western shoreline until reaching starting point.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	1	34.2	0.02
EO	1	34.2	0.02
Total	2	34.2	0.05

A spotlight survey was conducted on 15 January 1997. Water salinities during the survey ranged from 2.0 ppt at the starting point, 4.0 ppt in Main Creek, and 8.0 ppt in Southern Lagoon. A single C. moreletii (TL = 141.0 cm) was captured. The other crocodile was sighted in Main Creek and may have been an American crocodile, which occur in Southern Lagoon (see Southern Lagoon account). The results of this survey suggest low densities of C. moreletii are present in Northern Lagoon. However, much higher densities have been found in the mangrove swamps and lagoons just north of this area, and from the Southern-Western-Sapodilla Lagoon complex.

Northern River and Northern River Lagoon

Survey Route: Begin at mouth of lagoon (17° 51' 04" N; 88° 12' 42" W). Enter lagoon and follow eastern shoreline to northeast corner of lagoon (17° 53' 27" N; 88° 13' 04" W). Bear south and follow western shore to mouth of Northern River (17° 52' 48" N; 88° 13' 54" W). Proceed upstream to bridge at Maskall (17° 52' 54" N; 88° 18' 07" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	1	22.0	0.04
C. moreletii	2	22.0	0.09

Northern River (continued).

EO	1	22.0	0.04
Total	4	22.0	0.18

Four crocodiles were observed during a spotlight survey conducted on 23 October 1997. Water salinity ranged from 14.0 ppt in the lagoon to 0.0 ppt in Northern River. One C. acutus (TL = 150 cm), two C. moreletii (TL ca. 180 and 45 cm), and an unidentified crocodile were observed. This is the only mainland site in Northern Belize where C. acutus has been found. The C. acutus and the EO were found among the mangroves in Northern River Lagoon. The unidentified crocodile was observed approximately 500 m from the C. acutus and may have been the same species. American crocodiles are expected in other lagoons along the northern coast which were not surveyed. Both C. moreletii were sighted in the Northern River near Maskall Village.

Petrojam Lagoon

Survey Route: Begin at gate of Petrojam Oil Terminal (17° 28' 57" N; 88° 11' 56" W). Circumnavigate lagoon and return to starting point.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	1	1.2	0.83

This shallow mangrove lagoon in the Port Loyola area of Belize City has received considerable recent attention from local tour guides because of the abundance of birdlife and the proximity to major hotels (K. Mustafa Toure, University College of Belize, pers. comm.). A spotlight survey was conducted by canoe on 17 February 1997, and a single C. moreletii (TL ca. 75 cm) was observed. Water salinity was 2.0 ppt.

Piedra Lagoon

Survey Route: Begin at boat landing along Southern Highway (16°13'05"N; 88°55'41"W), circumnavigate lagoon and return to boat landing.

Distance = 0.8 km

This freshwater lagoon is readily accessible from the Southern Highway. A spotlight survey was conducted by canoe on 6 June 1997, but no crocodiles were observed. Residents report crocodiles (probably C. moreletii) were present in the recent past (Brain Holland, P.G. Dolomite, Inc., pers. comm.).

Placencia Lagoon

Survey Routes

27 January 1997: Begin at canal mouth at Maya Beach (16° 36' 28" N: 88° 27' 21" W). Follow shoreline around northeastern corner of lagoon to point on western shoreline (16° 36' 11" N; 88° 21' 42" W).

22 January 1997: Begin at mouth of Mango Creek (16° 35' 36" N; 88° 23' 45" W). Follow Mango Creek upstream to 16° 33' 03" N; 88° 04' 07" W. Follow right fork to village (16° 32' 45" N; 88° 24' 47" W). Return along same route to Placencia Lagoon (16° 32' 30" N; 88° 23' 37" W). Follow western shore to 16° 36' 26" N; 88° 22' 12" W. Cross lagoon to eastern shore (16° 36' 11" N; 88° 21' 42" W) and follow shoreline to jetty at Seine Bight Village (16° 34' 06" N; 88° 22' 08" W).

23 January 1997: Begin at Seine Bight Village (16° 34' 06" N; 88° 22' 08" W). Follow shoreline until reaching Placencia Village (16° 30' 49" N; 88° 21' 46" W).

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	21 Jan. 97	1	23.2	0.04
	22 Jan. 97	0	29.2	0.0
	23 Jan. 97	0	16.2	0.0
Total		1	68.6	0.01

Water salinity ranged from 0.0 ppt in Mango Creek, 12.0 ppt in the northeastern corner of Placencia Lagoon, and 30.0 ppt at the lagoon mouth. While the habitat and salinity regime appear typical of C. acutus habitats elsewhere on the mainland, no evidence of this species was found. The only crocodile encountered was a C. moreletii (TL = 60.3 cm) captured among red mangroves in the northeastern corner of Placencia Lagoon. This specimen was captured approximately 25 km south of the distributional limits presented by Lee (1995). Voucher photographs (CUSC #866) were deposited in the Vertebrate Collection, Clemson University, Clemson, South Carolina, USA.

Factors contributing to the low densities of crocodiles in Placencia Lagoon and Mango Creek remain unclear. Zisman (1996) suggested Placencia Lagoon may be important habitat for both species of Crocodylus. Local residents report occasional sightings, but crocodiles are considered rare, a consensus supported by survey results.

Potts Creek Lagoon

Survey Route: Begin at lagoon entrance (17° 38' 32" N; 88° 17' 18"W). Follow lagoon shoreline and return to starting point. Much of the lagoon is shallow and the shoreline cannot be approached in a skiff. Follow coastline to mouth of Rocky Point lagoon (17° 38' 31" N; 88° 16' 37" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
EO	1	4.25	0.23

Spotlight survey was conducted on 16 July 1997. A single crocodile (TL ca. 100 cm) was observed, but could not be approached closely enough for a positive species identification. Salinity was 26.0 ppt.

Punta Ycacos Lagoon

Survey Route: Begin at confluence of Freshwater Creek (16° 20.31' N; 88° 36.19' W). Follow a series of creeks, always bearing to the east, until reaching the lagoon mouth (16° 15.13' N; 88° 36.05' W).

Distance = 16.7 km.

No crocodiles were encountered during a spotlight survey on 7 November 1996. According to Eloy Cuevas (pers. comm.), a fishing guide with an extensive knowledge of local natural history, crocodiles are present, but rarely encountered. It is unknown which species are present, but both have been found in nearby Deep River (See Deep River account).

Rio Grande River

Survey Route: Begin at river mouth (15° 58' 43" N; 88° 56' 25"W). Follow river upstream to Wilson's Landing (16° 10' 10" N; 88° 48' 53" W).

Distance = 27.5 km.

A spotlight survey was conducted on 13 May 1997, but no crocodiles were observed. Many monofilament gill nets were found obstructing the river mouth and the upstream channel.

Rio Hondo

Survey Route: Begin at river mouth (18° 29' 16" N; 88° 18' 47" W). Proceed upstream past Santa Elena Bridge to 18° 29' 14"N; 88° 25' 29" W.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	12.7	0.15

A spotlight survey was conducted on 5 September 1997. Water salinity was 0.0 ppt at the river mouth. Two C. moreletii (TL ca. 100 and 120 cm) were encountered along the survey route. Considerably higher densities were found during previous surveys of the Rio Hondo near San Antonio Village and Blue Creek (2.5 and 0.74 crocodiles/km, respectively; Platt 1996).

Sapodilla Lagoon

Survey Route: Begin along western shoreline opposite large island (16° 46' 48" N; 88° 18' 14" W). Follow shoreline northeast to lagoon entrance, and then proceed along eastern shore and enter creek (16° 45'.48" N; 88° 18' 36" W). Follow creek upstream to fork (16° 45' 13" N; 88° 19' 43" W). Return along same route and exit lagoon at creek (16° 45' 41" N; 88° 18' 33" W). Most of western shoreline is too shallow to navigate.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
EO	1	4.1	0.24

A single crocodile was seen during a spotlight survey on 17 October 1997, but could not be approached closely enough for species identification. Local fishermen report occasional crocodile sightings in the lagoon, but which species are present remains unclear. Water salinity was 0.0 ppt.

Sarstoon River

Survey Route: Begin at the Belize/Guatemala border (15° 53' 27" N; 89° 13' 33" W). Proceed downstream to river mouth (15° 53' 40" N; 88° 55' 12" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	4	49.7	0.08

Spotlight survey conducted on 3 June 1997. All sightings were over 20 km from the river mouth. These included two recent hatchlings, a juvenile (TL ca. 60 cm), and an adult (TL ca. 240 cm), and represent a range extension of approximately 130 km south of the distributional limits presented by Lee (1995). The river mouth was almost completely obstructed by monofilament gill nets.

Sarteneja

An adult male C. moreletii was removed from a fish trap in Chetumal Bay near Sarteneja Village by Steve Nichols in September 1997. Water salinity was 20.0 ppt at the time of capture. This crocodile was tagged and translocated to the Sibun River. The skull of another C. moreletii was examined in May 1997 at a bar in the village (Appendix 6). This skull was recovered from a crocodile which drowned in a fishing net set in Chetumal Bay. Additionally, Meerman (1993) reported the capture of another C. moreletii in Chetumal Bay. Evidence for the occurrence of C. acutus in this area is lacking.

Sennis River

Survey Route: Begin upstream at aquaculture facility (16° 27.23' N: 88° 29.03' W). Proceed downstream to fork in river, turn to starboard and go upstream to 16° 27.36' N: 88° 28.33' W. Return to fork and proceed to river mouth (16° 26.22' N: 88° 26.38' W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	1	7.0	0.14
C. moreletii	1	7.0	0.14
Total	2	7.0	0.28

A spotlight survey was conducted on 6 November 1996. Water salinities at both sightings were 0.0 ppt. The C. moreletii (TL ca. 180 cm) was encountered near the starting point, and the C. acutus (TL ca. 75 cm) was found among the dwarf red mangroves at the river mouth.

Shipstern Lagoon

Survey Route: Begin at La Isle Boat Landing (18° 20' 02" N; 88° 07' 24" W). Go across lagoon to creek mouth (18° 19' 56" N; 88° 05' 56" W). Follow creek to Chetumal Bay and then go south along coast to Shipstern Creek (18° 18' 06" N; 88° 05' 49" W). Follow creek into open lagoon and stop at 18° 17' 41" N; 88° 07' 23" W. Go across lagoon and enter creek mouth (18° 13' 58" N; 88° 12' 18" W). Follow creek into lagoon. circumnavigate lagoon and return to creek mouth. Follow shoreline of lagoon back to La Isle Boat Landing.
Distance: 10.5 km.

A spotlight survey conducted on 5 October 1997, found no crocodiles. Elevated water levels and heavy rains resulted in suboptimal survey conditions that may have negatively biased results. Water salinity during the survey was 5.0 ppt. Salinity in Shipstern Lagoon ranges from 0.0 ppt to 16.0 ppt depending on the amount of recent rainfall and time of year (Zoe Walker, Wild Treks, Inc., pers. comm.). According to local residents crocodiles are rarely encountered in Shipstern Lagoon, but are common in the surrounding freshwater wetlands (Paul Walker, Wild Treks, Inc., pers. comm.). C. moreletii nesting has been reported in Shipstern Lagoon (Platt, 1996).

Sibun River

Survey Route: Begin at Burdon Canal/Northern Lagoon (17° 23' 46" N; 88° 18' 37" W). Follow Burdon Canal to the Sibun River and proceed downstream to river mouth (17° 25' 35" N; 88° 15' 42" W). Return upstream to Boom Creek (17° 25' 36" N: 88° 16' 17" W).

Follow Boom Creek to Jones Lagoon (17° 26' 34" N; 88° 16' 14" W). Circumnavigate lagoon and return to Boom Creek.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	8	15.1	0.52
EO	8	15.1	0.52
Total	16	15.1	1.05

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
0	3	2	3	8

An extensive mangrove swamp and creek system surround the mouth of the Sibun River. A spotlight survey was conducted on 16 January 1997. Water salinities ranged from 0.0 ppt in Burdon Canal to 9.0 ppt in Jones Lagoon. A salinity gradient was found in the Sibun River, ranging from 6.0 ppt at the river mouth, to 0.0 ppt approximately 3.0 km upstream. All crocodiles that could be identified were C. moreletii. It is probable that the EO's were also C. moreletii. No C. acutus were found during this survey. Previous surveys (Platt, 1996) have likewise failed to find C. acutus in this wetland system.

Sitee River

Survey Route

15 October 1997: Begin at Toucan Sitee boat landing (16° 49' 34" N; 88° 17' 40" W). Follow river downstream to 16° 48' 58" N; 88° 16' 04" W. Return along same route.
17 October 1997: Begin at river mouth (16° 48' 31" N; 88° 14' 59" W). Follow river upstream to Toucan Sitee Boat Landing (16° 49' 34" N; 88° 17' 40" W).

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	15 Oct. 97	12	6.7	1.79
	17 Oct. 97	10	8.0	1.25
Total		22	14.7	1.49

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
1	12	1	5	3

Spotlight surveys were conducted by canoe on 15 October 1997, and skiff on 17 October 1997. Water salinity ranged from 10.0 ppt at the river mouth to 0.0 ppt 2 km upstream. No C. acutus were sighted during these surveys, but 22 Morelet's crocodiles were observed and seven captured. All captured crocodiles appeared to be typical C. moreletii. These captures were made approximately 20 km south of the distributional limits presented in Lee (1995). Voucher photographs were deposited in the vertebrate Collection, Clemson University, Clemson, South Carolina, USA.

Southern Lagoon

Survey Routes

17 September 1996: Begin at southeastern corner of Southern Lagoon (17° 10.54' N: 88° 19.55' W). Follow shoreline to Main Creek (17° 16.67' N; 88° 19.33' W).

18 September 1996: Begin along eastern shoreline of lagoon (17° 14.72' N; 88° 21.88' W). Follow shore to 17° 15.66' N; 88° 21.73' W.

19 September 1996: Begin at 17° 15.39' N; Follow shore to 17° 14.96' N; 88° 20.59' W.

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	17 Sept. 96	1	10.4	0.09
	18 Sept. 96	4	6.7	0.59
	19 Sept. 96	1	1.6	0.62
EO	17 Sept. 96	1	10.4	0.09
Total		7	18.7	0.37

Southern Lagoon is a complex of mangrove and freshwater wetlands consisting of Southern, Western, and Sapodilla Lagoons, and tributary creeks. Water salinities ranged from 4.0 to 6.0 ppt during the survey period. Seven crocodiles were observed during the surveys; six were identified as C. acutus and one could not be approached closely enough for species identification. Both species are present in this lagoon system. Only C. moreletii were found in a 1993 survey (Platt, 1996), and skulls of both species are on display at Manatee Lodge in Gales Point (Appendix 6). These skulls (2 C. moreletii and 1 C. acutus) were collected from crocodiles that drowned in a fishing net set in the lagoon. One C. moreletii skull came from an animal with an estimated total length of 3.52 m, which is approaching the maximum size recorded for this species (Platt, 1996).

A daylight reconnaissance was conducted along the beaches north and south of Manatee Bar, and at White Ridge Farms (ca. 3 km SE Gales Point). Recent tracks and drag marks were found near Manatee Bar, and at White Ridge Farms a well-worn path was found leading from a freshwater swamp to the Caribbean Sea. Tracks at both locations were probably made by C. acutus.

Temash River
Survey Route: Begin at river mouth (16° 08' 21" N; 88° 44' 57" W). Follow river upstream to Crique Sarco Village (15° 58' 43" N; 89° 05' 49" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	2	37.7	0.05
EO	1	37.7	0.02
Total	3	37.7	0.07

A single spotlight survey was conducted on 19 May 1997. Water salinity ranged from 25.0 ppt at the river mouth to 0.0 ppt at Crique Sarco Village. All crocodiles were sighted in freshwater. Of the crocodiles observed, two were identified as C. moreletii (TL ca. 60 and 150 cm), and one could not be approached closely enough for species identification. The larger C. moreletii was encountered at an old nest mound, probably from the 1996 nesting season. These sightings represent a range extension of approximately 100 km south of the distributional limits presented by Lee (1995).

University College of Belize
Survey Route: Begin at canal mouth (17° 30' 57" N; 88° 12' 22" W). Follow canal to terminus (17° 30' 44" N; 88° 12' 18" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. moreletii	1	0.6	1.6

A spotlight survey was conducted on 17 February 1997 and a single C. moreletii (TL ca. 75 cm) was observed feeding on fiddler crabs (Uca sp.). While C. acutus were not observed, the species is present as nesting was noted in 1996 and 1997 (see Reproduction), and C. acutus have been captured along the coastline, less than 200 m from the canal mouth.

Waree Bight Cenote
Survey Route: Begin at the boat landing along dirt road (18° 19' 19" N; 88° 14' 19" W). Circumnavigate lagoon and return to starting point.

This cenote, located approximately 2 km south of Chetumal Bay, is a deep sinkhole surrounded by a fringe of red mangrove. A daylight reconnaissance was made on 9 May 1997, and a spotlight survey conducted on 3 October 1997. Water salinity was 0.0 ppt during both trips. No crocodiles were sighted during the spotlight survey, but a dead C. moreletii was found during the reconnaissance. The skull from the carcass was collected and TL was estimated to be 120 cm (Appendix 6). C. acutus were reported in this cenote by Ouboter (1992).

CAYS

Alligator Cay
Survey Route: Begin at northern tip of island (17° 11' 48" N; 88° 05' 19" W). Proceed along western shoreline to southern tip of island, and return to starting point following eastern shoreline.
Distance = 7.0 km.

Survey conducted on 5 March 1997. No crocodiles were observed. It is probable that high winds and rough seas negatively biased survey results. However, numerous fishing camps are located on the island and several residents reported shooting crocodiles in the vicinity of their camps.

Ambergris Cay

While Ambergris Cay is actually an extension of the Xcalac Peninsula of Mexico, it is typically considered the largest of the Belizean Cays.

Survey Routes
1. San Pedro/Hol Chan (30 September 1996): Begin at Cangrejo Cay (17° 51.80' N; 88° 03.17' W). Follow western shoreline of cay, cross open bay, and proceed along western shore of Ambergris Cay to mouth of San Pedro River (17° 55.83' N; 87° 57.47' W).
2. San Pedro Lagoon (1 October 1996): Begin at boat dock (17° 55.55' N; 87° 57.97' W). Follow mangroves to sandspit (17° 55.34' N; 87° 57.73' W). Survey terminated when large (TL = 301 cm) crocodile was captured.
3. San Pedro Lagoon (2 October 1996): Begin at boat dock (17° 55.55' N; 87° 57.97' W). Follow creek into lagoon, proceed northward along shore until reaching creek channel (17° 55.57' N; 87° 58.77' W).
4. Ambergris Cay - Western Shoreline (3 October 1996): Begin at creek mouth leading into Laguna Cayo Frances (18° 02.57' N; 87° 55.70' W). Follow shoreline until reaching entrance to San Pedro Lagoon (17° 55.40' N; 88° 00.24' W).
5. WASA (Water and Sewerage Authority) Ponds (4 October 1996): Begin at front gate of facility (17° 53.53' N; 87° 58.68' W). Follow road through mangrove swamp to treatment facility, walk around perimeter levee, return to road, and then walk back to starting point.

Bacalar Chico National Park (BCNP)

6. San Juan Lagoon (29 October 1996): Begin at park HQ (18° 09.06' N; 87° 53.24' W). Follow western shore until reaching bird rookery (18° 08.04' N; 87° 53.25' W). Proceed along eastern shoreline and return to starting point.

7. Santa Cruz Lagoon/Ambergris Cay Western Shore (31 October 1996): Begin at southwest corner of Santa Cruz Lagoon (18° 04.59' N; 87° 55.23' W). Follow shore around lagoon, exit lagoon and proceed north along the western shore of Ambergris Cay until reaching BCNP HQ (18° 09.06' N; 87° 53.24' W).

8. Ambergris Cay - Western Shore (28 May 1997): Begin at Bacalar Chico Creek (18° 11' 25" N; 87° 51' 40" W). Follow shore south to BCNP HQ (18° 09.06' N; 87° 53.24' W).

9. Laguna Cantena (29 May 1997): Begin in creek mouth at northern end of lagoon (18° 10' 11" N; 87° 51' 20" W). Follow western shoreline to southern end of lagoon. and then return along eastern shore to starting point.

Location	Number Observed	Kilometers of Survey Route	Crocodiles/km
San Pedro/Hol Chan	3	19.6	0.15
San Pedro Lagoon[1]	3	2.0	1.5
San Pedro Lagoon[2]	5	11.2	0.44
Ambergris Cay - Western Shoreline[3]	3	15.5	0.19
WASA Ponds	4	9.6	0.41
San Juan Lagoon	1	5.2	0.19
Santa Cruz Lagoon	3	11.1	0.27
Ambergris Cay - Western Shoreline[4]	3	9.4	0.31
Laguna Cantena	8	13.0	0.61
Total	33	96.6	0.61

[1] 1 October 1996
[2] 2 October 1996
[3] 3 October 1996
[4] 28 May 1997

In addition to crocodiles observed during spotlight surveys, the tracks of two adult C. acutus were found on a sandbar at the mouth of San Juan Lagoon. These crocodiles are included in the following table of size distribution.

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
1	4	12	9	9

Low density American crocodile populations appear to be present throughout Ambergris Cay. The densities in BCNP (0.38 crocodiles/km) and other areas of Ambergris Cay (0.31 crocodiles/km) are similar. American crocodile densities found in BCNP during this study are comparable to 1995 survey results (0.39 crocodiles/km: Platt and Thorbjarnarson, 1996).

The highest crocodile density recorded was in a 2.0 km stretch of San Pedro Lagoon where three crocodiles were observed. However, the capture of a large adult crocodile necessitated an early termination of the survey, and most of the planned route was not completed. A more comprehensive survey the following night found densities in San Pedro Lagoon similar to other sites on Ambergris Cay.

The WASA facility is located approximately 3.3 km south of San Pedro and consists of several borrow pits dredged to provide fill for a sewage treatment plant. The borrow pits comprise an area of about 40 ha, and the facility is completely surrounded by mangrove swamp. Water salinity during the survey was 34.0 ppt. A network of dirt roads provides access to the swamp, and the spotlight survey was conducted on foot. An adult was observed in the borrow pit and two juveniles and a recent hatchling were captured at widely scattered locations in the swamp. The borrow pits and surrounding swamps provide foraging and nesting (see Reproduction) habitat, and should be afforded protection by WASA. The site has already attracted the attention of local tour operators and could prove an economic asset to the community.

Surveys of BCNP indicate low densities of American crocodiles are present. Concentrations were noted at fishing camps, and according to fishermen, it is common practice to discard fish entrails in the water. This serves to attract crocodiles to the vicinity, where they may come into conflict with humans.

The major crocodile/human conflict at BCNP occurs when crocodiles enter fish traps (known locally as beach traps), and consume the catch. These traps are large wire-mesh corrals with wings of wire-mesh or monofilament netting that intercept schools of fish moving parallel to the shore, and funnel them into a central collecting pen. Fishermen periodically visit the traps and remove the catch. Crocodiles which enter the traps are generally released unharmed, but occasional mortality results when they become entangled in monofilament netting and drown. A crocodile drowned during September 1996 in a trap near BCNP, and other incidents have probably gone unreported (Dillon Gomez, BCNP, pers. comm.).

Traditional fishing is allowed in BCNP, and mandatory substitution of wire-mesh for monofilament netting would likely eliminate this source of mortality. Such measures would also reduce mortality among brown pelicans (Pelecanus occidentalis) and cormorants (Phalacrocorax sp.), which likewise become entangled in netting and drown (S. Platt, pers. obs.).

Bluefield Range

Survey Route: Begin at the southern tip (17° 13' 17" N; 88° 05' 27" W). Follow western shoreline to northernmost tip of island (17° 13' 40" N; 88° 05' 23" W).

Distance = 1.2 km.

A spotlight survey conducted on 5 and 6 March 1997 found no crocodiles. The staff of a tourist facility on one cay reported occasional crocodile sightings. However, little habitat is available in this chain of small cays making it unlikely that many crocodiles are present.

Cay Caulker

Survey Routes

1. Shoreline (8 July 1996): Begin at the southern tip of the island (17° 43.82' N: 88° 01.69' W). Follow shoreline to airstrip (17° 44.11' N; 88° 02.22' W).
2. Shoreline (9 July 1996): Begin at northern tip of island (17° 47.86' N; 88° 01.27' W). Follow western shoreline to channel dividing island (17° 45.09' N; 88° 01.53' W).
3. Airstrip: Begin at the western end of the airstrip (17° 44.11' N; 88° 02.22' W). Walk to eastern end of airstrip (17° 44.07' N; 88° 02.13' W).
4. Dump: Begin at 17° 44.17' N; 88° 01.89' W. Follow shoreline around lagoon and return to starting point.

Location	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
Shoreline	8 July 96	1	3.7	0.27
	9 July 96	1	6.2	0.16
Airstrip	8 July 96	3	1.0	3.0
	23 April 97	4	1.0	4.0
Dump	8 July 96	23	1.1	20.9
	23 April 97	16	1.1	14.5
Total		48	14.1	3.4

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO
0	11	0	2	35

The largest concentration of American crocodiles on Cay Caulker were found at the municipal dump. The dump was originally a borrow pit (ca. 2 ha.) excavated to provide fill for the nearby airstrip. The town began using the site as a dump about five years ago, and now the borrow pit is partially filled with garbage and soil. Much of the remaining open water is covered by floating debris. Serious groundwater contamination is believed to be occurring and fecal coliform counts in the municipal water supply are elevated (Ellen McRae, Sibawahn Foundation, pers. comm.). Water salinities at the dump ranged from 25.0 ppt in July 1996 to 30.0 ppt in August 1997.

The C. acutus densities encountered at the dump are the highest recorded during this study. Two spotlight surveys undoubtedly yielded conservative counts as parts of the pond were not visible from the shoreline, and crocodiles proved difficult to spot amidst the floating garbage. Spotlight surveys were conducted by walking a trail along the shoreline, and most crocodiles could not be approached closely enough for size determination, and thus classified as EO. Adult crocodiles were observed swimming in the dump during a daylight reconnaissance, but most individuals classified as EO were probably juveniles. Meerman (1993) reported similarly high densities at this site.

A number of isolated, shallow pools were examined along the airstrip. Red mangrove swamp is found on both sides of the airstrip and water salinity ranged from 34.0 to 37.0 ppt. Only juvenile C. acutus were found in these pools. Continuing residential development at the western end of the airstrip will undoubtedly destroy important foraging habitat for juvenile crocodiles.

Portions of Cay Caulker have been undergoing residential development since 1990. much of the littoral forest and mangrove swamp on the southern half of the cay has been cleared, and further development is planned. Habitat destruction is a serious threat to the C. acutus remaining on the cay. The northern half of Cay Caulker has been proposed as a nature reserve (Zisman, 1996).

Some evidence of illegal killing was found during a visit in July 1996. A large (TL ca. 240 cm) male C. acutus was shot by residents when it entered a populated area. Photographs and measurements of the dead crocodile were obtained by Darren Catterall (Coral Cay Conservation). Several fishermen also reported shooting crocodiles that were sighted around their piers. Further crocodile/human encounters can be expected as the human population of the island increases.

Cay Chapel

Survey Route: Begin at northern tip of island (17° 42' 54" N; 88° 02' 10" W). Proceed along western shore to Marina entrance, enter and circumnavigate marina, and then continue following western shoreline until reaching the southern tip of the island (17° 40' 43"N; 88° 02' 50"W).
Distance = 3.7 km.

A spotlight survey conducted on February 1997, found no crocodiles. Extensive development has removed all of the native vegetation on the northern end of the island, but some mangrove remains on the southern half of Cay Chapel. A seawall is being constructed along the western shoreline and backfilled with dredged sand, destroying the turtlegrass beds surrounding the island. It is unlikely that Cay Chapel will provide much suitable crocodile habitat in the future, but given the proximity of a source population on nearby Frenchman's Cay, a few crocodiles may continue to inhabit the mangroves at the southern end of the island.

Deer Cay
Survey Route: Begin at northern end of cay (18° 07.19' N; 87° 56.41' W). Follow channel to southern tip of cay (18° 06.06' N; 87° 57.35' W).
Distance: 8.75 km.

A spotlight survey was conducted on 30 October 1996, but no crocodiles were observed. However, local fishermen occasionally see crocodiles in the area (Dillion Gomez, Bacalar Chico National Park, pers. comm.), suggesting low densities of C. acutus are present on Deer Cay.

Frenchman's Cay
Survey Route: Begin at channel on eastern shore (17° 35' 49" N; 88° 04' 40" W). Follow eastern shore around northern tip of island, and then proceed along western shore to southern tip of cay (17° 33' 57" N; 88° 04' 32" W). Numerous shoals make survey route treacherous.

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	1	12.0	0.08

A single crocodile (TL ca. 210 cm) was observed during a spotlight survey on 30 January 1997.

Gulf of Honduras

Five cays in the Gulf of Honduras were surveyed on 5 June 1997. Survey routes either completely circumnavigated cays (beginning and endpoints the same) or followed the western shoreline. Locations with beginning and endpoints are listed below. No crocodiles were found on any cays.

Location	Begin	End	Distance (km)
Frenchman's Cay	16° 10' 45"N 88° 39' 32"W	16° 10' 19"N 88° 39" 47"W	2.0
Unnamed Cay	16° 10' 22"N 88° 40' 10"W	16° 10" 24"N 88° 39' 58"W	0.5
Kulo Cay	16° 09' 53"N 88° 40' 13"W	16° 09' 42"N 88° 40 15"W	0.3

Gulf of Honduras (continued).

Location	Begin	End	Distance (km)
Moho Cay	16° 09' 22"N 88° 40' 24"W	16° 09' 09"N 88° 40' 25" W	0.25
Stuart Cay	16° 08' 39"N 88° 43' 06"N	16° 08' 39"N 88° 43' 06"W	1.2
Total			4.2

Hicks Cay

Survey Route: Begin at northwest tip of cay (17° 43.11' N; 88° 05.75' W). Follow western shoreline to creek (17° 41.63' N; 88° 07.16' W). Follow creek to eastern shoreline and then return along the same route. Follow western shoreline to 17° 38.35' N: 88° 11.46' W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	5	13.7	0.36

Size Distribution

Hatchlings	Juveniles	Subadults	Adults	EO<1.8m
0	1	2	2	1

A spotlight survey was conducted on 19 July 1996. In addition to the five crocodiles observed during the survey, a subadult (TL ca. 120 cm) was encountered swimming in a mangrove creek during a daylight reconnaissance of the survey route. This animal is included in the above size distribution.

Long Cay

Survey Route: Begin at northern tip of island (17° 38' 39" N; 88° 03' 42"W). Follow western shoreline to lagoon entrance (17° 38' 27" N; 88° 04' 72" W). Enter lagoon and follow shoreline. Very shallow. Exit lagoon and continue along western shoreline to southern tip of island (17° 36' 29" N; 88° 04' 30" W).

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	30 Jan. 97	1	4.2	0.23
	20 Feb. 97	3	4.2	0.71
Total		4	8.4	0.47

Size Distribution

Hatchlings	Juveniles	Subadults	Adults
0	7	4	2

A shallow black mangrove lagoon is found in the interior of the cay, which was almost completely dry during the survey period. Surface water salinities ranged from 12.0 ppt on 30 January to 22.0 ppt on 19 February. A spotlight survey of the lagoon was conducted on 19 February 1997 using a canoe, and seven juveniles and two adult C. acutus were observed. The size distribution includes all crocodiles.

Maps Cay

Survey Route: Begin at southern tip of island (17° 26' 55" N; 88° 04' 06" W). Follow eastern shoreline around northern end of cay, and enter channel at 17° 29' 30" N; 88° 05' 30" W. Follow channel back to eastern shoreline (17° 30' 33" N; 88° 05' 05" W).

Species	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	3	21.0	0.14

A spotlight survey was conducted on 27 January 1997. All crocodiles observed during this survey were encountered along 7.0 km of eastern shoreline (0.42 crocodiles/km). Despite rough seas (winds up to 20 knots), crocodiles were foraging in the surf and one was found consuming a snapper (Lutjanus sp.). Maps Cay was previously surveyed on 21 July 1997, and 11 crocodiles were observed along 12.9 km of shoreline (0.85 crocodiles/km; Platt and Thorbjarnarson, 1996). As in the present survey, all observations were made in the surf along the windward shoreline. The lower densities recorded in 1997 are not believed to reflect an actual population change, but are probably due to the inclement weather prevailing during the survey.

Middle Long Cay
Survey Route: Begin at creek mouth on eastern shore (17° 15' 41" N; 88° 04' 59" W). Follow creek into lagoon, circumnavigate lagoon, and return to creek mouth. Proceed along eastern shoreline, and return to starting point.

Species	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
C. acutus	5 March 97	1	13.8	0.07
	6 March 97	1	13.8	0.07
Total		2	27.6	0.07

Spotlight survey conducted on 5 and 6 March 1997. A single crocodile was observed on each survey (TL ca. 75 cm and EO). High winds and rough seas at this time resulted in suboptimal survey conditions, which may have negatively biased results.

Moho Cay
Survey Route: Begin at boat landing (17° 31' 05" N; 88° 12' 14" W). Circumnavigate cay and return to starting point.
Distance = 1.3 km.

This cay is located approximately 1.0 km east of the UCB Campus. Because of reported crocodile sightings and the proximity to a known nesting area, Moho Cay is considered potential habitat. An exclusive residential community has recently been constructed and most of the natural vegetation removed. A spotlight survey conducted on 13 January 1997, found no crocodiles. It is likely that crocodiles reported by residents were transient individuals.

Southern Long Cay and Coulsons Cay

Southern Long Cay is a large cay with an extensive interior lagoon, and the adjacent Coulsons Cays are a small group of low-lying mangrove islands. Other than several fishing camps, these islands are uninhabited. No crocodiles were observed during a daylight reconnaissance on 6 March 1997. High winds and rough seas prevented a spotlight survey. The habitat on these cays appears suitable and a resident population of C. acutus is probably present on these cays.

Tobacco Range

A daylight reconnaissance was conducted on 16 October 1997. According to several fishermen, American crocodiles are common in these cays and routinely sighted in the vicinity of camps where fish are being cleaned. Several crocodiles were intentionally fed at one camp. A crocodile measuring approximately 270 cm was recently shot at another camp because of safety concerns. The fisherman kept the skin, but was absent during our visit and we were unable to examine it.

ATOLLS

Lighthouse Atoll

Survey Route

Long Cay: Begin at the northwestern tip of the island (17° 13.31' N; 87° 35.50' W). Follow shoreline to southern tip of cay (17° 11.54' N; 87° 36.36' W).

Half Moon Cay: Begin at eastern tip of island (17° 12.37' N; 87° 35.50' W). Follow shoreline to western tip of island (17° 12.38' N; 87° 31.86' W).

Location	Number Observed	Kilometers of Survey Route	Crocodiles/km
Half-Moon Cay	0	1.2	0.0
Long Cay	1	3.8	0.26
Total	1	5.0	0.20

Spotlight surveys were conducted of Half-Moon Cay on 22 August 1996, but no crocodiles were observed. According to the Lighthouse Keeper, a long-time resident, crocodiles are do not occur on this small cay. A spotlight survey was conducted of Long Cay on 24 August 1996, and a single adult (TL ca. 240 cm) American crocodile was encountered. The interior of Long Cay is inaccessible to boats, but contains a shallow, red mangrove lagoon which appears to be suitable crocodile habitat.

A daylight reconnaissance was made of Northern Cay on 11 July 1997. The construction of a tourist facility and airstrip has resulted in the destruction of most littoral forest on the cay. A single adult (TL ca. 210 cm) and a recent hatchling were found in a small (20 m X 10 m) freshwater pond near the airstrip. Numerous crocodile tracks and drag marks leading from the pond to an adjacent mangrove swamp were found, and it appears crocodiles frequently visit the pond to drink freshwater. Crocodile sightings are presented in Figure 12. A report by Stoddart (1962) that Morelet's crocodile was present on Northern Cay is believed erroneous, and probably resulted from confusion with C. acutus.

Turneffe Atoll

Survey Routes

1. Cay Bokel to Tarpon Creek (2 April 1997): Begin on western shore of Cay Bokel near dump (17° 10' 13" N; 87° 54' 38" W). Follow western shore of atoll to Tarpon Creek (17° 19' 58" N; 87° 55' 36" W).
2. Blackbird Cay - Eastern Shore (26 November 1996, 6 February 1997, and 3 April 1997): Begin at pier (17° 18' 22" N; 87° 48' 09" W). Follow shoreline north until meeting the barrier reef (17° 19' 37" N; 87° 67' 37" W).
3. Blackbird Cay - Western Shore (21 November 1996, 5 February 1997, and 10 April 1997): Begin in embayment behind Turneffe Flats Lodge (17° 25' 38" N; 87° 49' 07" W). Follow western shore to southern tip of island (17° 18' 15" N; 87° 49' 59" W).
4. Calabash Cay (28 November 1996, 4 February 1997, and 11 April 1997): Begin at creek mouth on western shore (17° 17' 11" N; 87° 48' 45" W). Enter lagoon, circumnavigate and return to starting point. Then follow shore along western side of cay to creek mouth (17° 16' 26" N; 87° 49' 14" W).
5. Calabash Cay - Interior Lagoon (28 February 1997): Begin at entrance to lagoon (17° 17' 11" N; 87°48' 45" W). Circumnavigate lagoon and return to starting point.
6. Northern Lagoon (23 November 1996, 7 February 1997): Begin at lagoon entrance (17° 29' 12" N; 87° 50' 43" W). Circumnavigate lagoon and return to starting point.
7. Northern Lagoon to Crikozeen Creek (24 November 1996, and 26-27 February 1997): Begin at southern entrance to Northern Lagoon (17° 29' 23" N; 57° 51' 01" W). Follow western shore of atoll until reaching Crikozeen Creek (17° 24' 10" N; 87° 54' 45" W).
8. Northern Cay - Interior Lagoon (21 August 1996, 21 November 1996, and 10 July 1997): Begin at 17° 29' 47" N; 87° 47' 01" W. Circumnavigate lagoon and return to starting point.

Location	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
Blackbird Cay (Eastern Shore)	26 Nov. 96	7	2.7	2.60
	6 Feb. 97	11	2.7	4.07
	3 April 97	6	2.7	2.22
Blackbird Cay (Western Shore)	21 Nov. 96	6	15.7	0.38
	5 Feb. 97	7	15.7	0.44
	10 April 97	11	15.7	0.70
Calabash Cay	28 Nov. 97	6	2.4	2.5
	4 Feb. 97	8	2.4	3.33

Turneffe Atoll (continued).

Location	Date	Number Observed	Kilometers of Survey Route	Crocodiles/km
Calabash Cay	11 April 97	7	2.4	2.91
Calabash Cay (Lagoon Only)	28 Feb. 97	3	1.4	2.14
Cay Bokel	2 April 97	14	19.8	0.70
Northern Lagoon	23 Nov. 96	12	21.6	0.55
	7 Feb. 97	16	21.6	0.74
Northern Lagoon to Crikozeen	24 Nov. 97	12	13.8	0.94
	26-27 Feb. 97	11	13.8	0.79
Northern Cay (Interior Lagoon)	21 Aug. 96	2*	0.8	2.50
	21 Nov. 96	7	0.8	8.75
	10 July 97	5*	0.8	6.25
Total		152	156.8	

*This number does not include hatchlings. See discussion.

In addition to crocodiles encountered during spotlight surveys, twelve others were opportunistically observed during field operations, and are included in the size distribution below. The total number of each size class is followed by frequency in parentheses.

Size Distribution

Juveniles	Subadults	Adults	EO	Total
24 (14.6)	45 (27.4)	50 (30.4)	45 (27.4)	164

The Turneffe Atoll was the area most intensively surveyed during this project. A total of 152 crocodiles (not including hatchlings) were observed and 156.8 km surveyed. A mean of 0.96 crocodiles was calculated from all surveys. This is almost twice the

m (Platt and Thorbjarnarson, 1996), but
' the population over the intervening
d during initial fieldwork (Platt and
dy an effort was made to survey areas
nd other regions were rarely visited.
it the atoll is probably much lower than

nterior lagoon on Northern Cay adjacent to
shallow lagoon is inaccessible to larger
adult, and adult crocodiles were
and July 1997 numerous hatchlings were
results. This was the only location in

eastern shore of Blackbird Cay, and the
ng the highest densities found at any site
one of the few sites along the windward
he danger of maneuvering boats over the
s here was surprising as crocodiles tend
omise their visual and respiratory
ier reef dissipates wave energy, creating
provides excellent foraging habitat, and
uction). Other sites along the windward
rbor concentrations of crocodiles.
many captured individuals had heavily
er coral.

served in a lagoon and creek system
ern shorelines. This creek system may
diles, providing rapid access to
grass beds and reef on the eastern shore.
adversely impact much of this habitat.

996) speculated on the existence of a
However, survey results from 1994
udy indicate that densities in Northern
e southern and western shorelines are
relatively deep (>1.5 m), providing
along the eastern and northern shores
ng easterly winds, and offer an

codiles/km) were found on the
n Creek, and from the mouth of

shallow water with extensive turtlegrass beds, offering excellent foraging habitat. Some crocodiles observed near Cay Bokel were found at a large, open garbage dump operated by Turneffe Island Lodge. The dump is not only an eyesore, but may also represent a human health risk and should be closed.

Appendix 2. A. American crocodiles captured and marked by scute clipping (1996 to 1997). TA = Turneffe Atoll; BCNP = Bacalar Chico National Park, Ambergris Cay. Sex: M = male; F = female.

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
2-2	Cay Caulker	07/08/96	?	57.5	27.7	0.5
2-3	Cay Caulker	07/09/96	M	181.0	95.0	19.5
2-4	Cay Caulker	07/09/96	M	117.5	59.5	5.1
2.5	Hicks Cay	07/19/96	M	116.0	58.5	4.5
2-6	Northern Cay, TA	08/22/96	?	26.8	13.4	0.05
2-7	Northern Cay, TA	08/21/96	?	28.1	14.0	0.06
2-8	Northern Cay, TA	08/21/96	?	29.0	13.8	0.06
2-9	Northern Cay, TA	08/21/96	?	29.8	14.3	0.07
3-2	Northern Cay, TA	08/21/96	?	29.5	13.7	0.06
3-3	Northern Cay, TA	08/21/96	?	27.6	13.0	0.05
3-4	Northern Cay, TA	08/21/96	?	31.2	15.0	0.08
3-5	Northern Cay, TA	08/21/96	?	26.7	13.1	0.05
3-6	Northern Cay, TA	08/21/96	?	28.1	13.3	0.06
3-7	Northern Cay, TA	08/21/96	?	27.9	13.5	0.05
3-8	Southern Lagoon	09/17/96	M	80.6	42.3	1.3
3-9	Southern Lagoon	09/18/96	M	100.5	51.4	2.7
4-2	Southern Lagoon	09/18/96	F	119.0	60.5	4.5
4-3	Southern Lagoon	09/18/96	M	105.3	54.5	3.1
4-4	Southern Lagoon	09/19/96	?	64.9	32.7	0.7
4-5	Ambergris Cay	10/01/96	M	301.7	162.0	110.0^{+}
4-6	Ambergris Cay	10/03/96	M	210.0	97.0	28.1

Appendix 2. A (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
4-7	Ambergris Cay	10/03/96	M	105.8	54.5	3.0
4-8	Ambergris Cay	10/04/96	?	38.0	18.7	0.16
4-9	Ambergris Cay	10/04/96	?	33.6	16.2	0.99
5-2	Ambergris Cay	10/04/96	?	19.5	13.9	0.71
5-3	Ambergris Cay (BCNP)	10/31/96	M	101.6	52.5	3.2
5-4	Deep River	11/08/96	M	110.2	57.1	3.7
5-5	Northern Cay, TA	11/21/96	M	211.8	109.0	38.6
5-6	Northern Cay, TA	11/21/96	M	67.1	33.5	0.8
5-7	Blackbird Cay, TA	11/21/96	M	124.5	63.8	5.0
5-8	Northern Lagoon, TA	11/23/96	F	208.5	108.5	32.7
5-9	Northern Lagoon, TA	11/23/96	F	192.0	98.0	31.3
6-2	Northern Lagoon, TA	11/23/96	F	199.5	100.6	27.2
6-3	Northern Lagoon, TA	11/23/96	F	172.0	87.5	17.7
6-4	Northern Lagoon, TA	11/23/96	F	195.0	98.2	28.1
6-5	Northern Lagoon, TA	11/23/96	F	194.5	99.5	26.3
6-6	Northern Lagoon, TA	11/23/96	M	106.8	54.3	3.1
6-7	Western Shoreline, TA	11/24/96	M	100.3	51.5	2.4
6-8	Western Shoreline, TA	11/24/96	F	107.8	55.5	3.4
6-9	Western Shoreline, TA	11/24/96	M	214.5	107.0	34.5
7-2	Western Shoreline, TA	11/24/96	M	141.0	70.7	8.4
7-3	Western Shoreline, TA	11/24/96	F	114.5	58.0	4.0
7-3[1]	Crikozeen, TA	11/27/97	F	117.5	60.0	4.6

Appendix 2. A (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
7-4	Western Shoreline, TA	11/24/96	F	178.0	93.8	21.8
7-5	Western Shoreline, TA	11/24/96	F	166.0	82.4	15.4
7-6	Blackbird Cay, TA	11/25/96	M	145.5	76.5	11.8
7-7	Blackbird Cay, TA	11/26/96	M	97.5	48.9	2.2
7-8	Blackbird Cay, TA	11/26/96	M	93.0	47.0	2.3
7-9	Blackbird Cay, TA	11/26/96	M	130.4	67.0	6.5
8-2	Blackbird Cay, TA	11/26/96	F	152.5	83.0	14.5
8-3	Calabash Cay, TA	11/28/96	F	212.6	106.0	38.1
8-4	Calabash Cay, TA	11/28/96	F	184.0	93.0	22.2

[1]Recapture

Appendix 2. B. American crocodiles captured and marked with toe tags (1997). TA = Turneffe Atoll; BCNP = Bacalar Chico National Park, Ambergris Cay. Sex: M = male; F = female.

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
103	Blackbird Cay, TA	02/05/97	M	60.8	29.4	0.6
105	Long Cay	02/19/97	M	68.9	34.7	0.9
106	Long Cay	02/19/97	M	43.2	21.1	0.23
107	Long Cay	02/19/97	M	43.0	20.9	0.22
108	Long Cay	02/19/97	M	44.5	21.9	0.25
112*	Northern Cay, TA	07/10/97	?	26.6	12.7	0.05
113*	Northern Cay, TA	07/10/97	?	26.2	12.4	0.05
114	Cay Caulker	04/23/97	M	68.5	34.1	0.7
119	Blackbird Cay	04/03/97	M	77.6	37.8	1.1
120*	Northern Cay, TA	07/10/97	?	26.5	12.5	0.05
121	Northern Cay, TA	07/10/97	F	58.0	28.6	0.57
122*	Northern Cay, TA	07/10/97	?	28.4	13.3	0.06
123*	Northern Cay, TA	07/10/97	?	28.2	13.5	0.05
125*	Northern Cay, TA	07/10/97	?	28.2	13.5	0.05
126	Northern Cay, TA	07/10/97	?	34.0	16.3	0.11
127	Northern Cay, TA	07/10/97	?	31.8	15.4	0.08
131	Northern Cay, TA	07/10/97	F	60.5	30.2	0.65
136*	Northern Cay, TA	07/10/97	?	28.6	13.6	0.06
137*	Northern Cay, TA	07/10/97	?	27.3	13.2	0.05
138	Northern Cay, TA	07/10/97	?	32.5	15.2	0.09

Appendix 2. B (continued)

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
144*	Northern Cay, TA	07/10/97	?	27.5	12.8	0.05
150*	Northern Cay, TA	07/10/97	?	29.6	13.8	0.06
152*	Northern Cay, TA	07/10/97	?	28.7	13.7	0.05
153*	Northern Cay, TA	07/10/97	?	28.4	13.6	0.06
154*	Northern Cay, TA	07/10/97	?	29.4	14.0	0.06
155*	Northern Cay, TA	07/10/97	?	27.1	12.7	0.05
157	Northern Cay, TA	07/10/97	?	32.5	15.6	0.09
159	Northern Cay, TA	07/10/97	?	30.0	14.6	0.07
160	Northern Cay, TA	07/10/97	?	30.5	14.8	0.08
164*	Northern Cay, TA	07/10/97	?	28.3	13.4	0.05
166*	Northern Cay, TA	07/10/97	?	28.0	13.1	0.05
168*	Northern Cay, TA	07/10/97	?	26.0	12.4	0.05
170*	Northern Cay, TA	07/10/97	?	27.5	13.1	0.04
171*	Northern Cay, TA	07/10/97	?	31.0	14.5	0.06
172[2]	Blackbird Cay, TA	04/10/97	M	69.5	38.0	1.1
173*	Northern Cay, TA	07/10/97	?	27.9	13.2	0.05
510	Cay Bokel, TA	04/02/97	F	146.9	75.7	8.5
525	Crikozeen, TA	02/26/97	M	150.0	81.5	10.0
526	Calabash Cay, TA	02/04/97	M	124.0	64.0	5.7
550	Blackbird Cay, TA	04/10/97	F	162.4	84.5	13.1
551	Maps Cay	01/27/97	F	96.6	59.8	4.8
552	Blackbird Cay, TA	04/10/97	F	124.6	70.6	7.6

Appendix 2. B (continued)

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
554	Ambergris Cay (BCNP)	05/29/97	M	91.7	46.0	1.7
559	Ambergris Cay (BCNP)	05/29/97	M	125.5	64.1	5.8
565	Cay Bokel, TA	04/02/97	F	96.0	49.0	2.2
566	Tarpon Creek, TA	04/02/97	F	123.5	62.4	5.4
567	Cay Bokel, TA	04/02/97	F	137.0	69.5	7.4
578	Calabash Cay, TA	02/04/97	F	160.7	83.5	14.0
583	Long Cay	02/20/97	F	170.0	86.5	19.0
589	Ambergris Cay (BCNP)	05/28/97	M	97.0	49.0	2.6
590	Ambergris Cay (BCNP)	05/28/97	M	154.0	79.1	12.0
593	Cay Bokel, TA	04/02/97	F	122.8	63.0	4.1
597	Crikozeen, TA	02/27/97	F	165.5	84.2	13.6
600	Belize City	01/14/97	M	93.5	48.0	2.9
602	Blackbird Cay, TA	02/06/97	M	166.0	85.5	17.2
603	Blackbird Cay, TA	02/06/97	F	212.0	108.5	40.0
604	Blackbird Cay, TA	02/06/97	F	189.0	100.5	28.1
605	Blackbird Cay, TA	02/06/97	F	182.5	94.4	24.5
606	Northern Lagoon, TA	02/07/97	M	278.0	141.0	?
607	Northern Lagoon, TA	02/07/97	M	218.0	108.5	40.5
609	Northern Lagoon, TA	02/07/97	F	200.0	104.0	27.7
610	Long Cay	02/19/97	F	210.0	111.0	38.6
611	Blackbird Cay, TA	04/10/97	F	172.5	90.0	15.0

Appendix 2. B (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
612	Northern Lagoon, TA	02/26/97	M	206.3	106.2	28.6
622	Turneffe Atoll	04/02/97	M	217.0	109.0	37.2
623	Crikozeen, TA	02/26/97	M	263.0	129.0	68.6
624	Blackbird Cay, TA	02/03/97	F	185.5	99.5	28.6
625	Blackbird Cay, TA	02/05/97	F	185.5	98.0	29.0

[1] Recapture

[2] Tip of tail missing.

* Denotes hatchlings ≤1 week old.

Appendix 2. C. Morelet's crocodiles captured and marked by scute clipping (1996 to 1997). GBL = Gold Button Lagoon; GBR = Gold Button Ranch; GJ = Gallon Jug; NRL = New River Lagoon.

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
RF1	Private Collection	11/11/96	M	79.8	38.9	0.95
SN1	Private Collection	11/101/96	M	102.0	51.9	3.1
SN2	Private Collection	11/01/96	M	90.9	45.0	2.2
SN3	Private Collection	11/01/96	F	79.8	38.4	1.5
SN4	Private Collection	06/10/97	M	79.0	38.5	1.3
1-3[1]	GBL	06/16/97	?	107.0	52.5	?
5-9[1]	GBL	04/13/97	F	160.0	77.0	?
2-8	GBL	04/13/97	M	132.0	64.5	7.3
2-9	GBL	04/13/97	?	32.0	15.3	?
2-10	GBL	04/06/97	?	41.4	19.1	0.14
1-5-8[1]	GBL	07/17/96	?	46.0	21.5	0.25
1-5-8[1]	GBL	04/26/97	?	51.9	24.4	0.25
2-4-2[1]	GBL	06/16/97	?	76.5	37.6	?
2-4-9[1]	GBL	07/17/96	?	49.0	23.4	0.3
6-4-5[1]	GBL	06/10/97	?	65.2	33.3	0.8
2-3-2-3	NRL	07/11/96	M	123.5	61.0	5.0
2-3-2-4	Four-mile Lagoon	07/02/96	M	215.0	96.0	29.5
2-3-2-4	NRL	07/11/96	M	157.0	77.0	10.9
2-3-2-5	GBL	07/17/96	?	39.0	18.2	0.15

Appendix 2. C (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
2-3-2-5[1]	GBL	04/13/97	?	41.6	19.9	?
2-3-2-6	NRL	08/02/96	M	93.9	45.6	1.9
2-3-2-7	NRL	08/02/96	M	155.5	75.2	12.7
2-3-2-8	NRL	08/03/96	M	125.0	60.2	5.6
2-3-3-2	NRL	08/03/96	M	136.6	67.2	7.0
2-3-3-3	NRL	08/05/96	M	205.0	97.0	25.4
2-3-3-4	NRL	08/07/96	M	158.0	77.1	11.3
2-3-3-5	Burdon Canal	08/12/96	M	106.0	51.1	3.5
2-3-3-6	Burdon Canal	08/12/96	M	69.0	32.7	0.65
2-3-3-7	Belize City	08/12/96	M	126.0	62.1	7.6
2-3-3-8	Stockpond, GBR	08/28/96	?	26.5	12.0	0.04
2-3-3-9	Stockpond, GBR	08/28/96	?	26.7	12.1	0.04
2-3-4-2	Stockpond, GBR	08/28/96	?	26.6	12.5	0.04
2-3-4-3	Stockpond, GBR	08/28/96	?	26.5	12.4	0.04
2-3-4-4	Stockpond, GBR	08/28/96	?	27.4	12.5	0.04
2-3-4-4[1]	Stockpond, GBR	11/14/96	?	35.2	16.2	0.10
2-3-4-5	Stockpond, GBR	08/28/96	?	26.6	12.3	0.04
2-3-4-6	Stockpond, GBR	08/28/96	?	27.1	12.4	0.04
2-3-4-7	Cox Lagoon	09/05/96	?	68.0	33.0	0.75
2-3-4-8	GBL	09/06/96	?	24.5	11.9	0.04
2-3-4-8[1]	GBL	04/06/97	?	41.7	20.0	0.17

Appendix 2. C (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
2-3-4-9	GBL	09/06/96	?	25.0	12.1	0.04
2-3-5-2	GBL	09/06/96	?	24.7	11.8	0.04
2-3-5-3	GBL	09/06/96	?	23.2	11.2	0.04
2-3-5-4	GBL	09/07/96	?	24.8	11.6	0.04
2-3-5-5	Sapote Lagoon	10/11/96	?	28.8	14.0	0.05
2-3-5-6	Sapote Lagoon	10/11/96	?	43.4	21.0	0.14
2-3-5-7	Sapote Lagoon	10/11/96	?	31.3	14.4	?
2-3-5-8	Sapote Lagoon	10/11/96	?	30.2	14.2	0.05
2-3-5-9	New River	10/12/96	?	66.5	31.8	0.70
2-3-6-2	New River	10/12/96	?	62.4	30.1	0.55
2-3-6-3	New River	10/12/96	?	58.6	28.2	0.45
2-3-6-4	New River	10/12/96	?	49.0	24.5	0.30
2-3-6-5	Stockpond, GBR	10/14/96	?	33.0	15.2	0.07
2-3-6-6	NRL	10/16/96	M	195.0	95.0	27.7
2-3-6-7	NRL	10/16/96	M	83.6	40.9	1.35
2-3-6-8	NRL	10/16/96	?	32.6	14.9	0.06
2-3-6-9	NRL	10/18/96	?	30.9	14.7	0.06
2-3-7-2	NRL	10/17/96	?	32.0	15.4	0.06
2-3-7-3	NRL	10/17/96	?	25.6	12.2	0.02
2-3-7-4	NRL	10/17/96	?	29.4	14.0	0.04
2-3-7-5	NRL	10/17/96	?	30.9	14.4	0.06
2-3-7-6	NRL	10/17/96	?	31.6	15.0	0.05

Appendix 2. C (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
2-3-7-7	NRL	10/18/96	M	259.5	127.5	65.0
2-3-7-8	NRL	10/20/96	M	107.8	53.4	3.1
2-3-7-9	NRL	10/20/96	?	32.9	15.6	0.06
2-3-8-2	NRL	10/20/96	?	29.6	14.1	0.06
2-3-8-3	NRL	10/20/96	?	31.7	14.9	0.06
2-3-8-4	NRL	10/20/96	?	29.8	14.1	0.05
2-3-8-5	NRL	10/20/96	?	32.2	14.9	0.06
2-3-8-6	NRL	10/21/96	M	148.9	72.0	10.4
2-3-8-7	NRL	10/21/96	?	31.9	14.9	0.05
2-3-8-8	NRL	10/21/96	?	32.0	15.0	0.06
2-3-8-9	NRL	10/22/96	?	37.2	14.5	0.05
2-3-9-2	NRL	10/22/96	?	32.2	15.1	0.07
2-3-9-3	Monkey River	11/09/96	F	166.5	79.5	17.2
2-3-9-4	Monkey River	11/10/96	M	37.9	24.0	0.03
2-3-9-5	Laguna Verde, GJ	11/19/96	F	194.0	90.0	12.1
2-3-9-6	Laguna Verde, GJ	11/19/96	?	32.5	15.3	0.07
2-3-9-7	Laguna Verde, GJ	11/19/96	?	29.6	13.7	0.05
2-3-9-8	Laguna Verde, GJ	11/19/96	?	39.2	18.6	0.14
2-3-9-9	Laguna Verde, GJ	11/19/96	?	37.0	17.1	0.11
2-4-2-2	Laguna Verde, GJ	11/19/96	M	35.1	16.6	0.09
2-4-2-3	Laguna Verde, GJ	11/19/96	M	39.1	18.5	0.14
2-4-2-4	Laguna Verde, GJ	11/19/96	M	62.9	30.9	0.50

Appendix 2. C (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
2-4-2-5[1]	GBL	09/06/96	?	38.1	18.2	0.08
2-4-2-5	New River	12/06/97	M	142.0	70.5	8.6
2-4-2-6	New River	12/06/97	?	39.0	18.7	0.12
2-4-2-7	New River	12/06/97	?	38.7	18.2	0.13
2-4-2-8	New River	12/06/97	?	36.2	17.5	0.10
2-4-2-9	New River	12/06/96	?	35.4	16.6	0.09
2-5-2-2	New River	12/06/97	?	34.5	16.7	0.08
2-5-2-3	GBL	04/26/97	M	144.5	75.0	9.2
2-5-2-4	GBL	04/26/97	?	34.3	16.5	?
2-5-2-5	GBL	04/26/97	?	37.6	28.0	?
2-5-2-6	GBL	04/26/97	?	50.0	24.0	0.35
2-5-2-7	GBL	06/16/97	M	117.0	66.5	?
2-5-2-8	GBL	06/16/97	F	127.3	63.2	?
2-5-2-9	GBL	06/16/97	?	37.3	17.3	?

[1] Recapture from a previous study (Platt, 1996).

Appendix 2.D. Morelet's crocodiles captured and marked with toe tags (1996 to 1997). GBL = Gold Button Lagoon; GBR = Gold Button Ranch; GJ = Gallon Jug; NRL = New River Lagoon.

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
100	Belize City	01/13/97	M	39.2	19.1	0.16
101	Placencia Lagoon	01/21/97	M	60.3	29.0	0.55
102	Monkey River	02/10/97	M	54.0	26.4	0.50
104	Monkey River	02/10/97	M	101.5	51.8	3.3
117	Bladen River Oxbow	04/18/97	M	45.2	22.4	0.20
118	Sapote Lagoon	08/28/97	?	23.4	11.2	0.04
128	Sapote Lagoon	08/28/97	?	24.0	11.2	0.04
129	Sapote Lagoon	08/28/97	?	24.9	11.7	0.04
130	Sapote Lagoon	08/28/97	?	25.0	11.8	0.05
132	Sapote Lagoon	08/28/97	?	24.1	11.0	0.04
133	Sapote Lagoon	08/28/97	?	24.5	11.4	0.05
135	Sapote Lagoon	08/28/97	?	24.5	11.4	0.05
141	Sapote Lagoon	08/28/97	?	23.5	11.1	0.04
142	Sapote Lagoon	08/28/97	?	23.9	11.5	0.04
143	Sapote Lagoon	08/28/97	?	23.5	11.0	0.04
147	Sapote Lagoon	08/28/97	?	25.2	11.7	0.05
148	Sapote Lagoon	08/28/97	?	24.2	11.3	0.04
149	Sapote Lagoon	08/28/97	?	24.6	11.5	0.05
158	Bladen River Oxbow	04/18/97	M	45.6	22.1	0.18

Appendix 2. D (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
162	Bladen River Oxbow	04/19/97	?	36.5	18.0	0.12
163	Sapote Lagoon	08/28/97	?	24.2	11.4	0.04
167	Barracouta Pond	05/10/96	M	85.2	41.8	1.7
169	Bladen River	05/23/97	?	37.7	18.2	0.10
175	Bladen River Oxbow	04/18/97	M	48.9	24.3	0.25
177	Sapote Lagoon	08/28/97	?	24.7	11.5	0.05
178	Sapote Lagoon	08/28/97	?	24.9	11.4	0.05
179	Sapote Lagoon	08/28/97	?	25.0	11.9	0.05
180	Sapote Lagoon	08/28/97	?	24.2	11.4	0.05
181	Sapote Lagoon	08/28/97	?	23.9	11.2	0.05
182	Sapote Lagoon	08/28/97	?	24.9	11.5	0.05
183	Sapote Lagoon	08/28/97	?	24.2	11.3	0.05
184	Sapote Lagoon	08/28/97	?	24.4	11.5	0.05
185	Sapote Lagoon	08/28/97	?	24.0	11.3	0.05
186	Sapote Lagoon	08/28/97	?	24.5	11.2	0.05
187	Sapote Lagoon	08/28/97	?	24.6	11.5	0.04
188	Sapote Lagoon	08/28/97	?	24.3	11.4	0.05
189	Sapote Lagoon	08/28/97	?	25.3	11.8	0.05
190	Sapote Lagoon	08/28/97	?	24.1	11.5	0.05
191	Sapote Lagoon	08/28/97	?	24.1	11.2	0.05
192	Sapote Lagoon	08/28/97	?	23.2	11.0	0.04
193	Sapote Lagoon	08/28/97	?	24.3	11.6	0.05

Appendix 2. D (continued).

Animal Number	Location	Date (Mo/Day/Yr)	Sex	Total Length (cm)	Snout-vent Length (cm)	Mass (kg)
194	Sapote Lagoon	08/28/97	?	23.7	10.9	0.04
195	Sapote Lagoon	08/28/97	?	24.2	11.3	0.04
196	Sapote Lagoon	08/28/97	?	24.9	11.6	0.05
197	Sapote Lagoon	08/28/97	?	23.8	10.9	0.04
198	Sapote Lagoon	08/28/97	?	25.0	11.6	0.05
199	Sapote Lagoon	08/28/97	?	24.5	11.6	0.05
503	Northern Lagoon	01/15/97	M	141.0	71.0	7.5
504	Jones Lagoon	01/16/97	M	157.0	77.0	14.4
505	Burdon Canal	01/16/97	M	171.5	85.0	15.0
506	Sibun River	01/16/97	F	108.0	54.6	3.8
507	Burdon Canal	01/16/97	M	75.3	36.7	1.2
508	Sibun River	01/16/97	M	106.1	58.3	4.2
549	Laguna Verde, GJ	08/26/97	F	98.1	47.8	?
557	Ditch, Western Hwy.	09/09/97	F	132.0	64.2	6.5
579	Belize City	01/27/97	F	150.0	74.8	13.1
613	Laguna Verde, GJ	08/26/97	F	151.0	76.0	?
621	Monkey River	04/15/97	M	179.5	92.5	20.0
649	Sartenja	07/14/97	M	192.0	96.0	24.0

Appendix 3. Summary of nesting habitat surveys in the coastal zone of Belize (July 1996 to October 1997). Sites are listed alphabetically by region (mainland, cays, and atolls). Coordinates of all beaches where signs of nesting activity were found are listed in Table 13. The following sites were visited and evaluated.

MAINLAND

Barracouta Pond

Ouboter (1992) reported finding a C. acutus nest on the "northern side" of Barracouta Pond during May 1991. However, a search of the shoreline on 10 May 1997 found no suitable habitat other than a small beach at the boat landing (18° 19' 07" N; 88° 17' 16" W). This beach is heavily vegetated, routinely used by fishermen, and only slightly elevated above the lagoon, and therefore considered marginal habitat. No evidence of nesting was found anywhere around the lagoon, and no C. acutus were observed during a spotlight survey (see Population Surveys).

Belize City: University College of Belize

An American crocodile nest was found on a spoilbank behind the UCB Campus on 29 June 1996. The nest contained a clutch of 29 rotten eggs. A female begin returning to the site in late March and early April 1997, excavated a hole, and two eggshells were found on 14 April 1997. The female was likely disturbed during egg laying and abandoned the site. This spoilbank is composed of dried organic muck and parallels a canal leading into the Caribbean.

Fabers Lagoon and Jones Lagoon

A reconnaissance of this area was conducted on 12 August 1996. A recently constructed spoilbank was found on the southern shoreline of Fabers Lagoon (17° 28.29' N; 88° 15.61' W). The spoilbank is composed of dried organic muck, and currently devoid of vegetation. No evidence of nesting activity was found, but because of the elevation (>1.0 m) and the lack of other suitable sites, this spoilbank represents potential nesting habitat.

Another spoilbank was found along a peripheral canal leading into Jones Lagoon (17° 27.13' N; 88° 15.51' W). This canal is surrounded by red mangrove swamp and leads directly into the Caribbean Sea, less than 100 m away. This spoilbank also represents potential nesting habitat, although no evidence of nesting activity was noted.

Monkey River

Extensive sandbars along this river are exposed by receding water levels during the dry season. American crocodiles are reported to nest on sandbars along rivers in Mexico (Alvarez del Toro, 1974), Honduras (Klien, 1977 as cited in Thorbjarnarson, 1989), and Panama (Breder, 1946). Searches were conducted along Monkey River in April and May 1997, but found no evidence of C. acutus. Three nests on sandbars were attributed to C. moreletii (Appendix 7). Beaches along the coast between Monkey River Town and Punta Negra were also searched, but no evidence of American crocodile nesting was found. This is one of the longest beaches in southern Belize (McField et al., 1996).

Northern Coastline

A search of approximately 45 km of coastline from Rocky Point (Sarteneja) south to 18° 02' 31" N; 88° 07' 53" W, was conducted on 5 October 1997. The coastline is dominated by red mangrove with little elevated habitat available. Two small beaches were found (18° 11' 34" N; 88° 05' 24" W and 18° 02' 31" N; 88° 07' 53" W). Both sites had been cleared for fishing camps, and neither appeared sufficiently elevated for C. acutus nesting.

Placencia Lagoon

A network of canals with high spoilbanks (up to 3.0 m) is located at Maya Beach (16° 36' 28" N; 88° 27' 21" W). These canals were excavated in the early 1970's (Mike Tupper, pers. comm.) as part of a planned resort development. Maya beach remains largely undeveloped and the canals have since revegetated. No evidence of nesting activity was found, but these spoilbanks are considered potential nesting habitat because of the similarity to nesting areas in south Florida, USA (Ogden, 1978; Gaby et al., 1985; Kushlan and Mazzotti, 1989a and b).

Sarteneja

An abandoned shrimp farm (18° 21' 40" N; 88° 08' 08" W) located near the Sarteneja airstrip was investigated on 3 October 1997. Construction was started in 1989, and the facility was abandoned shortly thereafter. A system of deep canals and levees remain and mangroves are beginning to revegetate the ponds. The levees are elevated up to 2 m above the surrounding swamp, composed of organic peat, parallel deep canals, and are sparsely vegetated. As such they appear to offer excellent C. acutus nesting habitat, but no evidence of nesting was found.

Shipstern Lagoon

A single beach (18° 19' 26" N; 88° 07' 04" W) was found in Shipstern Lagoon during a reconnaissance on 5 October 1997. This was the only elevated habitat in the lagoon. It is approximately 50 m long, composed of coarse sand and shell, and only slightly above normal lagoon level. No evidence of C. acutus nesting was found and the site is considered marginal nesting habitat.

Southern Lagoon

A recently (1996) excavated hole nest and eggshell fragments were found on 19 September 1996 on a beach ridge along the northeastern shore. On 27 May 1997, another hole nest containing 23 eggs was found. The beach ridge is composed of coarse sand about 60 cm above normal lagoon level. There is little undergrowth and the site is dominated by oak (Quercus sp.). A red mangrove swamp (water salinity = 4.0 ppt) behind the beach probably serves as nursery habitat for hatchlings. Another seemingly suitable site at Coconut Point (17° 15' 11' N; 88° 21' 17" W) was investigated, but no sign of nesting activity was found.

CAYS

Ambergris Cay

Fieldwork was conducted in the vicinity of San Pedro from 30 September to 5 October 1996. Two recently (1996) excavated hole nests were found on a spoilbank at the WASA Sewage treatment Facility in San Pedro. One hole contained a single eggshell and the other numerous eggshell fragments. The spoilbank is about 1.0 m high. consists of dried muck and sand, and borders a borrow pit and black mangrove swamp. Hatchlings and juveniles were found during a spotlight survey of the vicinity (Appendix 1). The site was revisited in April and May 1997, but no nesting activity was noted. Water salinity in the borrow pit ranged from 30.0 ppt to 34.0 ppt, but only 25.0 ppt in the black mangrove swamp. If undisturbed, this site will continue to provide nesting habitat.

Another nest site was found behind Journeys End Resort on 8 October 1997. The clutch of about 12 eggs was accidentally unearthed in May by resort staff and later reburied a short distance away. The clutch was found in a hole nest constructed on a high (ca. 1.0 m) man-made embankment composed of coarse sand on the edge of a mangrove swamp. The clutch apparently hatched successfully as four eggshells were found. Water salinity in October 1997 was 11.0 ppt. Interestingly the nest was constructed only 15 m from tourist condominiums which were occupied continuously during the nesting season. The resort manager is planning to pile additional sand at the site in hopes of expanding the area available for future nesting (Jim Scott, Journeys End Resort, pers. comm.).

An elevated beach ridge, bordered by extensive mangrove swamps extends along the eastern shore of northern Ambergris Cay. Much of this ridge appears suitable for nesting, but extensive landclearing and residential development is underway and little nesting habitat is likely to be available in the future.

Ambergris Cay - Bacalar Chico National Park

A nest site on a small island (<0.5 ha) in Santa Cruz Lagoon (Platt and Thorbjarnarson, 1996), was visited on 31 October 1996 and the coordinates determined. Water salinity was 13.0 ppt. No recent nesting activity was noted.

Two extensive beaches (18° 05' 59"N; 87° 54' 53" W and 18° 06' 57" N: 87° 54' 10" W) north of the lagoon were searched, but no recent nesting activity was found. Both beaches are about 1.0 m above sea level and appear to offer suitable nesting habitat. These sites should be monitored in the future by park personnel.

Cay Caulker

A single recently (1996) excavated hole nest was found on 9 July 1996 atop a spoilbank surrounding the municipal dump. The spoilbank is composed of sand and marl. and is about 2.0 m above the lagoon level. Water salinity was 25.0 ppt. An older excavation was found about 1.0 m away, and was probably a 1995 nest. On 23 April 1997 a second hole nest containing 30 eggs was found at the same site. Twenty-six of these eggs were non-viable. These were collected and frozen for later analysis. The dump is extremely polluted and contaminants may have been responsible.

The northern region of Cay Caulker has been proposed as a Nature Reserve (Zisman, 1996). This area was searched on 9 July 1996, and a small beach found near the northern tip of the island (17° 47.86' N; 88° 01.27' W). However, elevation is minimal and the substrate is waterlogged, and the site is not considered suitable for nesting. Other nesting habitat appears to be absent within the boundaries of the proposed reserve. Elsewhere on Cay Caulker American crocodile nests have been found in littoral forest bordering mangrove swamps (Ellen McRae, Sibawahn Foundation, pers. comm.). Most of this habitat has now been destroyed by residential and tourist developments.

Cocoplum Cay

A reconnaissance of 16 October 1997 found three beaches on this small cay. The most extensive beach (16° 32' 40" N; 88° 07' 11" W) is located at the southern tip of the island and appeared to be suitable nesting habitat. Another beach in the central part of the cay (16° 53' 15" N; 88° 07' 06" W) is subject to overwash. A series of sandbars and small islands at the northern tip of the cay (16° 53' 17" N; 88° 07' 01" W) are too low to provide nesting habitat. No evidence of nesting was found on this cay.

Columbus Cay

A reconnaissance on 16 October 1997 found no available nesting habitat. This large cay has several interior lagoons inaccessible to larger boats, and is surrounded by turtlegrass beds. Although the cay provides an abundance of foraging habitat, elevated sites for nesting are lacking.

Cross Cay

A reconnaissance on 16 October 1997 found only a single beach at the eastern tip of the island (16° 58' 42" N; 88° 03' 17" W). This beach is insufficiently elevated to serve as nesting habitat. Like nearby Columbus Cay, this large cay provides an abundance of foraging habitat.

Deer Cay

This cay is actually a cluster of small mangrove cays and shallow lagoons. A reconnaissance conducted on 30 October 1996 found two beaches on the eastern shore (18° 05' 59' N; 87° 56' 34" W and 18° 06' 27" N; 87° 56' 18" W). Both appeared to be sufficiently elevated to provide suitable nesting habitat, but a search of these sites found no evidence of nesting activity.

Fly Range

The Fly Range consists of three distantly spaced mangrove cays. A daylight reconnaissance was conducted on 16 October 1997, and a small beach found on one cay (16° 58' 57" N; 88° 05' 46" W). It is only slightly above sea level and not considered suitable nesting habitat.

Gulf of Honduras

A number of small cays are found in the Gulf of Honduras including the Mangrove and Frenchman's island groups, and Wild Cane Cay. Most are low lying cays with little terrestrial habitat. The few small beaches were composed of rock and coral, and do not provide suitable nesting habitat. The only elevated habitat on Wild Cane Cay was composed of water-logged soil and several mounds of rock. A small beach adjacent to a mangrove lagoon was found on Snake Cay, but no sign of nesting was noted.

Long Cay

Two nesting beaches were found on this cay. The sites are elevated beach ridges separated by a low swale. Both are dominated by cay littoral forest, although at one there is an abandoned fishing camp and much of the understory has been cleared. Two excavated hole nests were found (1996 nests) on 30 January 1997. One nest contained a single eggshell and 17 eggshells were found in the other. Recent tracks and scrapings were found during a visit to the cay on 23 April 1997, and a recently excavated hole nest containing two eggshells was found on 12 July 1997.

An extensive mangrove lagoon is located immediately adjacent to these beaches and provides nursery habitat for hatchlings and young juveniles. Nine juveniles were counted and a gravid female captured during a spotlight survey on 19 February 1997. Water salinity in the lagoon ranged from 12.0 ppt on 30 January 1997, 22.0 ppt on 19 February 1997, and 18.0 ppt on 12 July 1997. Wet season rains probably further depress water salinities.

Maps Cay

This site was first located during a spotlight survey in July 1994 when an excavated nest and five eggshells were found (Platt and Thorbjarnarson, 1996). No recent activity was noted during a visit in August 1996. However, a nest with 22 eggs was found in April 1997. The site consists of a low spoil deposit (50 m X 20 m) along a barge channel in the interior of the cay. The substrate is a mixture of organic matter, sand, and shell.

Hicks Cay

A small beach (ca. 30 m long X 4 m wide) composed of coarse sand was found at the northwestern tip of the cay (17° 43.08' N; 88° 05.78' W). This site is below normal high tide and is not considered suitable nesting habitat. Perkins (1983) reported American crocodile nesting on Hicks Cay, but suitable habitat is lacking.

Middle Long Cay

A reconnaissance was conducted on 4 March 1997. Nesting habitat appears lacking on this cay. An extensive beach on the western shore of the cay (17° 15' 45" N; 88° 05' 18" W) is composed of waterlogged sand and is unsuitable for nesting.

Sandfly Cay

This cay is actually a chain of low-lying mangrove cays. A reconnaissance conducted on 16 October 1997, found the only significant terrestrial habitat was a promontory located at the eastern tip of one island (16° 58' 03" N; 88° 05' 13" W). This mound is approximately 20 m x 30 m, 2.5 m above sea level, and composed of coral and crushed shell. It is likely one of the highest points on any offshore island in Belize. The origin of the mound is unknown, but probably natural. Although the site appears to be suitable habitat no sign of nesting was noted.. A single excavation found may be an old nest, as the hole dimensions and shape are consistent with observations of excavated C. acutus nests, but this remains uncertain. The hole is more likely a collapsed Ctenosaura burrow.

Tobacco Range

C. acutus nesting was reported in this chain of cays by Perkins (1983). but a reconnaissance on 16 October 1997 found little available nesting habitat. An elevated substrate adequate for nesting was found on the eastern shore (16° 53' 59" N: 88° 04' 45" W), and a shallow lagoon behind the beach offers excellent nursery habitat. However, the beach is currently occupied by fishermen and several additional houses are under construction. No evidence of crocodile nesting was found. The only other beach in the Tobacco Range (16° 52' 29" N; 88° 05' 14" W) is insufficiently elevated for nesting.

Water Cay

A reconnaissance of this cay on 4 and 5 March 1997 found three beaches, but no evidence of C. acutus nesting activity. The first beach (17° 22' 22" N; 88° 04' 08" W) was located on the leeward shore and composed of waterlogged soil unsuitable for nesting. The other two beaches (17° 23' 05" N; 88° 03' 42" W and 17° 22' 59" N; 88° 03' 37" W) were on the windward shore. The latter had an elevation approximately 1.0 m above sea level, and was suitable nesting habitat, although no evidence of nesting activity was noted.

ATOLLS

Lighthouse Atoll

Visits were made to Half Moon and Long Cay in the southern part of the atoll on 22 to 24 August 1996. Suitable beaches exist on Half Moon Cay, but C. acutus apparently do not occur on this small island (see Population Survey). Low-relief beaches occur on the western shoreline of Long Cay, but no evidence of nesting was found. These beaches are marginal nesting habitat because of the poorly developed topography.

A single excavated hole nest was found beside a small, man-made pond (water salinity = 0.0 ppt) on Northern Cay on 11 July 1997. Two eggshells were found in the hole and a hatchling was observed in the water. A trail led from the pond to an interior mangrove lagoon that probably serves as nursery habitat. The pond may also be an important source of freshwater for hatchlings.

Turneffe Atoll

Blackbird Cay (western shore)

This site is a slightly elevated ridge of coarse sand approximately 30 m long, covered in palmetto and cay littoral forest. A mound and hole nest with eggshells were found here in May 1994. Both nests had been opened by raccoons (Procyon lotor) and the eggs destroyed. Another hole nest and three eggshells were found in June 1995 (Platt and Thorbjarnarson, 1996), and a single hole nest and five eggshells were found in August 1996. A mound nest (ca. 200 cm and 160 cm wide X 30 cm high) containing two clutches of 19 and 32 eggs was found on 25 June 1997. The two clutches were readily separated based on obvious differences in egg size and extent of banding. This is the only site where mound nests have been found in Belize.

Blackbird Cay (eastern shore)

A well-developed beach ridge extends along the eastern shore of Blackbird Cay. Portions of this ridge have been cleared, and an early successional vegetative community is maintained through occasional fires set by fishermen and coconut harvesters. Blackbird Resort is located at the southern end of this ridge.

Three disjunct nesting areas were found on this ridge. A hole nest containing 12 eggs was found in an ecotone between littoral forest and the resort grounds on 23 April 1997. On 8 February 1997, a hole nest containing one eggshell from the 1996 nesting season was found at a second site further north. Two clutches of 20 and 15 eggs were found in a single hole at this site on 22 April 1997. The smaller clutch had been excavated and then partially reburied when the larger clutch was deposited, and 10 of 15 eggs were on the surface. The eggs in the larger clutch were unbanded and covered in mucous, indicating oviposition had occurred within the past 12 hours, while the smaller clutch was about five days old. The third nesting area is located at the northern end of the beach where four excavated hole nests from the 1996 nesting season were found on 8 February 1997. Numerous tracks and drag marks were found here in March and April 1997, but no active nests were located. A search in July 1997 failed to find excavated nests that may have been previously overlooked, and it does not appear this site was used in 1997. Nonetheless this beach ridge should be considered extremely important nesting habitat.

Another beach ridge (17° 18' 18N; 87° 48' 12" W to 17° 18' 21" N; 87° 48' 21" W) along Soldier Bight was searched on 4 February 1997. This ridge is adjacent to a black mangrove lagoon, and a well-worn trail leads from the lagoon, over the ridge, and into Soldier Bight. This ridge may have once been an important crocodile nesting site, but a tourist resort was constructed here in 1996 and it is no longer available, although crocodiles are still present in the lagoon.

Deadmans Cay

A nest was found on a peninsula along the eastern shoreline of this cay in 1995 (Platt and Thorbjarnarson, 1996). The site was located on a beach ridge adjacent to a deep water cove and red mangrove swamp. At that time, most of the peninsula had been cleared and a resort was under construction. The nest was excavated by the property owner, who reported finding 13 eggs, but destroyed most of them. Four eggs were recovered and the average measurements were: length = 74.3 mm (SE = 2.4; n = 4), width = 45.3 mm (SE = 0.9; n = 4), mass = 87.1 g (SE = 8.1; n = 3). These values are reported here, but were not used in the following calculations of clutch attributes. Likewise, in 1994 the property owner also reported finding a clutch at this site. The resort has since been abandoned and vegetation is becoming reestablished. Several visits in April, May, and June 1997, found no evidence of nesting. This appears to be the only suitable nesting habitat in the southern region of the atoll (Platt and Thorbjarnarson, 1996), and it is likely that females may nest here in the future if the site undeveloped.

Northern Cay

The most extensive nesting beach located in Belize was found on the eastern shore of Northern Cay. This site consists of an elevated beach ridge approximately 250 m long, composed of well drained coarse sand, and dominated by low thicket (Minty et al., 1995). A shallow black mangrove lagoon, which serves as nursery habitat for crocodile hatchlings is located adjacent to the beach. Water salinity in this lagoon varied greatly, from a low of 9.0 ppt in November 1996 to a high of 47.0 ppt on 25 June 1997. Water salinity is dependent on recent rainfall, and in general decreased during the wet season and increased during the dry season. A search in July 1994 found eight recently excavated hole nests and numerous eggshells. No nests were located during in June 1995, but this visit was made just prior to hatching and rainfall had erased tracks and scrapes normally used to detect nests. A visit in July 1995 would almost certainly have found excavated nests.

Seven excavated hole nests, each containing 7 to 21 eggshells were found in August 1996. Numerous hatchlings were observed in the adjacent lagoon and 10 were captured (Appendix 2). Five nests were found from 4 to 23 April 1997, and clutch size ranged from 12 to 31. Additional clutches were either deposited after visits or overlooked, for a search on 22 August 1997 revealed five additional excavated nests. Numerous hatchlings were found in the adjacent lagoon in July 1997, and 27 were captured and tagged (Appendix 2).

Another beach at Rendezvous Point (17° 32' 45" N; 87° 48' 45" W) was visited on 12 July 1997. A fishing camp is constructed on the beach, but otherwise it appears to be suitable nesting habitat. Anecdotal reports suggest nesting may have occurred here in the past (Platt and Thorbjarnarson, 1996).

Appendix 4. Clutch characteristics of 14 American crocodile nests found in Belize (1996 to 1997). Where appropriate, values are presented as mean ± 1SD (n). Note: n does not always equal clutch size because of broken or leaking eggs. When damaged eggs were present, clutch mass was determined by the number of damaged eggs X mean egg mass for that clutch.

Nest	Egg Length (mm)	Egg Width (mm)	Egg Mass (g)	Non-viable Eggs (%)	Clutch Mass (g)
1	70.6 ± 0.6 (16)	48.1 ± 0.3 (16)	NA[1]	100.0[1]	NA[1]
2	92.1 ± 0.4 (26)	44.9 ± 0.1 (26)	91.3 ± 0.6± (25)	0.0	2373.0[2]
3	74.7 ± 0.5 (22)	44.2 ± 0.1 (22)	92.8 ± 1.1 (22)	NA[2]	2040.5[3]
4	69.9 ± 0.3 (25)	45.9 ± 0.1 (25)	90.6 ± 0.5 (25)	NA[2]	2357.5
5	67.3 ± 0.4 (21)	42.6 ± 0.1 (21)	76.9 ± 0.7 (21)	14.2	1615.5
6	64.5 ± 0.2 (31)	42.6 ± 0.1 (31)	72.4 ± 0.5 (31)	0.0	2257.0
7	68.4 ± 0.7 (20)	42.6 ± 0.1 (20)	77.6 ± 0.9 (20)	NA[2]	1552.0
8	73.3 ± 0.7 (12)	44.6 ± 0.2 (12)	92.1 ± 2.1 (6)	0.0[3]	1105.5
9	72.9 ± 0.7 (11)	42.2 ± 0.3 (11)	81.5 ± 1.9 (11)	16.6	978.0
10	67.6 ± 0.5 (20)	44.3 ± 0.2 (20)	82.1 ± 0.7 (20)	0.0	1642.0
11	73.0 ± 0.3 (29)	45.0 ± 0.0 (29)	90.8 ± 0.5 (29)	86.6	2634.0
12	76.4 ± 0.6 (21)	43.7 ± 0.1 (21)	93.1 ± 1.0 (20)	8.6	2141.0
13	65.0 ± 0.5 (19)	41.7 ± 0.1 (19)	71.0 ± 0.9 19)	36.8	1350.0
14	73.1 ± 0.4 (31)	47.0 ± 0.1 (31)	97.7 ± 0.9 (31)	9.3	3126.0

[1] All eggs in clutch were rotten.

[2] Viability could not be determined as eggs were less than 24 hours old.

[3] All but five eggs were excavated from nest by another female. Viability is based on these eggs.

Appendix 6. American and Morelet's crocodile skulls examined in Belize (1996 to 1997). Total body length (TL) was estimated from head length (HL) using the equations TL = 6.63HL - 4.89 for American crocodile, and TL = 7.24HL - 6.3 for Morelet's crocodile (Platt, 1996).

Species	Location	Origin	Skull Width (cm)	Skull Length (cm)	Estimated Total Length (cm)
C. acutus	Manatee Lodge, Gales Point	Southern Lagoon[1]	29.3	38.5	250.3
C. moreletii	To be deposited CUSC	Waree Bight Cenote	9.3	17.5	120.3
C. moreletii	Sarteneja Village	Chetumal Bay[1]	15.1	29.2	205.0
C. moreletii	Belize Zoo	Mile 3, Western Hwy.[1]	13.2	24.6	171.8
C. moreletii	Belize Zoo	Unknown	23.7	40.7	288.3
C. moreletii	Manatee Lodge, Gales Point	Southern Lagoon[1]	13.0	25.6	179.0
C. moreletii	Manatee Lodge, Gales Point	Southern Lagoon[1]	26.6	49.5	352.0[2]

[1] Crocodiles which drowned in fishing nets.

[2] This individual is believed to be the largest Morelet's crocodile yet collected in Belize (Platt, 1996).

Appendix 7. Reproductive biology of Morelet's crocodile in southern Belize.

While the objectives of this project were to determine the status, and gather life history data on the American crocodile, a considerable body of information was also gathered on the reproductive biology of Morelet's crocodile in southern Belize. These findings complement a previous study (Platt, 1996) of Morelet's crocodile in inland freshwater habitats of northern Belize. The most significant findings are summarized below.

Eight recent (1997) C. moreletii nest mounds were found in southern Belize during April and May 1997. In addition, two older nest mounds were found that were probably constructed in 1996. The location and a description of each is provided in Table 32. Five of these mounds contained eggs, one had been opened by predators and the eggs destroyed, and two were empty. The two empty nests appeared to have been recently constructed, but repeated visits found no eggs. Both were located at sites frequented by tourists and it is suspected this disturbance may have caused abandonment by females. Six nests were mounds of sand constructed along rivers and creeks, and several were quite large. One nest on the Swasey River measured approximately 300 cm wide by 100 cm high (Figure 19). Numerous green iguana (Iguana iguana) nests were found on the same sandbars as crocodile nests. This is the first verified report of C. moreletii constructing nest mounds of sand. Earlier reports (Brazaitis, 1973) of C. moreletii nesting on sandbars in Honduras, are from outside of the known range of the species. The remaining two nests were typical nest mounds of soil, woody debris, and vegetation found along oxbow lakes adjacent to main river channel.

The estimated date of oviposition for five nests ranged from 9 April to 1 May, with a mean date of 19 April ± 10.2 days, coinciding with the peak of the dry season. Given a mean incubation period of 75 days (Platt, 1996), most clutches would hatch between 23 June and 15 July, at the onset of the wet season. The nesting season in southern Belize is in marked contrast to northern Belize where almost all nesting activity occurs from late June to early July (mean date of oviposition = 1 July ± 11 days; Platt, 1996).

The reasons for this difference remain speculative. Early nesting may be a local adaptation to heavy precipitation and greatly fluctuating water levels which characterize the wet season in southern Belize. If nesting followed the pattern found in more northern populations, nests would be constructed at a time of rising water levels, and probably suffer an increased risk of flooding. By nesting in the dry season, there is little danger of flooding, and hatchlings emerge during a period of rising water levels when survival may be enhanced. However, dry season nesting is extremely rare among mound nesting species of crocodilians. The mound nest is believed to be an adaptive response to wet season nesting by providing an elevated substrate to raise the clutch above potential water level fluctuations, (Campbell, 1972). Interestingly, there is an almost perfect concordance between the nesting season of C. acutus and southern populations of C. moreletii in Belize, which could facilitate gene flow between the two species (see Hybridization).

Five clutches of C. moreletii eggs were examined in southern Belize (Table 33), and clutch attributes are presented in Table 34. Clutch size ranged from 15 to 42, and averaged 31.4 ± 11.7 eggs. The mean clutch size is somewhat larger than found among populations in northern Belize (Table 34). However, the range is comparable to values reported from northern Belize and Mexico (Alvarez del Toro, 1974; Casas-Andrew and Rogel-Bahena, 1986).

Eggs found in southern Belize were considerably larger than those found in northern Belize (Table 34), and are among the largest reported for the species. Egg mass in this study ranged from 59.0 to 141.0 grams. Three nests had a mean egg mass of over 100 grams (108.3, 109.7, and 130.4 grams; Table 33), the largest yet reported for C. moreletii. Perez-Higareda (1980) found C. moreletii eggs up to 100 mm long, but unfortunately failed to report egg mass. As egg mass is a function of both egg length and egg width (Platt, 1996), it is possible these eggs were larger than found in the present study.

The mean egg width of each clutch was used to predict the SVL of the nesting female (Table 34) using the equation SVL = 5.5 EW - 137.5 (Platt, 1996). The estimated SVL of nesting females in southern Belize ranged from 91.3 cm (TL = 175.4 cm) to 134.2 cm (TL = 256.1 cm). These values are considerably larger than reported for northern Belize where estimated female SVL ranged from 77.1 cm (TL = 150 cm) to 112.0 cm (TL = 213 cm). The larger size of nesting females in southern Belize may account for the larger eggs, as female SVL is positively correlated with egg length, width, and mass (Platt, 1996).

Table 32. Location and description of Morelet's crocodile nests found in southern Belize during April and May 1997.

Nest #	Location	Latitude (N)	Longitude (W)	Description
1	Monkey River	16° 23' 21"	88° 32' 47"	Mound of soil and debris along oxbow.
2	Bladen River	16° 33' 31"	88° 42' 17"	Same as above
3	Paynes River	GPS unavailable		Sand mound (140 cm X 90 cm high) on creek bank.
4	Swasey River	16° 25' 42"	88° 32' 37"	Sand mound (120 cm wide X 0 cm high) on sandbar.
5	Swasey River	16° 25' 08"	88° 32' 48"	Sand mound (300 cm wide X 100 cm high) on sandbar.
6	Sennis River	16° 27' 11"	88° 28' 45"	Sand mound (100 cm wide X 30 cm high). Opened by predators. Six eggshells at site.
7	Bladen River	16° 24' 12"	88° 33' 38"	Sand mound, but contained no eggs.
8	Monkey River	16° 22' 53"	88° 30' 43"	Sand mound, but contained no eggs.
9	Sennis River	16° 27' 04"	88° 28' 48"	Old (1996?) mound nest of sand and pine needles.
10	Temash River	15° 58' 06"	89° 02' 59"	Old (1996?) mound nest of soil and leaves.

Table 33. Clutch characteristics of five Morelet's crocodile nests found in southern Belize during April and May 1997. Where appropriate, values presented as ± 1SE.

Nest	Date (Mo/Day/Yr)	Clutch Size	Egg Length (mm)	Egg Width (mm)	Egg Mass (g)
1	04/16/97	38	81.2 ± 0.4	46.5 ± 0.1	108.3 ± 0.7
2	04/19/97	15	69.1 ± 0.5	41.6 ± 0.1	73.7 ± 0.9
3	04/19/97	42	75.7 ± 0.4	49.4 ± 0.0	109.7 ± 0.8
4	05/15/97	23	69.0 ± 0.6	38.3 ± 0.1	65.3 ± 0.7
5	05/15/97	38	86.4 ± 0.3	49.1 ± 0.1	130.4 ± 0.5

Table 34. A comparison of clutch attributes from Morelet's crocodile nests found in southern and northern Belize. Data from northern Belize are from Platt (1996). Values presented as ± 1 SD (n).

Attribute	Southern Belize	Northern Belize
Clutch Size	31.4 ± 11.7 (5)	25.0 ± 7.6 (73)
Egg Length (mm)	78.0 ± 6.9 (157)	68.8 ± 4.1 (1722)
Egg Width (mm)	46.2 ± 4.0 (157)	41.1 ± 1.8 (1722)
Egg Mass (g)	104.3 ± 22.7 (156)	69.0 ± 9.4 (1702)
Clutch Mass (kg)	3.2 ± 1.7 (5)	1.7 ± 6.2 (68)
Female SVL (cm)*	109.8 ± 26.7 (5)	86.9 ± 9.9 (72)

*Estimated by the equation: SVL = 5.5 (mean egg width) - 137.5. TL is approximately 2 x SVL. From Platt (1996).