

American crocodile, *Crocodylus acutus*, population census in Ambergris Caye, Belize, Central America

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A census of the population of American crocodiles (*Crocodylus acutus*) in the southern region of Ambergris Caye, Belize, was conducted from October 2010 until December 2011. Combining evening, spotlight, eyeshine surveys and nest counts, the abundance and discontinuous distribution of *C. acutus* was determined within specific boundaries of the island. This baseline census of abundance, via sample counts, is a relative index of the true density due to sources of experimental bias (Bayliss, 1987). A mean total of 56.7 crocodiles were sighted on 59.56 km of survey route (0.95 crocodiles/km) during evening spotlight surveys. Encounter rates were highest at the local sewage treatment ponds and Laguna Mateo. Of the 5 nests discovered, 3 were located at the sewage ponds and two of those 3 had been raided by raccoons, yielding an extremely low number of hatchlings for 2011. The human alteration of mangrove habitat in the name of development occurring in the area of the highest population of American crocodiles in southern Ambergris Caye, is pressuring this threatened species to reside and nest in the local sewage treatment ponds. Additionally, the area with the second highest population of *C. acutus*, Laguna Mateo, is also currently being invaded by development. Elsewhere on the island American crocodile's were predominately found around human residences, attracted by indirect feeding through the improper disposal of food waste. The many issues effecting the American crocodile's population in Ambergris Caye need to be seriously addressed in a timely fashion to prevent the demise of this keystone species and Belize's mangrove ecosystems.

Crocodylians in Belize are comprised of two species of the genus *Crocodylus*, the freshwater Morelet's crocodile (*Crocodylus moreletii*) and the saltwater tolerant American crocodile (*Crocodylus acutus*) (Groombridge, 1987). While both species are currently protected by The Belize Wildlife Protect Act (Chapter 220), this study focuses solely on *C. acutus*. In 1998, Ross declared that the habitats of Belize are considered one of the last strongholds for American crocodiles; however, with surveys yielding the number of non-hatchling American crocodiles in Belize to be less than 1000 (Platt & Thorbjarnarson, 2000a; Platt et al., 2004; Rainwater & Platt, 2009), *C. acutus* in Belize may be literally "losing their ground."

Recognized by The Belize Department of Fisheries as threatened (McField et al., 1996; Platt & Thorbjarnarson, 2000a; Rainwater & Platt, 2009), the American crocodile is the primary apex predator, apart from man, inhabiting Ambergris Caye, Belize, today. Effecting the coral sand island's eco-structure abundantly greater than their own numbers, American crocodiles play a vital role in keeping Ambergris Caye's plant and animal life in a healthy balance. The main factors effecting today's crocodile populations are the continuation of illegal hunting and the fragmentation and loss of habitat (Platt & Thorbjarnarson, 2000a; Thorbjarnarson et al., 2006; Rainwater & Platt, 2009). These factors, combined with the unregulated dumping of noxious garbage resulting in environmental pollution, may be leading to a continued decline of this keystone species that could eventual cause the ecosystem of Belize's premier tourist destination, Ambergris Caye, to entirely collapse.

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Listed by the U.S. Fish & Wildlife Service (USFWS) Threatened and Endangered Species System (TESS) as endangered throughout their entire range, except in Florida where they are listed as threatened, and protected pursuant to the Endangered Species Act of 1973, the American crocodile is also deemed vulnerable by the International Union for the Conservation of Nature and Natural Resources (IUCN), and is to this day cataloged on Appendix I of the Convention on Trade in Endangered Species of Flora and Fauna (CITES) (Thorbjarnarson, 1992; Ross, 1998; Platt, Rainwater, & Nichols, 2004; Rainwater & Platt, 2009). Additionally, American crocodiles are listed as a critical species in terms of need for conservation and as a high priority crocodylian requiring wild population recovery, management, and nest site protection in Belize (Ross, 1998).

American Crocodile populations in Belize are decreasing due to the destruction of major nesting grounds, low hatchling survival rates, needless killings and insufficient means to adequately enforce protection laws (Platt & Thorbjarnarson, 2000a). Developmental destruction of Belize's most significant nesting beaches, Northern Caye, Turneffe Atoll, remains the greatest threat to the continued viability of the Belize crocodile population; and since potential nesting habitat appears limited, full protection is warranted (Platt et al., 2004). While Turneffe Atoll is documented as having the highest concentration of American crocodiles with the most active nesting grounds (Platt & Thorbjarnarson, 2000a, Platt et al., 2004), in 2009 Rainwater & Platt found lower crocodile encounter rates and reduced nesting activity compared to previous years largely due to humans altering nesting habitats for development. In sight of this increase in competing forms of land use, the preservation of American crocodiles will ultimately depend on maintaining suitable wetland habitats, and identifying and protecting alternative nesting sites on the offshore cayes of Belize.

Study Area

Ambergris Caye is a flat, coral sand island, stretching twenty-five miles south from the southern most tip of the Yucatan Peninsula with widths ranging from a few hundred feet to over four miles. Formed during the Pleistocene, some 135,000 years ago, Ambergris Caye is a karst limestone ridge surrounded by shallow water, calcareous sediments that were colonized by mangroves (Grimshaw, T., & Paz, M., 2004). Protected by the Mesoamerican Barrier Reef System on the east, the island's west coast is composed primarily of the ever decreasing Red Mangrove (*Rhizophora mangle*) and fresh, brackish and salt water lagoons. These critical wetland habitats are the home of the highly threatened American crocodiles and an important habitat to a wide variety of migratory birds.

Based on the American Crocodile Education Sanctuary's (ACES) annual crocodile rescues, confiscations, and relocations over the past four years, croc-human conflicts on Ambergris Caye are steadily increasing due to indiscriminate and unregulated development; low hatchling survival rates due to predation and low nest counts; deliberate illegal crocodile feeding to attract tourists; indirect crocodile feeding via improper discard of fish scraps and inadequate waste disposal; an increase in poaching for meat, trophy skulls, and teeth for souvenirs; and finally, needless crocodile killings out of plain fear (Chenot-Rose, C., et al., 2011). Furthermore, several large, wild *C. acutus* on the island have been documented lacking teeth and generally in poor health. While this may be due to a combination of elements, ill apex predators are an indicator of an environmental disturbance. The first step to addressing all the above factors, and the objective of this study, is to provide a preliminary, baseline census of the American crocodile population and identify critical nesting habitats in the southern region of Ambergris Caye, Belize.



Fig. 1. Map of Ambergris Caye, Belize, and enlarged survey area south of Laguna de Cayo Frances indicating approximate American crocodile, *Crocodylus acutus*, population census locations from October 2010 through December 2011. 1. Costa Maya - Mexico Rocks; 2. Laguna Mateo - Grand Belize Estates; 3. Buena Vista Coastal Lagoons; 4. Northern Laguna San Pedro; 5. San Mateo; 6. Boca Del Rio - San Juan - San Pedro Fishing Co-op; 7. San Pedrita - San Pablo - DFC; 8. Ambergris Lake; 9. WASA Lagoon - Sugar Caye Development; 10. San Pedro Sewage Plant; 11. Port Authority - Southern Laguna San Pedro; 12. Brahma Blue - Caye Winds; 13. Laguna de Boca Ciega; 14. Marco Gonzalez - Boca Chica; 15. Southwestern shoreline of San Pedro. *Maps are not to any specific scale.*



Methodology

Commencing October 2010, this study continued through to December 2011. Crocodile population census data was collected via random, nocturnal spotlight surveys, and nest counts (Bayliss, 1987) from either a 3.6 meter aluminum skiff powered by a 15hp outboard motor; a Bobcat Club Cart, gas operated, golf-cart; or foot depending on accessibility of the areas. The average speed by both skiff and cart was 2.5 km/hr. Censused areas included mangrove shorelines, canals, brackish water and freshwater lagoons, waterways, and immediate beachfront, shoreline areas in Ambergris Caye south of Laguna de Cayo Frances to the southern most tip of the island, Boca Chica.

Nocturnal expeditions began between 20 and 30 minutes after sunset, the point at which the sun was completely below the horizon, and crocodiles were spotted from one of three flashlights: a

22,000 candlepower maglite; a 28 Lumens, halogen, underwater, handheld flashlight; or a Q-beam 3,000,000 candlepower, handheld spotlight. Each spotlight eyeshine was confirmed by two of three observers before it was documented. Surveys were only conducted during times of optimal visibility, sustaining from rainy and/or windy nights. A handheld Global Positioning System (GPS) Garmin GPSmap 60CSx was used to document the startpoint and endpoint of all census areas, and the distance transversed due to the intricacies of the mangrove shorelines. A total of 15 locations (Fig.1) were randomly surveyed several times throughout the study period. Due to the duration of this study, sighted crocodiles were classified by their total length (TL) with hatchlings/yearlings (TL < 60cm), juveniles (TL = 60-90cm), sub-adults (TL = 90-180cm), and adults (TL >180cm). Total length estimates were gauged by the same observer (Vincent Rose) each time, whose level of accuracy was documented to be within 5-8 cm consistently based on comparing estimated TL to the measured TL of captured crocodiles. If the TL could not be determined, the crocodile sighting was recorded as eyeshine only (EO). The mean of the number of sighted crocodiles in each area was used to determine crocodile encounter rates. Crocodile encounter rates were calculated as the number of crocodiles observed per kilometer of survey route (Bayliss, 1987, Platt & Thorbjarnarson, 2000a, Platt et al., 2004).

When plausible, encountered crocodiles were captured by protocol and tagged via the scute-clipping method, or microchipped with a Pro-ID chip injected between the caudal scales on the animal's left side, 4th row posterior of the cloaca. Data collected on captured crocodiles is predominately survey statistics and includes: date and Global Positioning System (GPS) location; cloacal sexing when feasible without inducing stress; health determined by eye clarity, absence/presence of skin discolorations/lesions, and absence/presence/brittleness of teeth and claws; behavioral tendencies especially in regard to aggression; and the universal, crocodilian, scientific measurements TL, snout length (SL), head length (HL), snout-vent length anterior (SVLa), and snout-vent length posterior (SVLp), in centimeters (cm) via a flexible tape measure. In the future, this data will be utilized in a mark-recapture study for correlations among various parameters, such as sex, habitat and size to define population density distributions in Ambergris Caye.

Crocodile nest sites were identified as early as April 2, 2011, through June 2011. Hatching season for the American crocodile in Turneffe Atoll, Belize, is from late June to mid-July following the onset of the annual wet season (Platt & Thorbjarnarson, 2000b, Platt et al., 2004). Nest sites were verified by large disturbed areas on sandy shores of waterways and lagoons with tracks such as tail drags and foot prints, excavated holes with eggs or eggshells, and/or the nearby presence of a crocodile. All accessible potential areas within the spotlight census area were surveyed on foot for nest sites.

Results

Spotlight Surveys

During investigative, random, spotlight surveys from October 2010 to December 2011, a total 15 locations were randomly surveyed up to nine times. The means of the number of crocodiles encountered were used as a representative sample of the discontinuous crocodile population in those areas. A mean total of 56.7 American crocodiles were observed over 59.56 kilometer (km) of survey routes (0.95 crocodiles/km) (Table 1) through coastal, mangrove, and lagoon habitats in Ambergris Caye, Belize, south of Laguna de Cayo Frances to the southern most tip of the island, Boca Chica (Fig. 1). Of these, 10.21 (18.01%) were classified as 'eye-shine only' (EO), and the remaining 46.49 (81.99%) were either sizable by estimate or captured and measured: 14.4 (30.97%) hatchlings/yearlings, 9.22 (19.83%) juveniles, 7.42 (15.96%) sub-adults, and 15.25 (32.80%) adults (Table 2). Out of 19 Crocodiles tagged during spotlight surveys, 8 (42.10%) were males and 8

(42.10%) were females and 3 (15.79%) were undetermined. The resulting sex ration is 1:1; however, this ratio lacks statistical significance due to the small sample size.

Table 1. American crocodile density indices based on the mean number of crocodiles encountered during spotlight surveys in 15 different areas of Ambergris Caye surveyed randomly from October 2010 to December 2011.

Location	Number of crocodiles	Kilometers surveyed	Encounter rate (crocodiles/km)
Costa Maya - Mexico Rocks	4.00	4.92	0.81
Laguna Mateo - Grand Belize Estates	7.77	7.40	1.05
Buena Vista Coastal Lagoons	1.33	6.40	0.21
Northern Laguna San Pedro	1.00	3.50	0.28
San Mateo	2.00	0.60	3.33
Boca Del Rio - San Juan - San Pedro Fish Co-op	2.75	1.50	1.8
San Pedrita - San Pablo - DFC	3.00	2.47	1.21
Ambergris Lake	4.00	0.60	6.66
WASA Lagoon - Sugar Caye Development	3.29	3.75	0.87
San Pedro Sewage Plant	19.67	2.30	8.55
Port Authority - Southern Laguna San Pedro	2.89	5.70	0.51
Brahma Blue - Caye Winds	0.00	3.29	0.00
Laguna de Boca Ciega	1.00	4.14	0.24
Marco Gonzalez - Boca Chica	4.00	4.69	0.85
Southwestern shoreline of San Pedro	0.00	8.30	0.00

Nesting habitat

Five nests at 3 locations were verified in 2011. All sites were hole nests. Nests ranged between 247-365 cm from the water's edge. The highest percentage of nests (60%) were located at the local sewage treatment ponds in loose sandy soil, two of which had been raided by raccoons. The remaining two locations were documented as to having a nest the previous year, and were hard packed sand. Nest site reuse is common among *C. acutus*, especially where suitable habitat is scarce (Platt & Thorbjarnarson, 2000a), and, locations lacking suitable nursery habitat with access to fresh or brackish water (<10 ppt), typically results in decreased growth and survival of hatchlings.

Table 2. American crocodile size class means compared by survey area

Location	Hatchlings Yearlings	Juveniles	Subadults	Adults	EO
Costa Maya - Mexico Rocks	3.00	0.00	0.00	1.00	0.00
Laguna Mateo - Grand Belize Estates	1.11	0.55	1.00	1.11	3.88
Buena Vista Coastal Lagoons	0.00	0.00	0.00	1.33	0.00

Location	Hatchlings Yearlings	Juveniles	Subadults	Adults	EO
Northern Laguna San Pedro	0.00	0.00	1.00	0.00	0.00
San Mateo	0.00	1.00	1.00	0.00	0.00
Boca Del Rio - San Juan - San Pedro Fish Co-op	0.00	0.25	1.12	0.87	0.63
San Pedrita - San Pablo - DFC	1.00	0.20	0.67	0.80	0.20
Ambergris Lake	3.00	0.00	0.00	1.00	0.00
WASA Lagoon - Sugar Caye Development	0.29	0.00	0.29	2.14	0.50
San Pedro Sewage Plant	4.67	6.00	0.67	4.67	3.67
Port Authority - Southern Laguna San Pedro	0.33	0.22	0.67	0.33	1.33
Brahma Blue - Caye Winds	0.00	0.00	0.00	0.000	0.00
Laguna de Boca Ciega	1.00	0.00	0.00	0.00	0.00
Marco Gonzalez - Boca Chica	0.00	1.00	1.00	2.00	0.00
Southwestern shoreline of San Pedro	0.00	0.00	0.00	0.00	0.00

Discussion

The preservation of Belize's critical wetland habitats and mangrove ecosystems is obviously crucial in assuring the recovery of the American crocodile population in Ambergris Caye. Only through collective efforts of attaining current information concerning crocodile populations and hatchling survival rates, in conjunction with investigating habitat conditions which are deemed vital to hatchlings' survival (Mazzotti & Cherkiss, 2003), can one realize and implement the provisions essential for this critically vulnerable species, *C. acutus*, to once again become self-sustained.

In Ambergris Caye, south of Laguna de Cayo Frances to the southern most tip of the island is inhabited by less than 60 American crocodiles. Forty of those crocodiles are sub-adults or smaller and the largest breeding population is reproducing in the local sewage treatment plant in human feces and chemically treated water. Blindness and deformities in some of the animals have been documented. If these "chemically polluted" crocodiles are breeding with healthy individuals, which is very possible, these defects could be passed on through generations and eventual destroy the entire population in Ambergris Caye.

The overall status of the *C. acutus* population in Ambergris Caye should not be extrapolated from the data in this study for the entire island. Due to the inherent variable of sampling bias during spotlight surveys (Bayliss, 1987) some individuals could be concealed in the mangrove vegetation and escape detection (Platt, et al., 2004). More importantly, a greater number of crocodiles were sighted in and around human residences than "out in the wild." This skewed distribution is created by the improper disposal of food wastes attracting fish and raccoons, which in turn attracts the crocodiles.

ACES will continue to attempt to reduce man related crocodile mortality through education, relocations, protecting nesting site habitats, monitoring water qualities, and providing refuge and professional care for ill/injured and problematic crocodiles. Additional *C. acutus* census information is needed to provide the demographics for research scientists to implement

conservation and sustainable management efforts for American crocodiles, and protection plans for their bio-diverse, Red mangrove, wetland habitats in Belize.

The local populace is increasingly providing sighting information and reporting wildlife violations to ACES. While of course habitat destruction and fragmentation due to development play tremendous roles in reduction of the species, it is the direct feeding and poaching of these magnificent reptiles that decreases their numbers rapidly. Throughout the duration of this research there has been a substantial increase in the number of residents that report problematic crocodiles rather than taking matters into their own hands and indiscriminately killing a crocodile as they have in the past; however, it does still happen. People fear what they do not understand. This study and ACES educational outreach in Ambergris Caye has helped raise awareness; and, has given residents a better understanding of crocodiles and the important role they play in Belize's ecosystems.

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