Population Assessment of American Crocodiles (*Crocodylus acutus*) in Turneffe Atoll, Belize, 2010

Submitted to:
Oceanic Society

Submitted by:
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15 October 2010

INTRODUCTION

The American crocodile (*Crocodylus acutus*) is widely distributed throughout the northern Neotropics, ranging from the southern tip of Florida, USA, the Caribbean islands of Cuba, Jamaica, and Hispaniola, along the Atlantic and Pacific coasts of Mexico and Central America, to coastal South America from northern Peru to eastern Venezuela (Platt and Thorbjarnarson, 2000a; Thorbjarnarson et al., 2006). Although primarily inhabiting coastal lagoons and estuaries, *C. acutus* also occurs on offshore cays (islands) and atolls, and in some parts of its range is found inland, particularly along major rivers and land-locked lakes of varying salinities (Platt and Thorbjarnarson, 2000a; Thorbjarnarson et al., 2006).

From 1920 to 1970, *C. acutus* was widely hunted for its skin, and over-harvesting significantly depleted populations throughout its historical range (Thorbjarnarson et al., 2006). By the 1970s, population declines intensified owing to the development of coastal areas and subsequent loss of crocodile habitat (Thorbjarnarson et al., 2006). In 1973, *C. acutus* was listed as endangered under the U.S. Endangered Species Act and in 1979 was listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Groombridge, 1987; Platt and Thorbjarnarson, 2000a) where it remains today. Since that time, national and international trade restrictions and the availability of skins from other crocodilian species from ranching and farming programs have significantly reduced the commercial hunting of *C. acutus*, leading to the recovery of populations in many regions within its range (Thorbjarnarson et al., 2006). Today, while some deliberate killing persists, habitat loss and fragmentation are recognized as the primary factors affecting the survival of *C. acutus* populations (Platt and Thorbjarnarson, 2000a; Thorbjarnarson et al., 2006), although additional factors such as accidental drowning in fishing nets and exposure to environmental pollution may also present a subtle yet significant long-term risk to populations (Platt and Thorbjarnarson, 1997; Wu et al., 2000; Rainwater et al., in press). Currently, *C. acutus* is recognized as "vulnerable" by the International Union for the Conservation of Nature and Natural Resources (IUCN) and considered threatened by the Belize Department of Fisheries (McField et al., 1996; Platt and Thorbjarnarson, 2000a).

In the early 1990s, owing to a lack of reliable population estimates, surveys of *C. acutus* in Belize were accorded high priority by the IUCN Crocodile Specialist Group (Thorbjarnarson, 1992; Ross, 1998). Preliminary surveys of offshore cays and atolls were initiated in 1994 and 1995 (Platt and Thorbjarnarson, 1996), and a country-wide survey of offshore and mainland habitats was completed in 1997 (Platt and Thornjarnarson, 1997, 2000a; Platt et al., 1999b; Platt et al., 2004). Survey results suggested that fewer than 1000 non-hatchling *C. acutus* inhabit Belize, and that the largest *C. acutus* population (ca. 200-300 non-hatchlings, 15-25 breeding females) and the highest concentration of nesting activity occurs on Turneffe Atoll, approximately 35 km from the mainland (Platt et al., 1999a; Platt and Thorbjarnarson, 2000a;

Platt et al., 2004). In addition, Turneffe Atoll is thought to serve as source population for *C. acutus* elsewhere in the coastal zone of Belize, and therefore believed to play a critical role in regional metapopulation dynamics (Platt and Thorbjarnarson, 2000a; Platt et al., 2004). Reproduction of *C. acutus* in Turneffe Atoll is highly dependent on elevated beach ridges composed of coarse sand, and owing to a combination of natural and anthropogenic factors suitable nesting beaches are rare in the atoll (Platt and Thorbjarnarson 2000a; Platt et al., 2004). Because nesting beaches are increasingly threatened by development, Platt and Thorbjarnarson (2000a) concluded that the conservation status of *C. acutus* in Turneffe Atoll should be considered tenuous at best, and recommended a long-term monitoring program based on spotlight surveys and nest counts to determine population trends (Platt et al., 2004).

Since the completion of the country-wide survey in 1997, *C. acutus* population assessments were conducted in Turneffe Atoll in 2002 and 2004 (Platt et al., 2004). Increased crocodile encounter rates and nests found during these surveys suggested a possible population increase since 1997 (Platt et al., 2004). However, surveys conducted in 2008 revealed the lowest crocodile encounter rates and number of nests found since surveys were first initiated in 1994 (Rainwater, 2008; Rainwater and Platt, 2009). These data, in conjunction with the development of some known crocodile nesting beaches, suggested a possible decline in the Turneffe Atoll crocodile population. In 2009, American crocodile encounter rates and nesting activity in Turneffe Atoll were higher than in 2008, but both were still low compared to previous years (Platt et al., 2004; Rainwater, 2008; Rainwater and Platt, 2009, 2010). Here, we provide results of a recent assessment of *C. acutus* in Turneffe Atoll conducted in July 2010.

METHODS

Fieldwork was conducted from July 18-22, 2010. The crocodile population was censused using both spotlight surveys (Bayliss, 1987) and nest counts. Census methods used have been previously described by Platt et al. (2004) and Rainwater and Platt (2009). Briefly, spotlight surveys were conducted from a 5 m motorized skiff beginning 15 to 30 minutes after sunset (July 18, 19, 21, 22). Crocodile eyeshines were detected using a 3,000,000 candlepower Q-beam spotlight. All crocodiles sighted were classified by total length (TL) as hatchlings (TL < 30 cm), juveniles (TL = 30-90 cm), subadults (TL = 91-180 cm), or adults (TL > 180 cm). Crocodiles that submerged before TL could be determined were classified as "eyeshine only" (EO). The beginning and endpoints of each survey route and the distance traversed were determined with a Garmin® GPS Map60. Encounter rates were calculated as the number of crocodiles observed per kilometer of survey route (Platt and Thorbjarnarson, 2000a; Platt et al., 2004; Rainwater and Platt, 2009).

When possible, crocodiles were captured by hand or self-locking snares to confirm size estimates, obtain morphometric data, and mark individuals for future identification (Platt and Thorbjarnarson, 1997). Sex was determined by cloacal examination of the genitalia (Brazaitis, 1968). Following data collection, each crocodile was marked by clipping a unique series of caudal scutes (Jennings et al., 1991; Rainwater et al., 2007). Crocodiles were then released at the site of capture.

Nesting areas identified during previous surveys were revisited (Platt and Thorbjarnarson, 1996, 1997; Platt et al. 2004; Rainwater and Platt, 2009) and searched for signs of nesting activity. *C. acutus* in Belize generally nests in mid-April, and eggs hatch from late June to mid-July following the onset of the annual wet season (Platt and Thorbjarnarson, 1997, 2000b; Platt et al., 2004; Rainwater and Platt, 2009). Female crocodiles typically excavate nests to remove neonates, leaving a readily obvious hole containing eggshell fragments and membranes (Platt and Thorbjarnarson, 1997, 2000b; Platt et al., 2004; Rainwater and Platt, 2009). Nests are difficult to detect during May and early June, as wind and rain in the weeks following oviposition usually obscure or eliminate crocodile scrapes and drag marks useful in identifying nest locations. However, old (previous year) nests can often be located during this period (Platt and Thorbjarnarson, 1997). In addition to known nesting areas, potentially suitable beaches where nesting has yet to be documented were also searched (Platt et al. 2004; Rainwater and Platt, 2009).

RESULTS

Spotlight surveys

Spotlight surveys were conducted along the eastern and western shores of Blackbird Cay and the southern and western shores of Calabash Cay (Table 1). A total of 19 *C. acutus* was observed along 55.2 km of survey route (encounter rate = 0.34 crocodiles/km) (Table 1). Of these, 9 (47.4%) were classified as EO, and 10 (52.6%) were approached closely enough to estimate size; these included 2 (20%) juveniles, 7 (70%) subadults, and 1 (10%) adult (Figure 1; Figure 2). Six *C. acutus* were captured, marked, and released during spotlight surveys (Table 2). These included two juveniles (both males), two subadults (both females), and 2 adults (one male, one female). None of these animals had been previously captured during our study. All crocodiles appeared to be in good physical condition.

Additional crocodiles were also observed in Turneffe Atoll during July, incidental to spotlight surveys. Two adult crocodiles (ca. 360 cm TL, Figure 3; ca. 240 cm TL), were observed on 20 July at approximately 0700 hr in the ephemeral mangrove lagoon behind the Oceanic Society Field Station on the southern tip of Blackbird Cay. In addition, 14 hatchlings

were observed in shallow water among mangroves adjacent to a recently excavated nest on the western shore of Blackbird Cay between Blackbird Cay Resort and the airstrip.

Nest counts

Ten crocodile nests were found during four days of searching known and potential nesting beaches on Blackbird (1 nest), Northern (Cockroach) (4 nests), and Calabash (5 nests) Cays (Table 3) (Figure 4, Figure 5, Figure 6, Figure 7). All of these appeared to be new, recently excavated nests. An additional excavated nest was found by Oceanic Society Expeditions (OSE) staff member Alton Jeffords on 15 August in a swampy area adjacent to the eastern beach of Blackbird Cay between the OSE field station and Blackbird Cay Resort (no GPS was available to determine coordinates) (Figure 5). Overall, the majority of nests were found on Calabash Cay (5; Figure 7) and a single beach on Northern Cay (Table 3, Table 4; Figure 6). All nests discovered during the 2010 survey were hole nests, and various numbers of dried egg shells were found in association with these nests (Table 3) (Figure 8). As previously mentioned, 14 hatchlings were observed among mangroves in shallow water along the western shore of Blackbird Cay, approximately 3 m from a recently excavated nest (Figure 9, Figure 10). No nests were found on other known and potential nesting beaches on Blackbird Cay (eastern and western beaches) (Platt et al., 2004; Rainwater and Platt, 2009).

DISCUSSION

The overall crocodile encounter rate for 2010 (0.34 crocodiles/km) was slightly lower than that observed in 2009 (0.58 crocodiles/km) and the same as that observed in 2008 (0.34 crocodiles/km) (Table 5). These encounter rates (2008-2010) are considerably lower than those observed in previous years (Table 5). Encounter rates in 2010 were 2.7-, 3.5-, and 3.6-fold lower than those observed in 1996, 1997, and 2002, respectively (Table 5). Whether or not this difference actually reflects a decrease in crocodile population size in Turneffe Atoll remains unknown. As pointed out in previous reports, spotlight surveys are inherently variable, and as such, long-term monitoring is generally required to detect population changes (Bayliss, 1987; Platt et al., 2004; Rainwater and Platt, 2010). For example, temporal variation (e.g., dry season versus wet season) in spotlight surveys may influence encounter rates if crocodile habitat use also varies temporally. Indeed, data from crocodile spotlight surveys conducted in Turneffe Atoll since 1996 suggest an influence of season on crocodile detection. However, these data also highlight the potential variability in crocodile encounter rates even when surveys are conducted during the same general time period (e.g., season).

The number of crocodile nests found during 2010 (11) was the most since 2004 (Table 4). This increase was primarily driven by the five nests found on Calabash Cay, the most found on

this cay since surveys began in 1994 (Table 4). Nesting on Blackbird Cay increased slightly from the previous two years but overall remains low (Table 4). The number of nests on Northern Cay (4) mirrored that of 2009. Although the number of nests found on this critical nesting beach has been consistent over the last three years, nesting activity remains markedly reduced compared to previous years (Table 4). The discovery of a recently hatched nest on Blackbird Cay in August (after official nest surveys had been completed) by an OSE staff member highlights the possibility that each year some clutches have not yet hatched at the time nest surveys are conducted and corresponding nests go undetected. Because excavated nests are usually still identifiable within a year of hatching, annual nest surveys will therefore continue to be essential to obtain the most accurate estimate of crocodile nesting activity in Turneffe Atoll.

The nesting beach on the southeastern shore of Blackbird Cay again yielded no nests in 2010. From 1994 to 2004, this beach was one of the most productive sites in Turneffe Atoll with respect to number of crocodile nests found. Three nests were found on this beach in 2004, but none have been found since. Since 2004, sections of this beach have been significantly altered by human activities, primarily the clearing of mangrove and beach habitat for construction of an airstrip and fishing camp (Rainwater and Platt, 2009, 2010) (Figure 11). In 2010, evidence of additional clearing of mangrove and cay littoral forest since 2009 was observed. In addition, multiple large mounds of sand were situated along the southern end of the beach, presumably as a result of dredging and excavation from the adjacent sea (Figure 11). The effects of these activities on the resident crocodile population are currently unknown. It is possible that clearing of shoreline forest could actually create crocodile nesting habitat, but thus far no nesting activity has been observed in recently cleared areas. More likely, disturbance and development of potential nesting beaches will reduce crocodile nesting in this area of the atoll.

To summarize, the number of American crocodiles encountered during spotlight surveys in 2010 was slightly lower than in 2009. Overall, encounter rates since 2008 remained low compared to numbers in the 1990s and early 2000s. Conversely, the number of crocodile nests found in 2010 was almost double the number found in 2009, and was the highest since 2004. This was largely driven by a marked increase in nesting activity on Calabash Cay. Nesting on Northern Cay, the most critical American crocodile nesting locality in Belize, remained consistent since 2008 but reduced compared to previous years. The overall increase in crocodile nesting in Turneffe Atoll observed in 2010 is encouraging, but continued long-term monitoring is essential to determine if this increase simply reflects annual variation in nesting effort.

The alteration of crocodile nesting habitat on Blackbird Cay described in 2009 (Rainwater and Platt, 2010) continued in 2010. Along the eastern shoreline, additional clearing of mangrove and cay littoral forest persisted, and large mounds of sand (presumably dredged) were deposited along the southern end of the beach. On the southern tip of the cay, one nest site had been bulldozed to provide increased access to the trash dump. Continued alteration of

crocodile nesting habitat in Turneffe Atoll will likely have a detrimental effect on crocodile nesting activity and consequently population stability. We strongly reiterate our previous recommendation that beaches on Blackbird, Calabash, and Northern Cays be protected to provide critical nesting habitat for crocodiles. Particularly, it is absolutely imperative that the nesting beach on Northern Cay be granted national protection immediately to prevent development. In addition, given the high level of nesting activity observed in 2010, national protection for the two nesting beaches on Calabash Cay is warranted and should also be pursued. Last, we continue to recommend the implementation of nesting beach restoration efforts by clearing brush and vegetation from known or potential nesting beaches.

ACKNOWLEDGMENTS

Richard Aranda and Alton Jeffords are thanked for their masterful boat handling skills throughout the project. Kate Crosman, Ginny Fuhs, Steve Lawson, and numerous Academic Treks students are thanked for assistance with spotlight surveys and nest counts. Research permits were kindly issued by the Conservation Division, Forest Department, Belmopan, Belize. Birgit Winning and the entire staff at the Oceanic Society Field Station are thanked for logistical support during this and previous American crocodile population assessments on Turneffe Atoll. This project was supported by the Oceanic Society.

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Table 1. Information regarding spotlight surveys conducted in July 2010 to assess American crocodile (*Crocodylus acutus*) populations in Turneffe Atoll, Belize.

Date	General survey location	Start location	Stop location	Distance Surveyed (km)	Crocodiles encountered	Encounter rate (crocodiles / km)
18 July	Blackbird east	17°22'53.3" N, 87°48'28.9" W	17°18'22.3" N, 87°48'07.5" W	9.7	4	0.41
19 July	Blackbird northwest	17°25'37.9" N, 87°48'46.3" W	17°21'38.5" N, 87°49'30.4" W	13.7	2	0.15
21 July	Blackbird southwest	17°21'38.8" N, 87°49'30.1" W	17°18'14.9" N, 87°48'14.7" W	16.0	10	0.63
22 July	Calabash southeast, west	17°15'07.3" N, 87°50'26.2" W	17°17'24.3" N, 87°48'57.1" W	15.8	3	0.19
			Total / Overall encounter rate	55.2	19	0.34

Table 2. Information on American crocodiles (*Crocodylus acutus*) captured in Turneffe Atoll, Belize during July, 2010. NA = Not applicable.

Date	Caudal scute ID	Toe tag #	Sex	Total length (cm)	Snout-vent length (cm)	General capture location	GPS coordinates
18 July	S7-R3-L8	NA	Male	59.4	29.8	Eastern shore of Blackbird Cay	17°20'37.4" N, 87°47'54.5" W
18 July	S7-R3-L9	NA	Male	41.0	21.0	Eastern shore of Blackbird Cay	17°20'37.4" N, 87°47'54.5" W
19 July	S7-R4-L2	NA	Female	191.1	99.1	Western shore of Blackbird Cay	17°21'56.6" N, 87°48'49.4" W
21 July	S7-R4-L3	NA	Female	160.7	79.7	Western shore of Blackbird Cay	17°19'52.6" N, 87°49'25.7" W
21 July	S7-R4-L4	NA	Male	185.7	99.1	Western shore of Blackbird Cay	17°20'48.5" N, 87°49'16.1" W
21 July	S7-R4-L5	NA	Female	148.0	76.2	Western shore of Blackbird Cay	17°19'27.7" N, 87°49'15.4" W

Table 3. Information on American crocodile (*Crocodylus acutus*) nests found in Turneffe Atoll, Belize during July and August, 2010.

Date	General location	GPS coordinates	Canopy	# egg shells
18 July	Blackbird Cay	17°18'51.5" N, 87°48'03.3" W	Open	8*
19 July	Calabash Cay	17°15'45.7" N, 87°49'40.0" W	Open	4
19 July	Calabash Cay	17°15'47.2" N, 87°49'36.9" W	Open	3
19 July	Calabash Cay	17°15'47.7" N, 87°50'02.5" W	Open	1
19 July	Calabash Cay	17°15'45.6" N, 87°50'07.9" W	Open	2
19 July	Calabash Cay	17°15'40.5" N, 87°50'12.8" W	Open	2
22 July	Northern Cay	17°29'43.3" N, 87°47'04.4" W	Open	8
22 July	Northern Cay	17°29'41.2" N, 87°47'05.0" W	Open	15
22 July	Northern Cay	17°29'40.2" N, 87°47'05.9" W	Open	4
22 July	Northern Cay	17°29'39.5" N, 87°47'06.4" W	Open	10
15 August	Blackbird Cay	Not determined	Not determined	5

*14 hatchlings also observed in shallow water among mangrove roots approximately 15 m from the excavated nest.

Table 4. Counts of American crocodile (*Crocodylus acutus*) nests at various beaches in Turneffe Atoll surveyed from 1994 to 2010. Data are from Platt and Thorbjarnarson (1997), Platt et al. (2004), Rainwater and Platt (2009), Rainwater and Platt (2010), and the present study. Numbers in 2008 have been adjusted to include three nests that were excavated in 2008 following the completion of surveys and were found later in 2008 or in 2009. Note that 1995 counts are based on incomplete survey data. NA = Not available.

Location	1994	1995	1996	1997	2002	2004	2008	2009	2010
Calabash Cay	0	NA	0	0	1	2	1	1	5
Blackbird Cay (south)	0	NA	5	3	1	3	1	1	2
Blackbird Cay (west)	2	1	1	2	0	0	0	0	0
Northern Cay	8	NA	7	10	6	11	3	4	4
Total	10	1	13	15	8	16	5	6	11

Table 5. Spotlight survey data for American crocodiles (*Crocodylus acutus*) in Turneffe Atoll, Belize, 1996-2010.[a]

Location	Date	Season[b]	Distance surveyed	Crocodiles encountered	Encounter rate (crocodiles / km)
Blackbird Cay (Eastern shore)	Nov. 1996	wet	2.7	7	2.60
	Feb. 1997	dry	2.7	11	4.07
	April 1997	dry	2.7	6	2.22
	May 2008	dry	10.5	5	0.48
	June-July 2008	wet	9.2	0	0
	July 2009	wet	8.6	10	1.16
	July 2010	wet	9.7	4	0.41
Blackbird Cay (Western shore)	Nov. 1996	wet	15.7	6	0.38
	Feb. 1997	dry	15.7	7	0.45
	April 1997	dry	15.7	11	0.70
	May 2008	dry	30.4	14	0.46
	June-July 2008	wet	24.1	6	0.23
	July 2009	wet	29.2	12	0.41
	July 2010	wet	29.7	12	0.40
Calabash Cay	Nov. 1996	wet	2.4	6	2.5
	Feb. 1997	dry	2.4	8	3.3
	April 1997	dry	2.4	7	2.91
	May 2008	dry	5.7	4	0.70
	June-July 2008	wet	12.0	2	0.17
	July 2009	wet	19	11	0.58

	July 2010	wet	15.8	3	0.19
Turneffe Atoll (Sites combined)	1996	wet	20.8	19	0.91
	1997	dry	41.6	50	1.20
	2002	wet	40.1	49	1.22
	2008	dry, wet	91.9	31	0.34
	2009	wet	56.8	33	0.58
	2010	wet	55.2	19	0.34

[a]Data from Platt and Thorbjarnarson, 1997; Platt et al., 2004; Rainwater and Platt, 2009; Rainwater and Platt, 2010; this study.

[b]A pronounced wet season occurs in Belize from mid-June through late November, followed by the dry season which peaks in April and May.

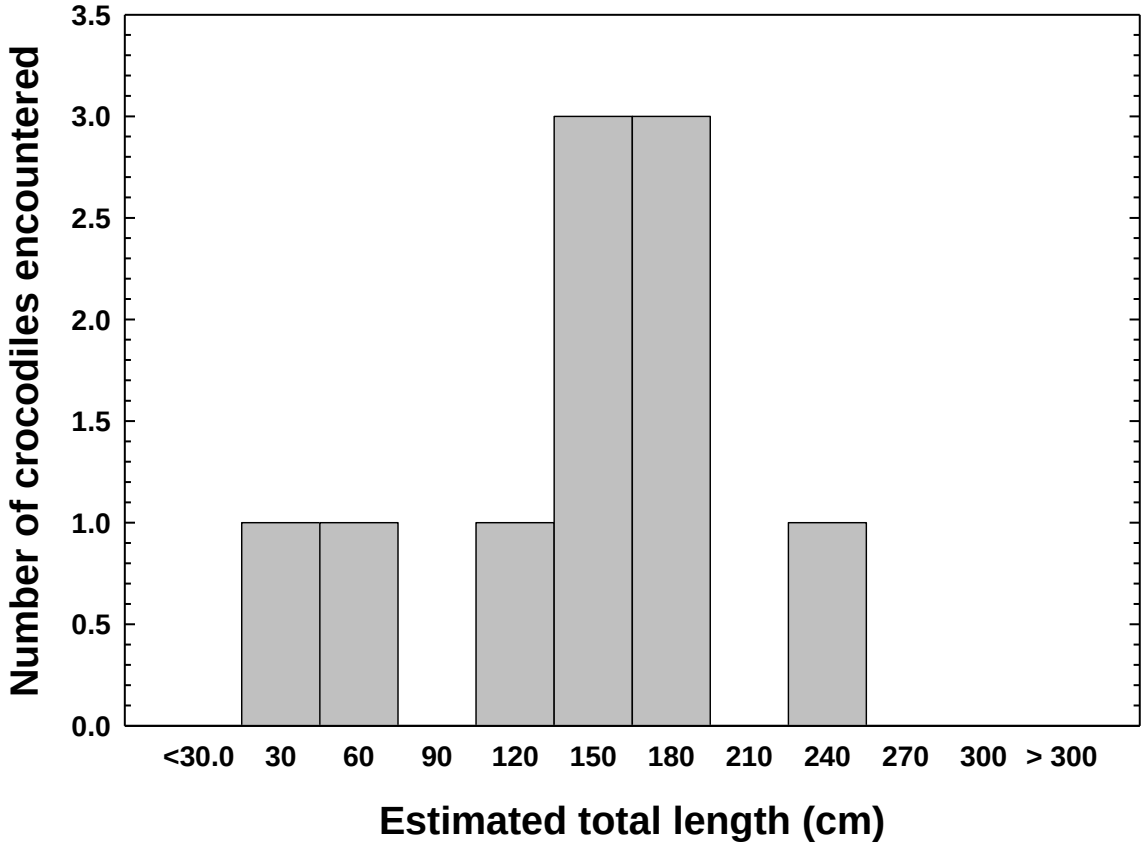

Figure 1. Size class distribution of American crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) from 18-22 July 2010.

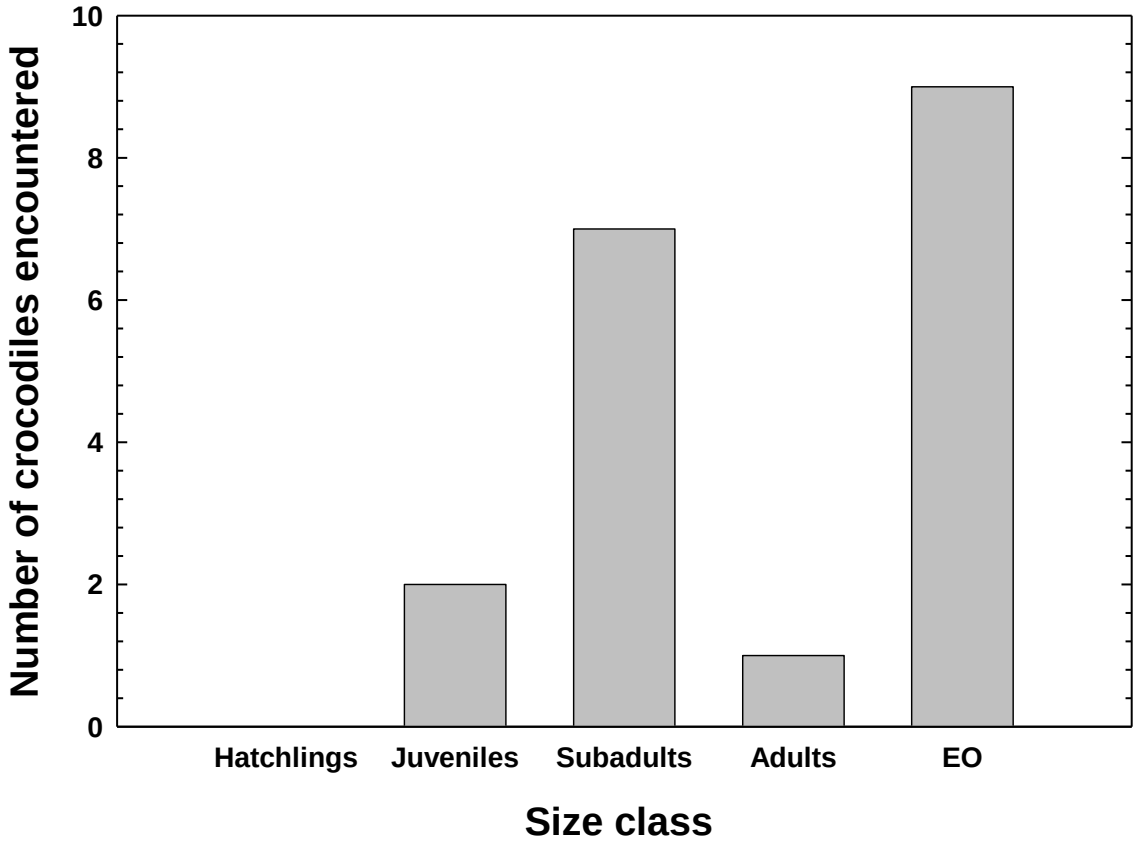

Figure 2. Size class distribution of American crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) from 18-22 July 2010. EO = Eyeshine only.

Figure 3. A large adult (ca. 360 cm total length) American crocodile in an ephemeral pool directly behind the Oceanic Society Expeditions Field Station, Blackbird Cay, Turneffe Atoll, Belize (20 July 2010).

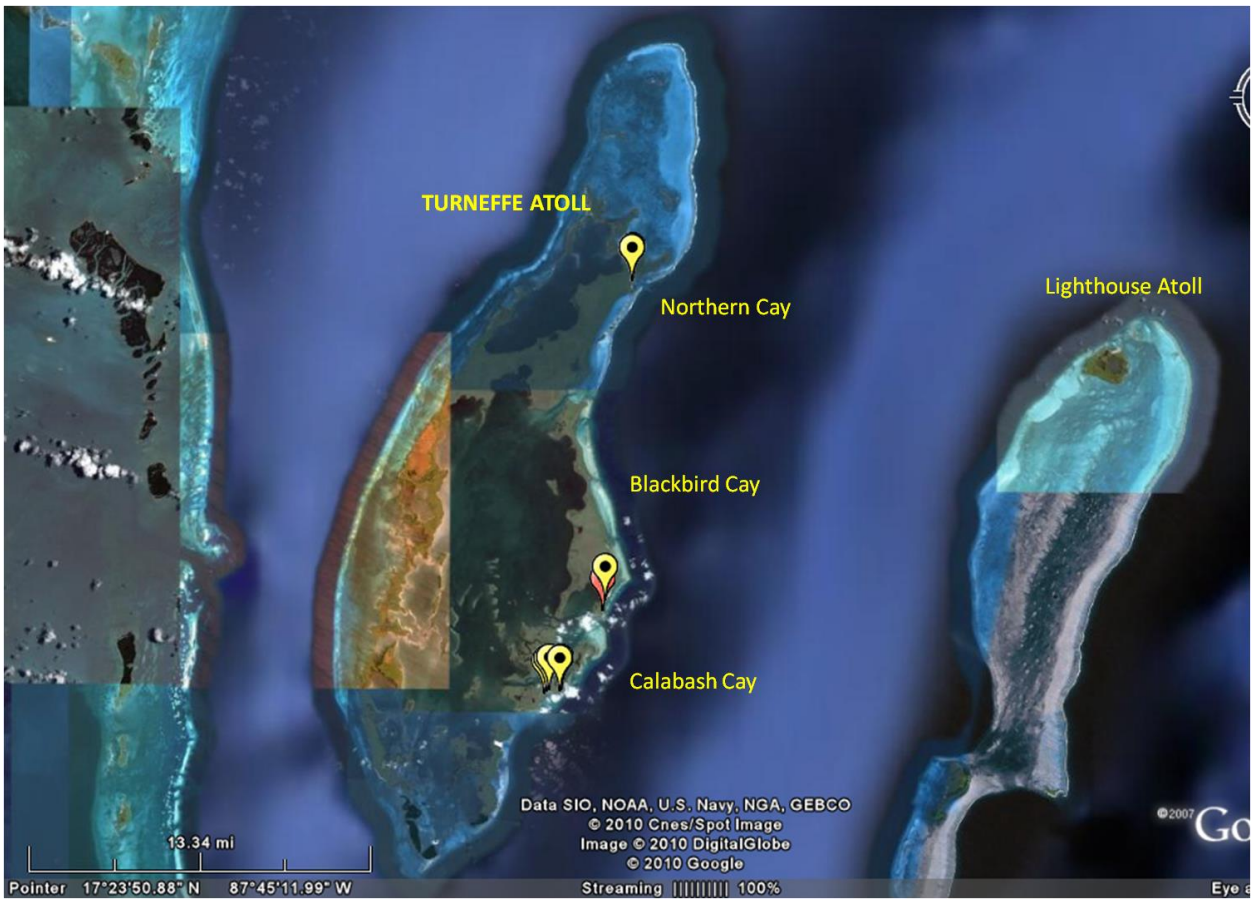

Figure 4. Map of Turneffe Atoll, Belize showing locations (yellow markers) where American crocodile nests were found in July 2010 (image from Google Earth).

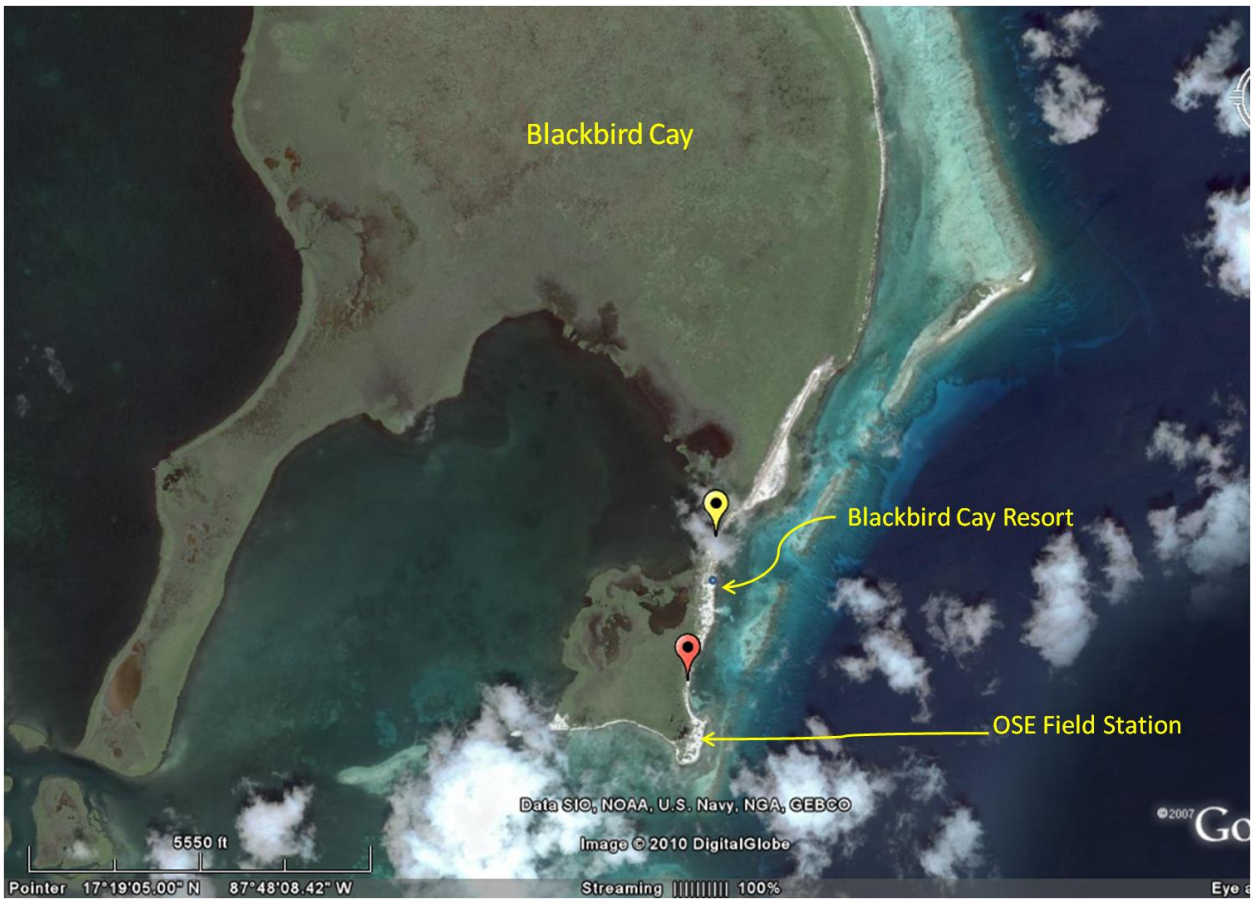

Figure 5. Map of southern Blackbird Cay, Turneffe Atoll, Belize showing locations where American crocodile nests were found in July 2010 (image from Google Earth). The yellow marker indicates a nest found in July 2010 as part of official nest surveys; the red marker indicates a nest found in August 2010, incidental to nest surveys.

Figure 6. Map of northeastern Northern Cay, Turneffe Atoll, Belize showing locations (yellow markers) where American crocodile nests were found in July 2010 (image from Google Earth).

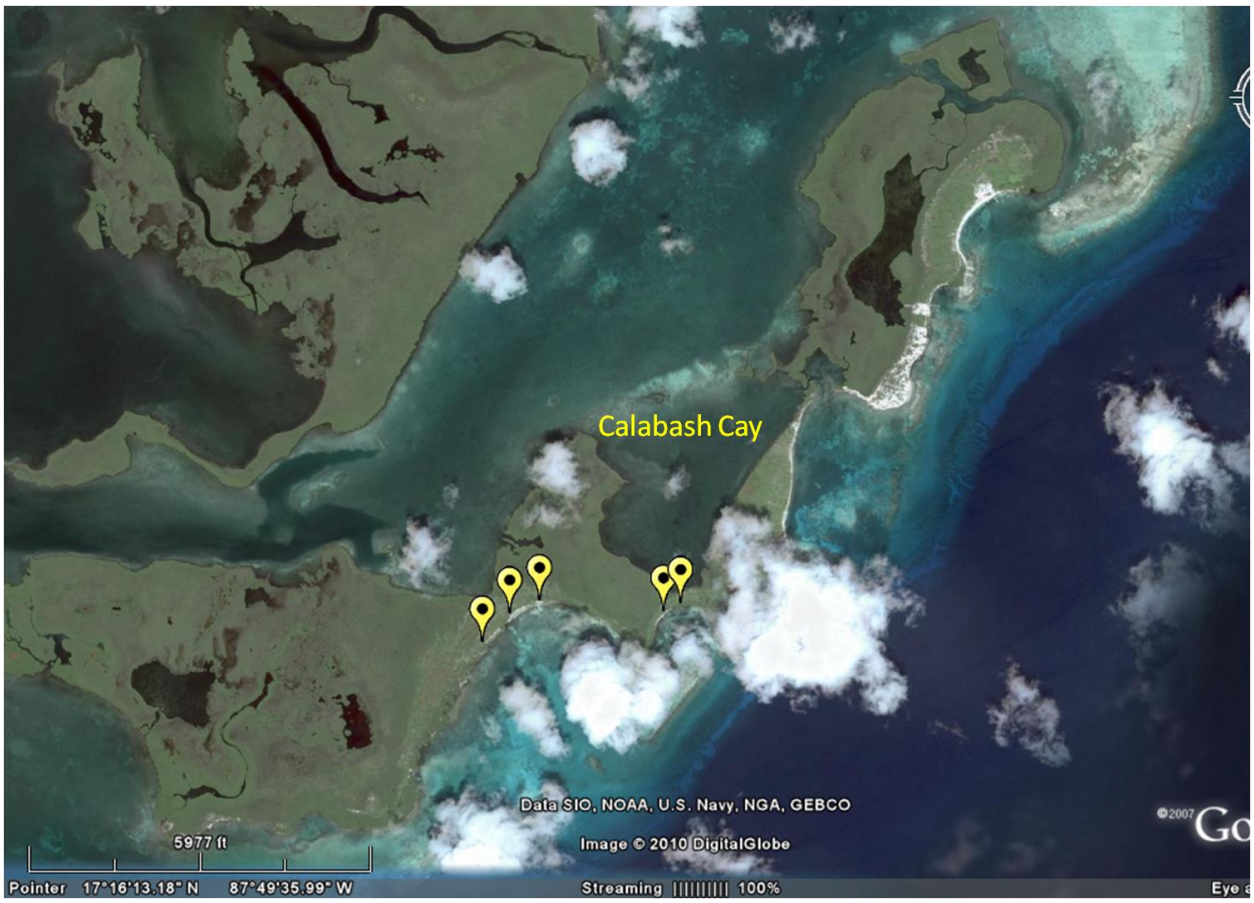

Figure 7. Map of Calabash Cay, Turneffe Atoll, Belize showing locations (yellow markers) where American crocodile nests were found in July 2010 (image from Google Earth).

Figure 8. A recently excavated American crocodile nest on Blackbird Cay, Turneffe Atoll, Belize (18 July 2010). Note the remaining egg shells in and around the nest cavity.

Figure 9. A pod of American crocodile hatchlings among mangroves along the western shore of Blackbird Cay, Turneffe Atoll, Belize (18 July 2010).

Figure 10. American crocodile hatchlings from a recently excavated nest along the western shore of Blackbird Cay, Turneffe Atoll, Belize (18 July 2010).

Figure 11. Areas along the southeastern shore of Blackbird Cay, Turneffe Atoll, Belize where clearing of mangrove and cay littoral forest has occurred since crocodile surveys were conducted in 2008 (18 July 2010). The large sand mound on the beach in the top photograph is purportedly from sand dredging and excavation from the adjacent sea. Multiple such mounds are situated on the beach.