

Population Assessment of American Crocodiles (*Crocodylus acutus*)
in Turneffe Atoll, Belize, 2008

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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 is 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 Thorbjarnarson, 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 is 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, additional *C. acutus* population assessments were conducted in Turneffe Atoll in 2002 and 2004 (Platt et al., 2004). Here, I provide results of a recent assessment of *C. acutus* in Turneffe Atoll conducted in May and June-July 2008.

METHODS

Fieldwork was conducted from May 18-23 and June 28-July 4, 2008. The crocodile population was censused using both spotlight surveys (Bayliss, 1987) and nest counts. Census methods were previously described by Platt et al. (2004). Briefly, spotlight surveys were conducted from a 5 m motorized skiff beginning 15 to 30 minutes after sunset. 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 = 90-180 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 was 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).

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 placing a uniquely numbered aluminum toe tag in the webbing of the rear foot and 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) and searched for signs of nesting activity. *C. acutus* 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). 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). Nests are typically 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).

RESULTS

Spotlight surveys

Spotlight surveys were conducted along the eastern and western shores of Blackbird Cay and the western shore of Calabash Cay in May (Table 1; Figure 1) and in late June-early July (Table 2; Figure 2) 2008. In May, A total of 23 *C. acutus* was observed along 46.6 km of survey route (encounter rate = 0.49 crocodiles/km) (Table 1). Of these, 9 (39.1%) were classified as EO, and 14 (60.9%) were approached closely enough to estimate size; these included 2 (14.3%) juveniles, 7 (50.0%) subadults, and 5 (35.7%) adults (Figure 3; Figure 4). Four *C. acutus* were captured, marked, and released during spotlight surveys (Table 3). These included 1 juvenile (female) and 3 adults (2 males, 1 female). All crocodiles appeared to be in good physical condition, although two of the adults exhibited fresh wounds (e.g., holes, gashes) suggestive of conflicts with other crocodiles.

In late June-early July, a total of 8 *C. acutus* was observed along 45.3 km of survey route (encounter rate = 0.18 crocodiles/km) (Table 2). Of these, 4 (50%) were classified as EO, and 4 (50%) were approached closely enough to estimate size; these included 3 (75%) subadults and 1 (25%) adult (Figure 5). One *C. acutus* (subadult male) was captured, marked, and released during spotlight surveys, and an additional crocodile (subadult female) was captured in an ephemeral (rainwater) mangrove lagoon behind the Oceanic Society Field Station on the southern tip of Blackbird Cay (Table 4). Both crocodiles appeared to be in good physical condition.

Additional crocodiles were also observed in Turneffe Atoll during June-July, incidental to spotlight surveys. Four crocodiles were observed in the ephemeral mangrove lagoon behind the Oceanic Society Field Station on the southern tip of Blackbird Cay. These included two adults (~ 300 cm TL), one subadult (~ 60 cm), and one individual identified as “eyeshine only”. In addition, two crocodiles (eyeshine only) were also observed along a beach ridge in Soldier Bight. As Platt and Thorbjarnarson (1997) noted, this beach ridge is adjacent to the aforementioned ephemeral mangrove lagoon behind the Oceanic Society Field Station, and well-worn trails lead from the lagoon, over the ridge, and into Soldier Bight. Thus, it is possible that these two crocodiles are among those previously spotted in the ephemeral lagoon.

Nest counts

During May 2008, no active nests were found during three days of searching known and potential nesting beaches on Blackbird, Northern (Cockroach), and Calabash Cays. One old nest containing two egg shells, likely from 2007, was found on the nesting beach at Northern Cay. Multiple crocodile slides and tracks were observed on this beach suggesting movement from the sea to a nursery lagoon behind (west) the beach (Platt and Thorbjarnarson, 2000a; Platt et al., 2004) and vice versa. One juvenile crocodile was observed in the nursery lagoon (ca. 1130 hr). On May 18, a researcher (Tino Chi) stationed at Calabash Cay informed me that he had found a nest protected by a crocodile (presumably the maternal female) on Deadmans Cay in 2007. On a return inspection after hatching, he found three unhatched eggs still in the nest. Mr. Chi also claims to have also observed crocodile nests on the east side Calabash Cay, just south of the University of Belize Marine Science Station.

During June-July 2008, a total of two recently excavated crocodile nests was found during searches of the same (and additional) nesting beaches searched in May (Table 5). Both nests were located at a single beach on Northern Cay on July 3. This beach is considered the most significant *C. acutus* nesting site in the entire coastal zone of Belize (Platt et al., 2004). Both nests were hole nests and contained dried egg shells (five and nine, respectively), and four hatchlings were observed among vegetation in a shallow, brackish lagoon approximately 15 m from one nest. On July 1, researcher Tino Chi informed me that approximately 10 days before, he had found a recently excavated nest on this same beach. This nest contained one unhatched egg. In addition, Mr. Chi provided a photograph of a pod of approximately 15 hatchlings on the edge of the brackish lagoon. It is likely that the unhatched egg and hatchlings originated from one of the two nests found on July 3, as no other nests were found after intensive searching of this beach.

No nests were found on other known and potential nesting beaches on Blackbird Cay and Calabash Cay (Platt et al., 2004). Tino Chi provided the GPS coordinates of the crocodile nest he encountered on Deadman’s Cay in 2007 (17°11'41.0" N, 87°51'57.0" W).

DISCUSSION

During 2008, the overall crocodile encounter rate for June and July (0.18 crocodiles/km) was lower than that observed in May (0.49 crocodiles/km). Due to the relatively short period (~40 days) between these surveys, it is unlikely that the lower encounter rate observed in June and July reflects a population decrease during that time. Rather, this may reflect seasonal differences in habitat use. The wet season in Belize begins in early June (Johnson, 1983; Platt, 1996), and the resulting influx of rainwater often reduces the salinity of brackish lagoons in the interior of the atoll (Platt and Thorbjarnarson, 1997, 2000b) and may also create small, ephemeral fresh water lagoons. Crocodiles otherwise restricted to marine habitats during the dry season may move into these brackish and fresh water interior lagoons during the wet season (as we have noted in the aforementioned ephemeral lagoon behind the Oceanic Society Field Station) for access to fresher water (Mazzotti et al., 1986; Richardson et al., 2002; Leslie and Taplin, 2001) and therefore may go undetected during spotlight surveys along the shoreline of the atoll.

Data from previous spotlight surveys of Turneffe Atoll are equivocal with regard to the influence of season on crocodile encounter rates. If availability of brackish or fresh water in the interior of the atoll is the primary factor influencing the number of crocodiles present in marine habitat, encounter rates in marine habitats would be expected to increase from wetter to dryer conditions as brackish habitats become more saline and fresh water habitats disappear. This pattern was observed from 1996-1997 on the western shore of Blackbird Cay, with crocodile encounter rates increasing from the wet season (November 1996) to the early dry season (February 1997) to the late dry season (April 1997) (Table 6). However, from 1996-1997, the crocodile encounter rate on the eastern shore of Blackbird Cay during the wet season (November 1996) was lower than that in the early dry season (February 1997) but similar to that in the late dry season (April 1997) (Table 6). Yet a different pattern was noted along Calabash Cay, where crocodile encounter rates remained relatively constant throughout the same period (Table 6). Future spotlight surveys of these areas during back-to-back wet and dry seasons will be useful in determining the influence of season on crocodile encounter rates along Turneffe Atoll. Other factors such as weather, location of area surveyed (windward or leeward side of the atoll), tide, and access or barriers to interior brackish or fresh water habitats should also be considered.

The most important result of spotlight surveys conducted in this study is that the overall crocodile encounter rate in Turneffe Atoll for 2008 is markedly lower than those observed over the last 12 years (Table 6). The overall crocodile encounter rate in Turneffe Atoll for 2008 is 0.34 crocodiles/km, which is 2.7-, 3.5-, and 3.6-fold lower than that observed in 1996, 1997, and 2002, respectively (Table 6). Whether or not this difference actually reflects a decrease in crocodile population size in Turneffe Atoll is unknown. Spotlight surveys are inherently variable, and as such long-term monitoring is generally required to detect population changes

(Bayliss, 1987; Platt et al., 2004). Prior to this year, crocodile encounter rates on Turneffe Atoll (specifically Blackbird and Calabash Cays) have increased each year spotlight surveys have been conducted. This is the first year a reduction in the overall number of crocodiles has been observed. Future spotlight surveys of these areas will be critical in determining whether the lower overall encounter rates observed in 2008 are a product of survey variability or a reflection of population change. As noted by Platt et al. (2004) in previous surveys, the high proportion of subadults and adults during this investigation is likely due in part to sampling bias; hatchlings and juveniles often remain concealed in mangrove vegetation and escape detection during spotlight surveys.

While the low encounter rate observed in 2008 suggests a possible decline in the Turneffe Atoll *C. acutus* population, a more concerning finding of this study is the low number of crocodile nests found during nest surveys (Table 5). Only two nests were found in 2008, and both were on the same beach at Northern Cay. No nests were found on three other beaches known to have yielded nests in previous years (Blackbird Cay south, Blackbird Bay west, Calabash Cay) (Table 5). One of these beaches (Blackbird south) has been significantly altered by human activities since the last nest survey was conducted in 2004. One nesting area on the southern end of the beach has been covered by debris (primarily dead mangrove) following the construction of an airstrip (Figure 6), likely rendering this site unsuitable for crocodile nesting. The primary nesting area on the northern end of this beach has been impacted by the construction of a fish camp (Figure 7). The overall number of crocodile nests found on our study sites in Turneffe Atoll in 2008 is 10-, 6.5-, 7.5-, 4-, and 8-fold lower than that found in 1994, 1996, 1997, 2002, and 2004, respectively (Table 5). It is possible that some clutches had not yet hatched at the time of the survey and corresponding nests went undetected. However, it is expected that at least 50% of 2008 clutches would have hatched by early July, as hatching of *C. acutus* clutches in Turneffe Atoll is known to occur from late June to mid-July (Platt and Thorbjarnarson, 1997, 2000b; Platt et al., 2004). If only one half of crocodile nests had hatched by the time the survey was conducted, this suggests a total of four nests constructed at known nesting beaches in Turneffe Atoll in 2008, still a substantial decrease in nesting compared to previous years (Table 5). Future nest surveys will be crucial in determining whether the low number of *C. acutus* nests found in Turneffe Atoll in 2008 is a reflection of a decrease in the number of nesting females in the atoll or a function of annual variability in nesting effort (Platt et al., 2004).

Finally, we learned that during the past year one crocodile (estimated TL = 150 cm) was shot and killed in the lagoon behind (west) Blackbird Cay Resort. Owing to the relatively small *C. acutus* population in Belize and the high importance of the Turneffe Atoll population (Platt and Thorbjarnarson, 1997, 2000b; Platt et al., 2004), the loss of even a single subadult or adult crocodile, particularly a female, may have a significant impact on the overall population of *C. acutus* in Belize.

In summary, the combination of low crocodile encounter rates, low nesting activity, and human alteration of known nesting beaches on Blackbird Cay observed during this study suggests a possible decline in the *C. acutus* population in Turneffe Atoll. Following the most recent crocodile survey conducted prior to the present study, Platt et al. (2004) reported that with the exception of Northern Cay, nesting beaches in Turneffe Atoll remained relatively undisturbed with little sign of human disturbance. However, while the nesting beach at Northern Cay has since been designated as a Temporary Reserve and is currently protected, alteration of nesting habitats on Blackbird Cay since 2004 has likely rendered sites known to have yielded nests in the past unsuitable for future nesting. Management and conservation efforts should be made to protect beaches on Blackbird, Calabash, and Northern Cays to provide critical nesting habitat for crocodiles. In addition, spotlight surveys and nest counts are essential for monitoring the status of the *C. acutus* population in Turneffe Atoll and should be continued.

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Table 1. Information regarding spotlight surveys conducted in May 2008 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 May	Blackbird southeast	17°20'42.9" N, 87°47'49.3" W	17°18'22.8" N, 87°48'06.8" W	5.36	3	0.56
19 May	Blackbird northwest	17°25'39.2" N, 87°48'49.1" W	17°21'19.3" N, 87°49'11.4" W	14.9	11	0.74
21 May	Blackbird southwest	17°21'26.3" N, 87°49'17.7" W	17°18'14.9" N, 87°48'14.7" W	15.5	3	0.19
22 May	Blackbird northeast	17°22'53.3" N, 87°48'28.6" W	17°20'39.6" N, 87°47'50.3" W	5.13	2	0.39
23 May	Calabash northwest	17°16'15.9" N, 87°49'46.2" W	17°17'28.9" N, 87°48'51.1" W	5.68	4	0.70
Total / Overall encounter rate				46.6	23	0.49

Table 2. Information regarding spotlight surveys conducted in June-July 2008 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)
29 June	Blackbird east	17°22'54.0" N, 87°48'27.9" W	17°18'22.3" N, 87°48'07.5" W	9.2	0	0.00
30 June	Blackbird southwest	17°21'26.3" N, 87°49'17.7" W	17°18'14.9" N, 87°48'14.7" W	11	2	0.18
2 July	Calabash west	17°15'56.6" N, 87°51'34.6" W	17°17'28.9" N, 87°48'40.8" W	12	2	0.17
4 July	Blackbird northwest	17°25'38.6" N, 87°48'45.5" W	17°21'51.4" N, 87°49'27.7" W	13.1	4	0.31
Total / Overall encounter rate				45.3	8	0.18

Table 3. Information on American crocodiles (*Crocodylus acutus*) captured in Turneffe Atoll, Belize during May 2008.

Date	Caudal scute ID	Toe tag #	Sex	Total length (cm)	General capture location	GPS coordinates
18 May	S8-R2-L7	OS-827	Female	89.2	Eastern shore of Blackbird Cay	17°20'00.82" N, 87°47'36.31" W
19 May	S8-R2-L5	OS-825	Male	189.0	Western shore of Blackbird Cay	17°22'27.97" N, 87°48'44.45" W
19 May	S8-R2-L6	OS-801	Female	182.5	Western shore of Blackbird Cay	17°22'03.47" N, 87°48'43.92" W
23 May	S7-R2-L5	OS-702	Male	235.0	Western shore of Calabash Cay	17°16'19.06" N, 87°49'16.17" W

Table 4. Information on American crocodiles (*Crocodylus acutus*) captured in Turneffe Atoll, Belize during June-July 2008.

Date	Caudal scute ID	Toe tag #	Sex	Total length (cm)	General capture location	GPS coordinates
28 June	S7-R2-L6	NA	Female	95.3	Ephemeral pond behind OSE Field Station (Blackbird Cay)	17°18'19.60" N, 87°48'08.03" W
4 July	S7-R2-L7	OS-817	Male	150.0	Western shore of Blackbird Cay	17°23'53.7.0" N, 87°49'12.80" W

Table 5. Counts of American crocodile (*Crocodylus acutus*) nests at various beaches in Turneffe Atoll surveyed from 1995 to 2008. Data are from Platt and Thorbjarnarson (1997), Platt et al. (2004), and the present study. Note that 1995 counts are based on incomplete survey data. NA = Not available.

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

Table 6. Spotlight survey data for American crocodiles (*Crocodylus acutus*) in Turneffe Atoll, Belize, 1996-2008.*

Location	Date	Season	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
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
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
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

*Data from Platt and Thorbjarnarson, 1997; Platt et al., 2004; this study.

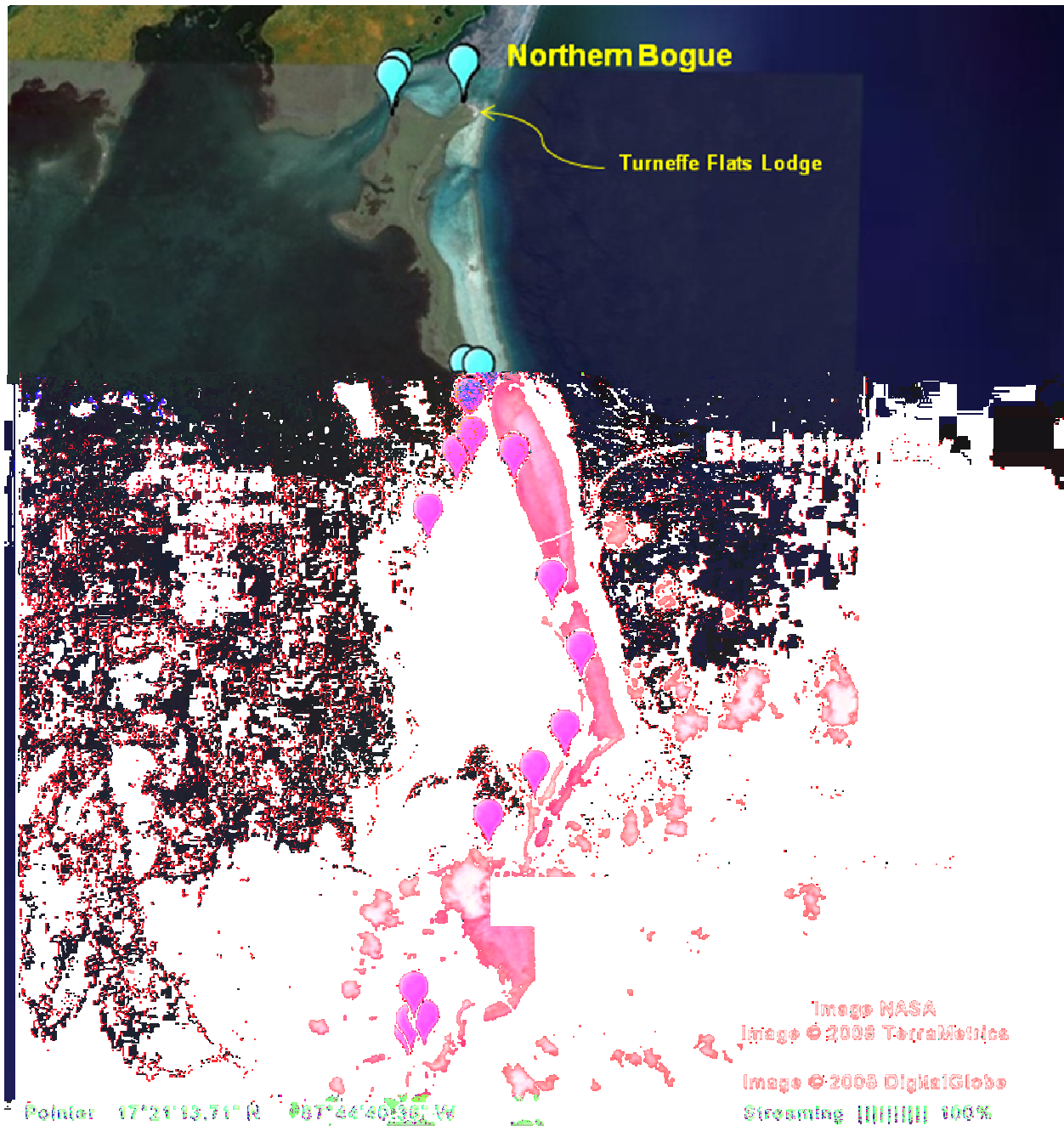


Figure 1. Satellite image (provided by Google Earth) of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) depicting locations where American crocodiles (*Crocodylus acutus*) were encountered during spotlight surveys conducted from 18-23 May 2008. Aqua-colored location markers may denote more than one sighting.

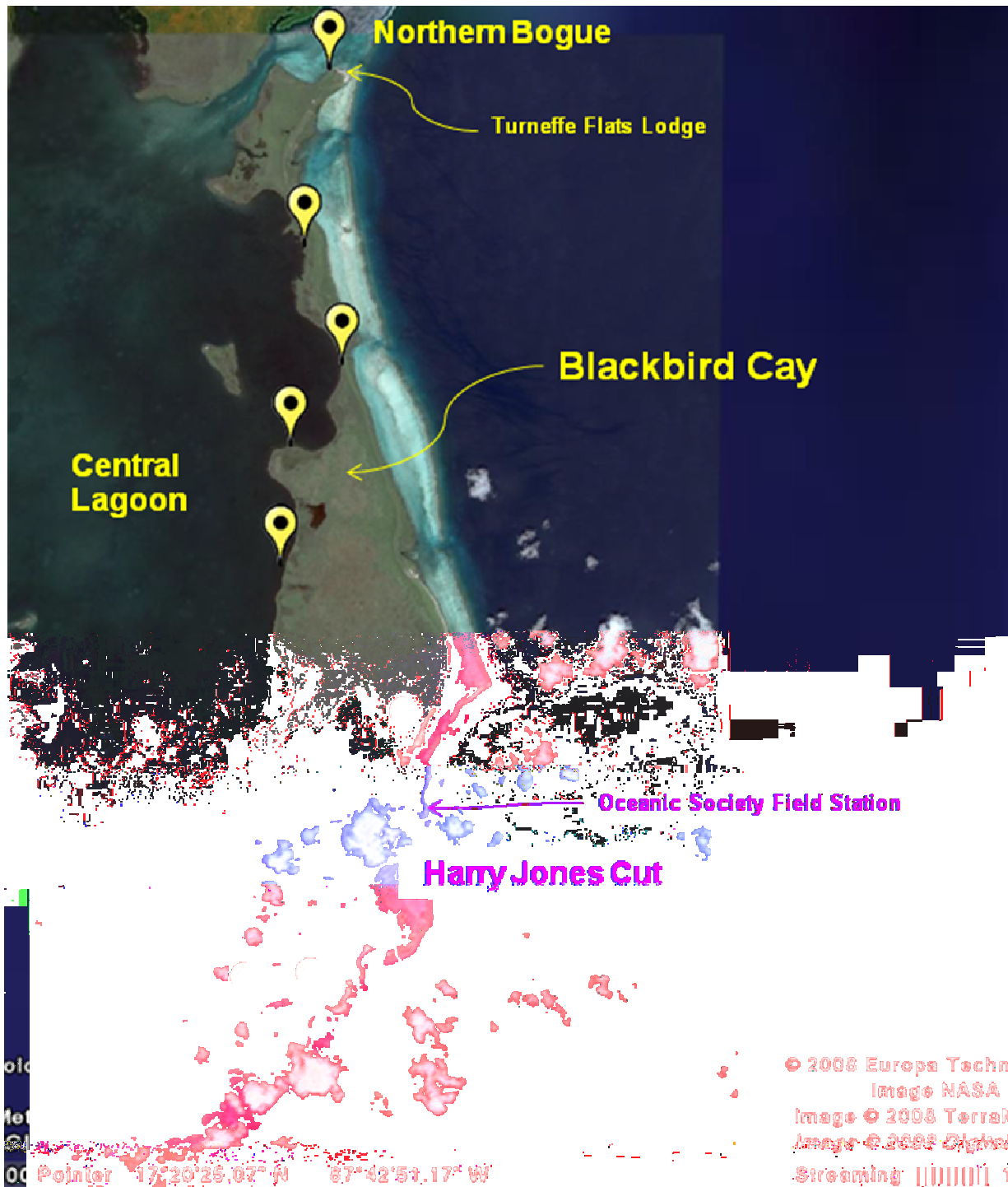


Figure 2. Satellite image (provided by Google Earth) of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) depicting locations (yellow markers) where American crocodiles (*Crocodylus acutus*) were encountered during spotlight surveys conducted from 29 June-4 July 2008.

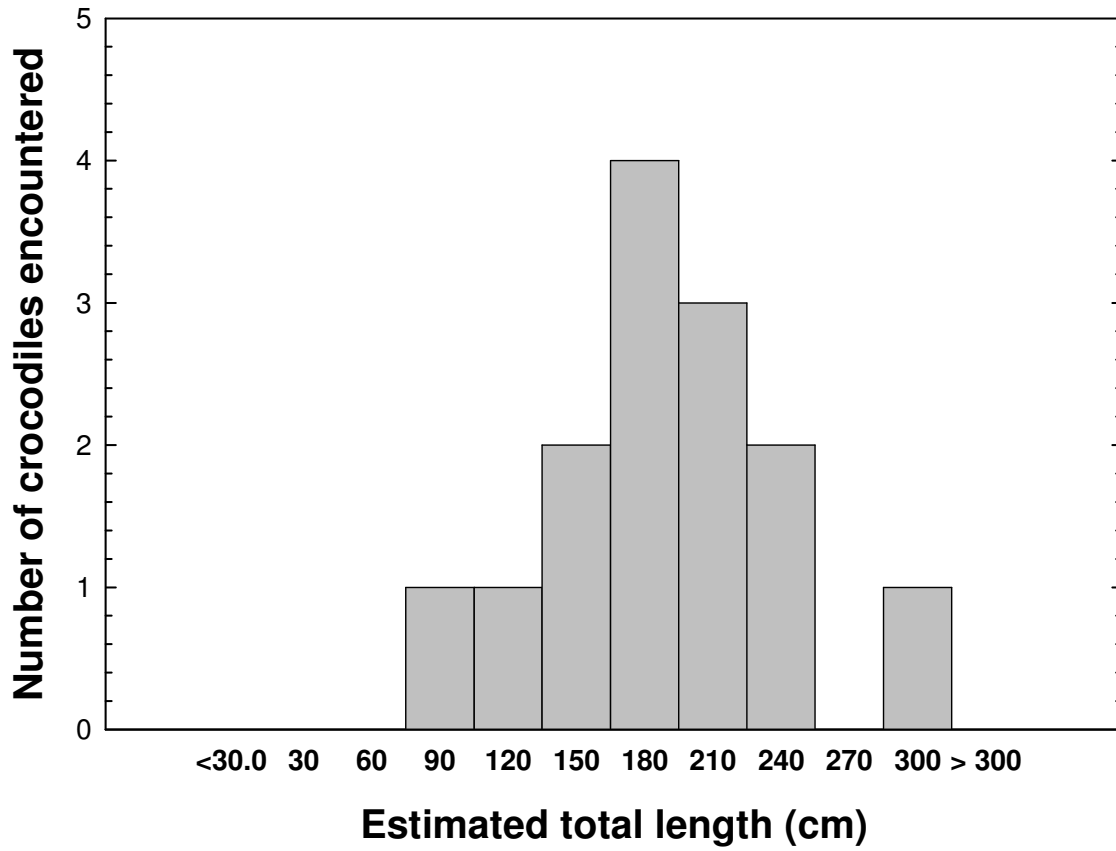


Figure 3. Size class distribution of American crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) from 18-23 May 2008.

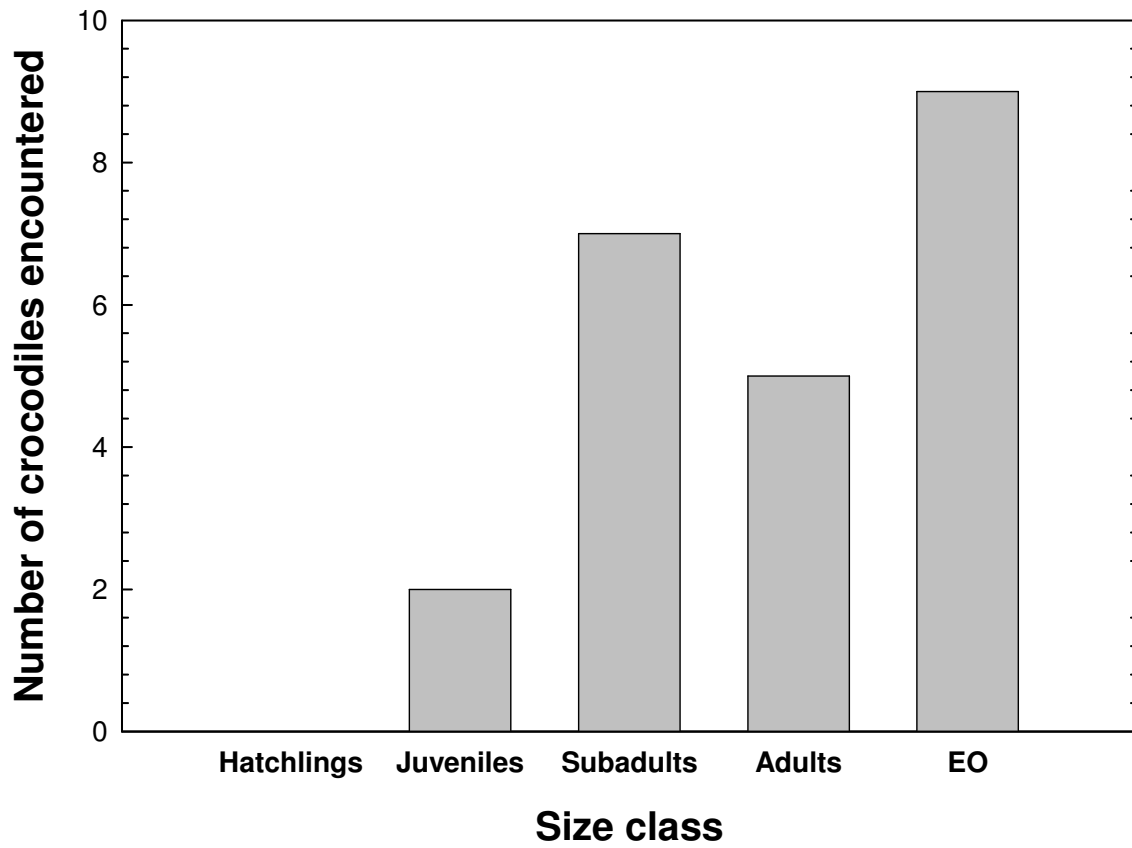


Figure 4. Size class distribution of American crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) from 18-23 May 2008. EO = Eyeshine only.

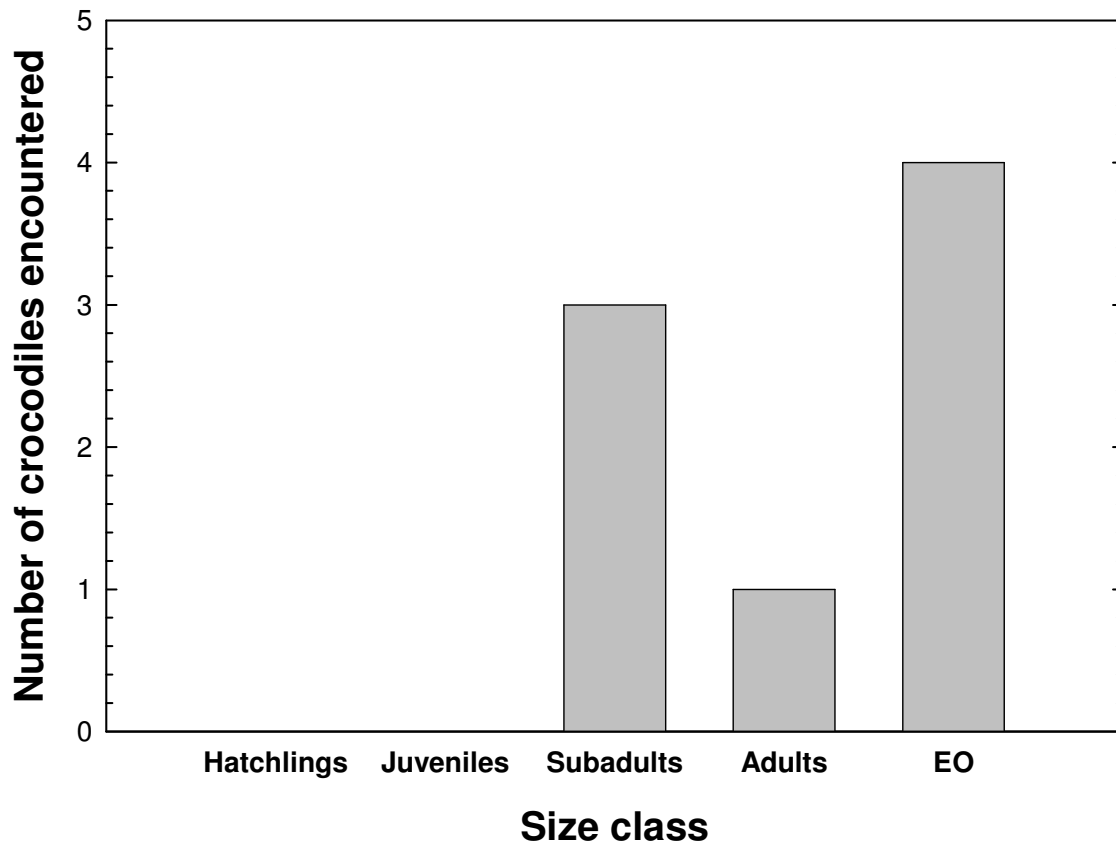


Figure 5. Size class distribution of American crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) from 29 June – 4 July 2008. EO = Eyeshine only.



Figure 6. An airstrip recently constructed on southern Blackbird Cay (top). Debris (primarily dead mangrove) from airstrip construction piled atop a former American crocodile (*Crocodylus acutus*) nest site.



Figure 7. Photographs of a fish camp at the northern end of the beach located on the southeastern shore of Blackbird Cay. The fish camp is situated on an elevated beach ridge previously used by American crocodiles (*Crocodylus acutus*) as a nesting area.