

Possible decline of an American Crocodile (*Crocodylus acutus*) population on Turneffe Atoll, Belize

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ABSTRACT – Surveys of the American Crocodile (*Crocodylus acutus*) in Turneffe Atoll, Belize over the last decade have suggested that populations remain stable but are increasingly threatened by habitat loss, particularly human development of critical nesting beaches. In May, June and July 2008 we used a combination of spotlight surveys and nest counts to evaluate the current status of *C. acutus* populations in Turneffe Atoll. A total of 23 *C. acutus* was observed along 46.6 Km of survey route (0.49 crocodiles/Km) during spotlight surveys in May, and 8 crocodiles were observed along 45.3 Km of survey route (0.18 crocodiles/Km) during late June-early July, yielding an overall 2008 encounter rate of 0.34 crocodiles/Km. This encounter rate was significantly lower than that reported for surveys conducted in 2002. Two recently hatched nests, both on the same beach, were found during nest counts; no nests were found on other beaches known to have routinely yielded nests in the past. The number of nests found in this study is 4- to 10-fold lower than those reported from 1994 to 2004, suggesting a reduction in breeding females in the Turneffe Atoll crocodile population. Development of two important nesting beaches on Blackbird Cay since 2004 has likely rendered these habitats unsuitable for future nesting. The combination of low crocodile encounter rates, reduced nesting activity and human alteration of known nesting beaches observed in this study suggests a possible decline in the *C. acutus* population in Turneffe Atoll. Continued population assessments will be essential in monitoring the status of *C. acutus* in Turneffe Atoll, and immediate management and conservation efforts should be made to protect beaches on Blackbird, Calabash, and Northern Cays to provide critical nesting habitat for crocodiles.

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 & 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 United States Endangered Species Act, and in 1979 was included on Appendix I of the Convention on International

Trade in Endangered Species of Wild Fauna and Flora (CITES) (Groombridge, 1987; Platt & 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 programmes 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 & 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 & 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 & Thorbjarnarson, 2000a).

In the early 1990s, owing to a paucity of reliable population estimates, surveys of *C. acutus* in Belize were given 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 & Thorbjarnarson, 1996), and a country-wide survey of offshore and mainland habitats was completed in 1997 (Platt & 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 (Platt et al., 1999a; Platt & Thorbjarnarson, 2000a; Platt et al., 2004). In addition, Turneffe Atoll is thought to serve as a 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 & 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 & Thorbjarnarson, 2000a; Platt et al., 2004). Because nesting beaches are increasingly threatened by development, Platt & 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 programme based on spotlight surveys and nest counts to determine population trends (Platt et al., 2004). Since 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). Results of these assessments suggested

that the *C. acutus* population in Turneffe Atoll was stable and possibly increasing. Here, we provide results of a recent population assessment of *C. acutus* in Turneffe Atoll conducted in May, June, and July 2008.

METHODS AND MATERIALS

Fieldwork was conducted from 18th to 23rd May and from 28 June to 4 July 2008 in Turneffe Atoll, Belize (Fig. 1).

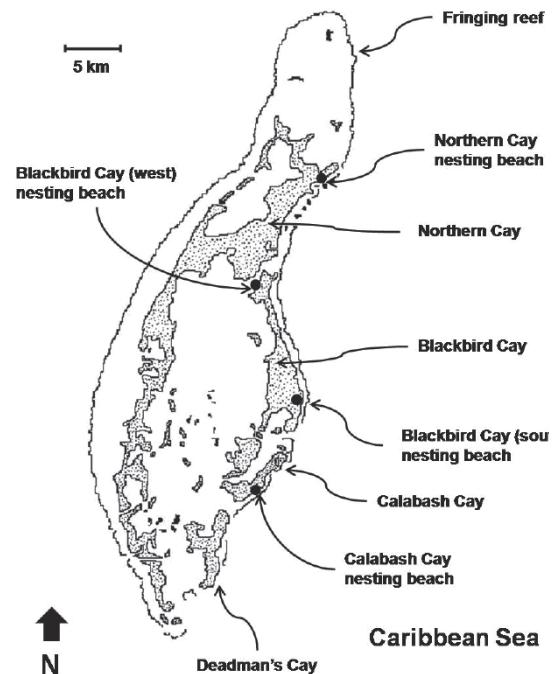


Figure 1. Map of Turneffe Atoll showing localities mentioned in text. Black dots indicate the primary nesting beaches surveyed during this study and correspond to those listed in Table 4.

Turneffe Atoll, located approximately 35 Km east of the Belize mainland, is 50 Km long (north-south), 16 Km wide (east-west), and has an estimated surface area of 533 Km² (Perkins, 1983; Platt et al., 2004). Mean annual rainfall is 1347 mm/year, with a pronounced wet season from June through November (Hartshorn et al., 1984). Rainfall is negligible in April and May, but this may vary annually (Hartshorn et al., 1984). The topography, climate, vegetation, biodiversity and history of the atoll have been previously

described elsewhere (Stoddart, 1962; 1963; Perkins, 1983; McField et al., 1996; Platt et al., 1999a, 2000, 2004).

The *C. acutus* population in Turneffe Atoll 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 eye-shines were detected using a 3,000,000 candlepower Q-beam spotlight. All crocodiles sighted were estimated 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 Map 60. Encounter rates were calculated as the number of crocodiles observed per kilometer of survey route (Platt & Thorbjarnarson, 2000a; Platt et al., 2004).

Nesting areas identified during previous surveys were revisited (Platt & Thorbjarnarson, 1996; 1997; Platt et al., 2004) and searched for signs of nesting activity. *Crocodylus 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 & 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 & 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 & 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) and in late June-early July (Table 2), 2008. Beginning and endpoints of surveys are contained in field notes archived in the Campbell Museum (Clemson University, South Carolina). 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. 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. Combining results of all surveys in

Date	General Survey Location	Distance Surveyed (km)	Crocodiles Encountered	Encounter Rate (Crocodiles/Km)
18 May	Blackbird southeast	5.36	3	0.56
19 May	Blackbird northwest	14.9	11	0.74
21 May	Blackbird southwest	15.5	3	0.19
22 May	Blackbird northeast	5.13	2	0.39
23 May	Calabash northwest	5.68	4	0.70
Total / Overall encounter rate		46.6	23	0.49

Table 1. Results of spotlight surveys conducted in May 2008 to assess American Crocodile (*Crocodylus acutus*) populations in Turneffe Atoll, Belize.

Date	General Survey Location	Distance Surveyed (km)	Crocodiles Encountered	Encounter Rate (Crocodiles/Km)
29 June	Blackbird east	9.2	0	0.00
30 June	Blackbird southwest	11	2	0.18
2 July	Calabash west	12	2	0.17
4 July	Blackbird northwest	13.1	4	0.31
Total / Overall encounter rate		45.3	8	0.18

Table 2. Results of spotlight surveys conducted in June-July 2008 to assess American Crocodile (*Crocodylus acutus*) populations in Turneffe Atoll, Belize.

2008 yielded an overall encounter rate of 0.34 crocodiles/Km (Table 3), with subadults and adults accounting for 89% of the crocodiles for which TL could be estimated (Fig. 2). This encounter rate was significantly lower ($\chi^2 = 37.2$; $df = 1$; $P < 0.05$) than that reported in a similar *C. acutus* survey conducted in 2002 (1.2 crocodiles/Km) (Table 3; Platt et al., 2004).

Nest Counts

During May 2008, no active nests were found during three days of searching at known and potential nesting beaches on Blackbird, Northern, 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

Location	Date	Season	Distance surveyed	Crocodiles encountered	Encounter rate (Crocodiles/Km)
Blackbird Cay (Eastern shore)					
	Nov. 1996	Wet	2.7	7	2.59
	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	0.25
Calabash Cay					
	Nov. 1996	Wet	2.4	6	2.50
	Feb. 1997	Dry	2.4	8	3.33
	April 1997	Dry	2.4	7	2.92
	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

Table 3. Spotlight survey data for American Crocodile (*Crocodylus acutus*) in Turneffe Atoll, Belize, 1996-2008 (Data from Platt and Thorbjarnarson 1997; Platt et al. 2004; this study).

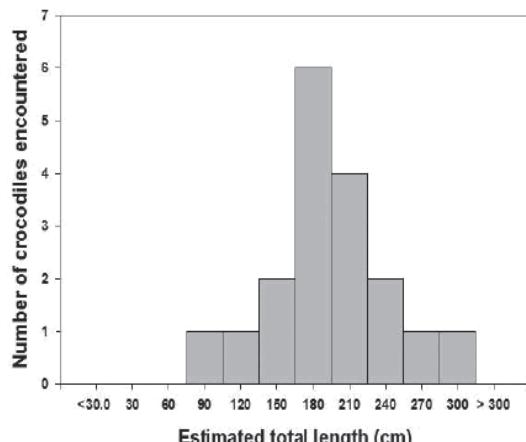


Figure 2. Size-class distribution of American Crocodiles (*Crocodylus acutus*) encountered during spotlight surveys of Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) conducted in May, June and July 2008.

suggesting movement from the sea to a nursery lagoon behind (west of) the beach (Platt & Thorbjarnarson, 2000a; Platt et al., 2004) and vice versa. One juvenile crocodile was observed in the nursery lagoon (ca. 11:30 hrs).

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 4). Both nests were found on a single beach on Northern Cay on 3 July. 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,

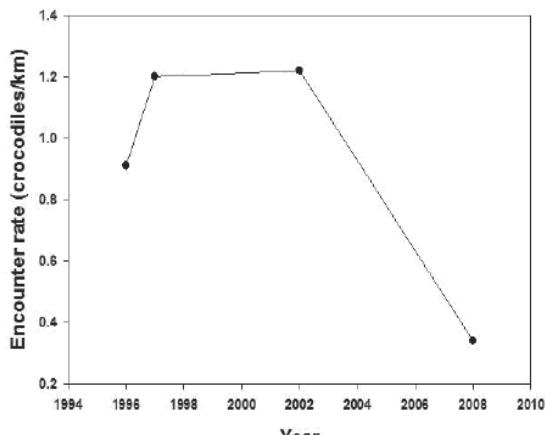


Figure 3. Encounter rates (crocodiles/Km shoreline) of American Crocodiles (*Crocodylus acutus*) along Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) during spotlight surveys conducted in 1996, 1997, 2002 and 2008.

respectively), and four hatchlings were observed among vegetation in a shallow, brackish lagoon approximately 15 m from one nest. On 1 July, a researcher (Tino Chi) stationed at Calabash Cay informed us 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 3 July as no other nests were found after intensive searching of this beach. No nests were found on other known and potential nesting

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 4. Counts of American Crocodile (*Crocodylus acutus*) nests at various beaches in Turneffe Atoll surveyed from 1994 to 2008. Data are from Platt & Thorbjarnarson (1997), Platt et al. (2004), and the present study. Note that 1995 counts are based on incomplete survey data. NA = Not available.

beaches on Blackbird Cay and Calabash Cay (Platt et al., 2004). Coordinates of nest locations are contained in field notes archived in the Campbell Museum.

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 (approximately 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 & Thorbjarnarson, 1997; 2000b) and also creates 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 for access to less saline water (Mazzotti et al., 1986; Richardson et al., 2002; Leslie & Taplin, 2001; Rainwater & Platt, pers. obs.) and therefore 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 could 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 3). 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 3). Yet a different

pattern was noted along Calabash Cay, where crocodile encounter rates remained relatively constant throughout the same period (Table 3). Future spotlight surveys of these areas during consecutive 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 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 3, Fig. 3). The overall crocodile encounter rate in Turneffe Atoll for 2008 (0.34 crocodiles/Km) is 2.7-, 3.5-, and 3.6-fold lower than that observed in 1996, 1997, and 2002, respectively (Table 3, Fig. 3). 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 the result of survey variability or reflect actual 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, of greater concern is the low number of crocodile nests found during nest surveys (Table 4). 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

that yielded nests in previous years (Blackbird Cay south, Blackbird Cay west, Calabash Cay) (Table 4, Fig. 1). One of these beaches (Blackbird Cay 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, 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. The overall number of crocodile nests found on our study sites

Turneffe Atoll in 2008, still a substantial decrease in nesting compared to previous years (Table 4). Future nest surveys will be crucial in determining whether the low number of *C. acutus* nests found in Turneffe Atoll in 2008 reflect a decrease in the number of nesting females in the atoll or 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 &

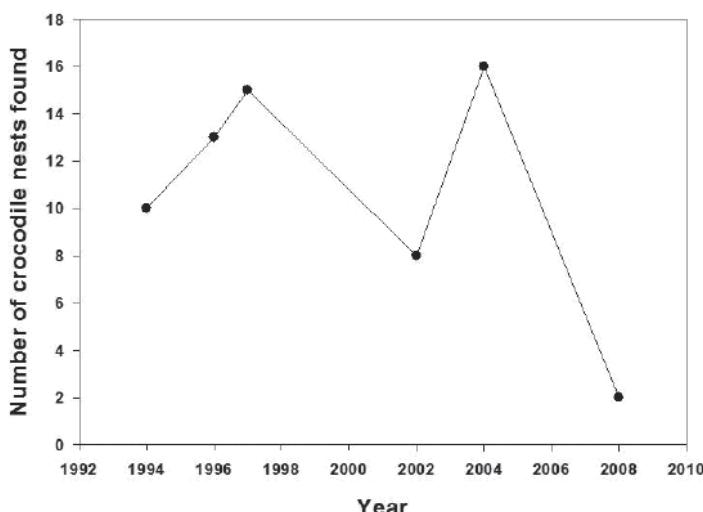


Figure 4. Number of American Crocodile (*Crocodylus acutus*) nests found during nest counts conducted on Blackbird Cay and Calabash Cay (Turneffe Atoll, Belize) in 1994, 1996, 1997, 2002 and 2008.

in Turneffe Atoll in 2008 is 5-, 6.5-, 7.5., 4-, and 8-fold lower than that found in 1994, 1996, 1997, 2002, and 2004, respectively (Table 4, Fig. 4). 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 & 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 possible total of four nests constructed at known nesting beaches in

Thorbjarnarson, 1997; 2000b; Platt et al., 2004), the loss of even a single subadult or adult crocodile, especially a female, may have a significant impact on the overall population of *C. acutus* in Belize.

To summarize, the combination of low crocodile encounter rates, reduced nesting activity, and human alteration of known nesting beaches on Blackbird Cay observed during this study strongly suggests a decline in the *C. acutus* population in Turneffe Atoll. Following crocodile surveys conducted in 2002, Platt et al. (2004) reported that with the exception of Northern Cay, nesting beaches in Turneffe Atoll remained relatively undisturbed. However, while the nesting beach at

Northern Cay has since been designated a Temporary Reserve and is currently protected, alteration of nesting habitats on Blackbird Cay since 2004 has likely rendered this beach unsuitable for future nesting. Management and conservation efforts should be made to protect critical nesting beaches on Blackbird, Calabash, and Northern Cays. 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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