

CONSERVATION

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The Lessons of History and the Future of American Crocodile Conservation in Belize

The American Crocodile (*Crocodylus acutus*) is the most widely distributed crocodylian in the New World, inhabiting coastal and lowland wetlands from southern Florida, USA to the limits of mangrove forest in Peru (Ernst et al. 1999; Platt and Thorbjarnarson 2000a; Fig. 1). In 1973, the American Crocodile was listed as endangered by the International Union for the Conservation of Nature (IUCN), and listed under Appendix I by the Convention of International Trade in Endangered Species (CITES) because of overexploitation, deliberate killing, illegal hunting, habitat loss, and drowning in fishing nets (Thorbjarnarson 1989; Thorbjarnarson et al. 2006). These threats led to a 30% decline in many wild populations of *C. acutus* in the 75 years prior to the establishment of the IUCN, CITES, and national protection laws (Thorbjarnarson et al. 1992). With the implementation of new national laws, international laws, and management strategies over the last 45 years, a few populations have recovered, thus the down-listing of *C. acutus* as Vulnerable by the IUCN (IUCN 2012). Despite population recovery in some areas, American Crocodile abundance and density throughout its historical range remain low and some populations remain at risk of extirpation, requiring continued conservation and evaluation of management strategies (Thorbjarnarson et al. 2006). This holds specific relevance for populations in Belize (Fig. 2), a past stronghold of the American Crocodile (Ross 1998; Platt and Thorbjarnarson 2000b).

Belize is a small country (22,791 km²) nestled south of Mexico on the Caribbean side of Central America, rich in marine and terrestrial biodiversity; a likely reflection of the diverse marine and terrestrial biomes that include the Belize Barrier Reef and Mesoamerican Biological Corridor. Belize is also home to a melting pot of various cultures (i.e., Maya, Creole, Garifuna, East Indian, Mestizo, East Asian, Mennonite and Central American), each with its own unique connection to the native flora and fauna. A preliminary ethnozoological study investigating the relationship between wildlife (particularly crocodiles) and

the residents of Belize (which include recent immigrants from North America) illustrates diverse perceptions and relationships among the different ethnic groups towards the archaic predator (Tellez, pers. obs.). Understanding the diverse views, myths, and misguided information people have of crocodiles is essential in moving forward with the development of an effective management and educational program as conservation is not necessarily just about wildlife, it is about people. The efforts and actions under the umbrella of conservation will rarely be successful if there is a lack of support by the local people who interact with the focal species daily. Currently, there is no management program for the American Crocodile in Belize, and any actions towards its conservation and future management are still in its infancy. As key stakeholders move forward in the decision-making process to protect the American Crocodile, it is pertinent to consider current human-crocodile relations while simultaneously proactively educating the facts to extinguish any false beliefs to further the support of crocodile conservation, or at least establish a tolerance for co-existence.

To further understand human-crocodile relations, and the threats and possible future population trends of the American Crocodile of Belize, an exploration of historical data as well as identifying cultural perspectives and relationships could be advantageous in the creation of a successful conservation program. Here, we provide a brief, yet detailed, review of the historical population trends of the American Crocodile in Belize, and

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FIG. 1. *Crocodylus acutus* (American Crocodile) in Belize.

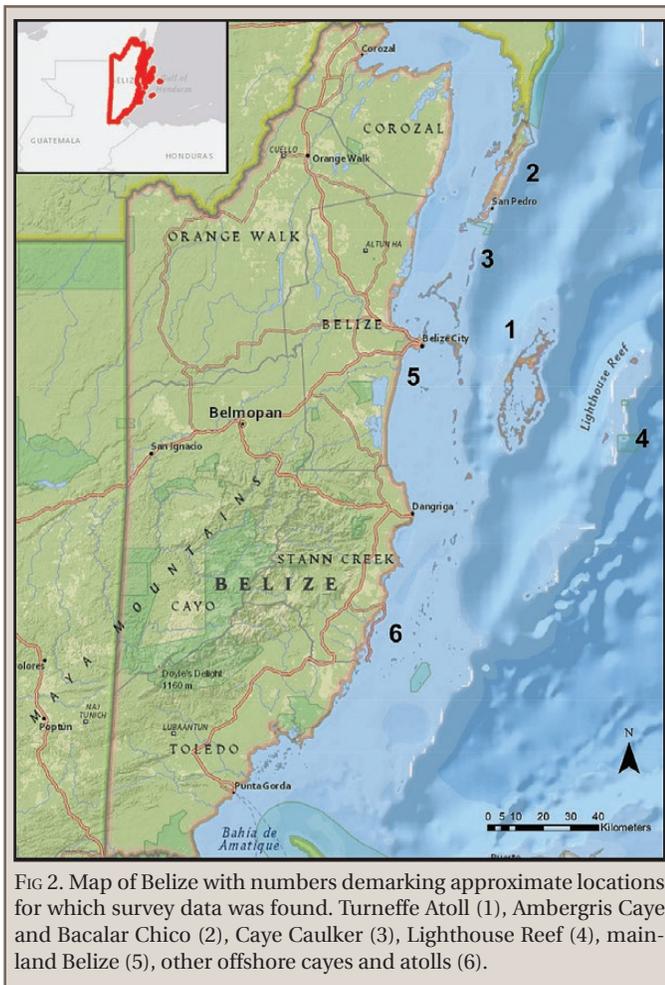


FIG 2. Map of Belize with numbers demarking approximate locations for which survey data was found. Turneffe Atoll, Ambergris Caye and Bacalar Chico (1), Caye Caulker (2), Lighthouse Reef (4), mainland Belize (5), other offshore cayes and atolls (6).

conclude with a discussion of current and future conservation efforts by key stakeholders, which include the creation of a crocodile conservation and management program, and community outreach programs that endorse active community participation in crocodile conservation and their habitat.

METHODS

Literature review.— Prior to addressing collected data, several considerations merit review. Recorded surveys are sparse for Belize and contiguous data is unavailable for most sites with the exception of Ambergris Caye and Turneffe Atoll. Additionally, credible data of antiquity are nearly non-existent and consist primarily of anecdotal observations and reports.

We collected material for review by conducting rigorous database searches, including Science Direct, Wiley Online Library, and BioOne, using the terms “population; status; survey of American Crocodiles; *C. acutus*; *Crocodylus acutus*; Belize/British Honduras” as search criteria. We retrieved further documentation from publicly sourced newsletters and proceedings of the IUCN/Species Survival Commission-Crocodile Specialist Group (CSG), and by direct request from the journal *Oryx* and from the InterLibrary Loan Internet Accessible Database (ILLiad) of West Virginia University. Following collection of relevant materials we extracted quantitative data and collated nest and population survey results into a collective spreadsheet. We recorded metadata for each entry to include; survey year, location, site, kilometers surveyed, nest counts,

total crocodiles encountered, and crocodile encounter rate. Our data is not structured appropriately for statistical analyses as available data was not sufficient, and the purpose of our report is to provide a review of past work. Rather, our results are presented in discussion and as figures or tables for collected data.

RESULTS

History of *Crocodylus acutus* in Belize.—“Alligators of large size infest most of the inland lagoons, and provide good sport at the out-stations” (Morris 1883). The earliest accounts of crocodiles in Belize suggest a relatively abundant population of both species, with few confirmed records of *C. acutus* on the mainland (Schmidt 1924). American Crocodile populations still appeared healthy and abundant in the late 1930s despite the rise of crocodile hunting in the 1920s, a response to the fashion industry demand for crocodile products (Sanderson 1941). By the late 1950s, indiscriminate hunting of the last 30 years led to near extirpation of the species (Wright et al. 1959; King et al. 1980; Ross 1998; Platt and Thorbjarnarson 2000a). The rarity of *C. acutus* sightings along the coast mirrored the decline of the once thriving populations of crocodiles amongst the cayes, now devoid of the aquatic predator (Charnock-Wilson 1970; Powell 1971; King et al. 1980; Abercrombie et al. 1982). This scenario provides a glimpse of the possible pivotal role of caye populations as the source population of American Crocodiles in the region.

Forty years of intense commercial harvesting and trophy hunting of *C. acutus* (particularly among the cayes) decimated the American Crocodile population in Belize to near extirpation by the late 1970s (Powell 1971; King et al. 1980). Interestingly, description of crocodiles observed during a 1978 study in saltwater mangrove lagoons, swampy creeks or sandy beaches describe animals that did not adhere implicitly to the standard morphometric characteristics of *C. moreletii* or *C. acutus* (Abercrombie et al. 1982). Given our current observations of crocodiles along the coast of southern Belize, perhaps the lack of *C. acutus* sightings is a glimpse of evidence of hybridization between the two species (Tellez, pers. obs.). Identifying *C. moreletii* x *C. acutus* hybrids in the wild can be troublesome, and misidentification of an individual is probable (Sanchez-Hererra et al. 2012; Pacheco-Sierra et al. 2016; Tellez pers. obs.). Although hybridization may be a common phenomenon between the two species (Hekkala et al. 2015; Pacheco-Sierra et al. 2016), perhaps the 1978 population survey reflects a relatively recent rise of hybridization as parental species (particularly *C. acutus*) became scarce due to past overexploitation.

In 1981, Belize gained its independence from the United Kingdom, and created the Wildlife Protection Act (WPA), which included strict legislation against hunting and trade of wildlife products. Although crocodiles finally became legally protected under this national mandate, officially banning commercial hunting of crocodiles in Belize, opportunistic killing continued due to a lack of tolerance and fear (Aguilar, pers. obs.). Some members of the older generation in Belize contribute the lack of involvement in wildlife management and decisions pre-Independence as a principal factor causing the lack of tolerance or co-existence with wildlife (Manglar, pers. obs.), particularly with crocodiles. Despite the fear and lack of tolerance, the protection of American Crocodiles under the WPA Chapter 220 likely initiated the slow recovery of the species on the atolls (Turneffe Atoll, N = 200–300), with few confirmed sightings of the species along the mainland (Perkins and Carr 1985; Meerman

TABLE 1. Population survey data of American Crocodiles (*Crocodylus acutus*) in Turneffe Atoll, Belize, from 1994–2010. Data from Platt and Thorbjarnarson (1996, 2000a), Platt et al. (2004), Rainwater (2008, 2010), and Rainwater and Platt (2009).

Year	Location	Distance surveyed (km)	Crocodiles spotted	Encounter rate (crocodiles/km)
1994	Turneffe Atoll	94.60	50	0.53
1995	Turneffe Atoll	37.60	17	0.45
1996	Turneffe Atoll	20.80	19	0.91
1997	Turneffe Atoll	41.60	49	1.18
1997	Turneffe Atoll (countrywide)	156.80	152	0.96
2002	Turneffe Atoll	40.10	49	1.22
2008	Turneffe Atoll	91.90	31	0.34
2009	Turneffe Atoll	56.8	33	0.58
2010	Turneffe Atoll	52.2	19	0.34

TABLE 2. Nest survey data of American Crocodiles (*Crocodylus acutus*) on Turneffe Atoll from 1994–2008. Note that 1995 survey data are incomplete, NA = not available. Data from Platt and Thorbjarnarson (1996), Platt et al. (2004), Rainwater (2008, 2010), and Rainwater and Platt (2009).

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

1994). However, any achievements made between 1980 and the early 1990s by the implementation of this law are unclear. With the perceived small population of the American Crocodile inhabiting Belize, as well as low numbers throughout its range, the IUCN declared the American Crocodile Endangered in 1986.

By the late 1980s–early 1990s, concern for the conservation status of the American Crocodile throughout its range initiated discussion amongst CSG members for increased population assessments and investigation into the ecology of American Crocodiles for the development of a conservation management plan of the species (Thorbjarnarson et al. 1992). The commencement of American Crocodile population surveys in Belize sparked a crocodile renaissance in-country, creating an increased collection of relevant quantitative survey data from various locations, generating a multitude of data sets. As a result, a few locations began encompassing contiguous years of vital data, such as Turneffe Atoll.

Turneffe Atoll and its surrounding cayes have had the most comprehensive American Crocodile survey data to-date (Table 1). Published surveys commenced in 1994 (0.53 crocodiles per km shoreline surveyed) with encounter rates increasing linearly from 1996, 1997, and 2002, (Platt and Thorbjarnarson 1996; Platt and Thorbjarnarson 2000a; Platt et al. 2004). In 2008, the linear population increase came to a halt with a severe drop in the crocodile encounter rate (0.34 crocodiles per km), mirrored by a decrease nesting activity (Rainwater and Platt 2009). However, crocodile nesting and encounter rates both began to increase again over the next five years (T. Rainwater and S. Platt, pers. comm.). The rise in development on Turneffe Atoll may be a primary factor contributing to the population and nesting declined observed. Even with adequate aquatic habitat, limited nest site availability

has the potential to limit the growth of crocodile populations and decrease recruitment (Platt et al. 1998, Platt and Thorbjarnarson 2000b). However further monitoring is required to determine if the decline is legitimately the result of anthropogenic disturbance, natural variation in nesting effort in relation to the small number of adult females (Rainwater and Platt 2009), both.

Ambergris Caye is another area in Belize with somewhat contiguous population survey data since the 1990s. The first official crocodile population survey on Ambergris Caye recorded a total encounter rate of 0.34 crocodiles/km across 96.9 km (Platt and Thorbjarnarson 1997). Almost 15 years later encounter rates increased to 0.71–0.96 crocodiles per km (Chenot-Rose et al. 2011; Chenot-Rose 2013), likely reflecting a decrease in illegal hunting and opportunistic killings in conjunction to a population recovering from past exploitation. Observations from an ongoing project examining immunology and parasitology of American Crocodiles on Ambergris Caye further support the hypothesis of recovery given the identification of 276 individuals across ~177.6 km (1.55 crocodiles/km; Partyka, unpubl. data). However, this recovery might also reflect dispersal of American Crocodiles from Mexico moving south as habitat reaches carrying capacity in Mexico. Thus, even with the ongoing rapid loss of habitat, in addition to a resurgence of opportunistic killings (particularly to sell crocodile products to tourists and illegally sell the meat), the American Crocodile population may continue to grow and remain stable via immigrants from the north. A collaboration between researchers from Mexico and Belize is currently underway to investigate dispersal patterns of American Crocodiles in this area to validate the aforementioned hypothesis. Interestingly, American Crocodiles appear to be seeking refuge from loss of habitat around the cayes sewage

TABLE 3. Population survey data of American Crocodiles (*Crocodylus acutus*) from the coastal zone of Belize, including the mainland. Data from Platt (1995) and Platt and Thorbjarnarson (1997).

Year	Location	Distance surveyed (km)	Crocodiles spotted	Encounter rate (crocs/km)
1994	Maps Cay	12.9	11	0.85
1997	Maps Caye	21.0	3	0.14
1995	Bacalar Chico	42.7	8	0.19
1997	Frenchman's Caye	12.0	1	0.08
1997	Hick's Caye	13.7	5	0.36
1997	Lighthouse Atoll	5	1	0.20
1997	Long Caye	8.4	4	0.47
1997	Middle Long Caye	27.6	2	0.07
1997	Caye Caulker	14.1	48	3.4
2016	Caye Caulker	22.15	55	2.4
2004	Twin Cayes	—	3	—
1997	North Mainland	206.1	3	0.01
1997	South Mainland	369.5	11	0.02

ponds, as data illustrate an increase in density within this area (Tellez and Boucher, unpubl. data).

Since the nationwide survey of *C. acutus* in 1997, the population of Caye Caulker has been surprisingly ignored (given the size of the population relative to the size of the caye). During the initial survey, Platt and Thorbjarnarson (2000a) reported a relatively high encounter rate compared to other locations in Belize ($N = 52$, 3.40 crocodiles per km), yet, a population still in a state of recovery from past over-exploitation. Almost 20 years later, a recent survey describes the Caye Caulker population as relatively stable ($N = 55$, 2.4 crocodiles per km) (Tellez et al. 2016). However, a rapid rise of habitat destruction in 2017 in response to increase residential and hotel development in conjunction to an increase illegal trade of crocodile products have exponentially increased human–crocodile conflict, resulting in a rise of crocodile deaths, thus the stability of this population is in question (Tellez, pers. obs.).

Population data of other offshore islands are available, yet sparse in comparison to the aforementioned islands (Table 3). It is likely these islands have been largely ignored given the initial small populations of *C. acutus*, i.e., Maps Caye in 1995 ($N = 11$) and 1997 ($N = 3$); Lighthouse Atoll from 1996–1997 ($N = 2$ adults, 1 hatchling, 1 nest) and Twin Cayes in 2004 ($N = 3$) (Platt and Thorbjarnarson 1996, 1997; Platt et al. 1999; McKeon and Feller 2004). Other confirmed nest sites found among surveyed islands include Maps Caye during the 1994 and 1997 survey, and Long Caye in 1997 (Platt and Thorbjarnarson 1996, 1997).

Similar to offshore cayes, mainland survey data are limited to those from the countrywide survey completed in 1997 (Platt and Thorbjarnarson 2000a). A total of 14 *C. acutus* in only 5 locations were observed over 574.6 km, the lowest encounter rate of any data found (Platt and Thorbjarnarson 2000a). However, this may no longer be representative of mainland populations as in recent years there has been increased concern by northern communities of Belize about the increase of American Crocodiles encountered around human developments (Sandoval, pers. obs.). Additionally, the recent discovery of two large populations of *C. acutus* on the mainland not previously identified in southern Belize reforms the past conjecture that *C. acutus* is not common on the mainland (Tellez and Boucher, pers. obs.).

LEARNING FROM HISTORY TO WRITE A NEW CONSERVATION CHAPTER

So what has history taught us about the American Crocodile in Belize? Exploitation of crocodiles for their skin and meat almost led to the extirpation of *C. acutus* in Belize by the 1950s. The population remained desolate for the next 30–40 years as a result of the continuous lack of wildlife enforcement and laws to protect these animals, and recovery did not transpire until the establishment of legal protection and enforcement in the early 1980s (Rainwater and Platt 2009; Tellez et al. 2016; Rainwater, pers. obs.; Tellez and Boucher, pers. obs.). The recovery of the American Crocodile in Belize correlated to the increase of crocodile abundance among the cayes, suggestive of the cayes' importance as a source population within the region. Perhaps mainland populations of *C. acutus* represent dispersed individuals or progeny from the cayes as habitat reached its carrying capacity of the species. However, given the rise of *C. acutus* in some locations along the coast, conservationists and researchers should be open to the idea that we currently may be witnessing a shift in location of source and sink populations. Resident crocodiles of Turneffe Atoll, Ambergris Caye, and Caye Caulker are already facing the pressure of dispersing and finding new suitable (nesting) habitat as the cayes are currently under rapid development relative to the coast of Belize, and it's possible that more individuals are dispersing towards the coast seeking refuge. The development among the cayes is likely not to stop in the near future given the increased popularity of Belize as a retirement and tourist destination, thus, it is significant to locate key habitat and nesting locations to ensure the stability and reproductive vitality of *C. acutus*. Perhaps the creation of an American Crocodile reserve or sanctuary among some closely-linked cayes could provide the necessary habitat (Hekkala et al. 2015) and refuge for *C. acutus*.

Undoubtedly the American Crocodile population succumbed to the hands of hunters in the past 100 years in Belize, however illegal hunting is no longer the principal danger. Pollution, and development seem to be the primary dangers threatening the American Crocodile (Platt and Thorbjarnarson 1996, 2000a; Rainwater and Platt 2009; Rainwater 2010; Chenot-Rose 2013;

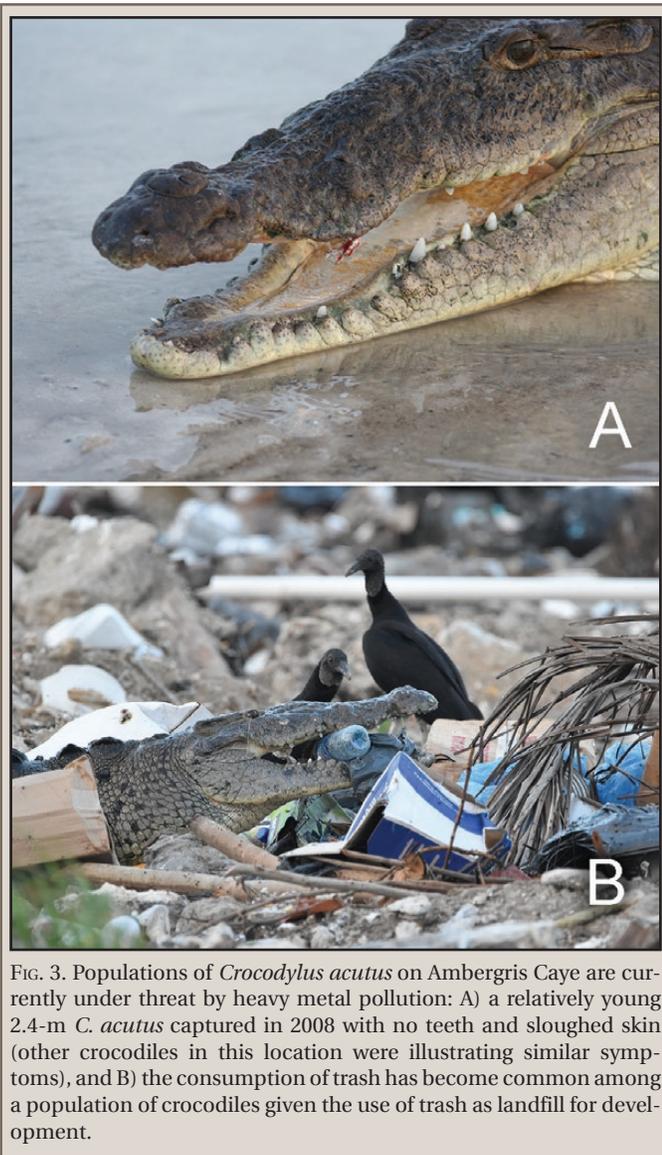


FIG. 3. Populations of *Crocodylus acutus* on Ambergris Caye are currently under threat by heavy metal pollution: A) a relatively young 2.4-m *C. acutus* captured in 2008 with no teeth and sloughed skin (other crocodiles in this location were illustrating similar symptoms), and B) the consumption of trash has become common among a population of crocodiles given the use of trash as landfill for development.

Tellez and Chenot-Rose 2015). Shoreline development decreases available nesting and nursery habitat, and large-scale mangrove clearance impacts overall habitat use by American Crocodiles. As a result, American Crocodiles may increasingly seek more unconventional habitats such as residential communities, inland wetlands, and man-made structures in which they would not normally be found. The thriving population of American Crocodiles in the wastewater treatment ponds of an offshore caye is a prime example. The area is surrounded by extensive development, mangrove clearance, and dredging. However, the ponds themselves are isolated and see little human traffic. Additionally, the raised berms of the ponds are, not by design but function, extremely suitable for nesting and are used annually by the resident adult population. The raw sewage does not appear to hamper the growth or health of individuals observed and captured in the ponds, however, pollution has had considerable impact on American Crocodiles in other locations in Belize. Current research addressing increases of pollution within crocodylian habitat is indicating that crocodiles and aquatic biota are beginning to show the effects of their toxic environment, such as on Ambergris Caye (Tellez, unpubl. data). Crocodiles of all sizes have been caught emaciated, with no teeth, skin

sloughing off, physical deformities (particularly in hatchlings), or illustrating symptoms of neurological disorders such as star-gazing (Fig. 3). These abnormalities may be a result of living in an environment in which trash is being used as landfill and chemical waste is seeping into the aquatic habitat. Moreover, stomach content data and behavior observations infer crocodiles are exposed to non-organic chemicals through the consumption of trash (Boucher and Tellez, pers. obs.). Collaborative efforts among various environmental and conservation organizations are gathering increasing evidence of the adverse effects of environmental toxicity on crocodiles and adjacent wildlife in Belize (Tellez, unpubl. data). However, the negative impacts of pollution seem to outpace the scientific research.

Although not as formidable a threat to survival such as habitat destruction and pollution, hybridization between *C. acutus* and *C. moreletii* has recently raised concerns among key stakeholders about the future genetic integrity of the parental species (Hekkala et al. 2015). Hybridization or introgression is a common phenomenon between the sympatric crocodylian species, possibly existing for several generations as a result of natural processes (Ray et al. 2004; Hekkala et al. 2015; Pacheco-Sierra et al. 2016). The present level or occurrence of hybridization between *C. acutus* and *C. moreletii* is unknown, however, of concern is the possible increase rate of admixing as *C. acutus* loses more habitat along the coast, dispersing further inland into historically *C. moreletii* habitat. Individual specimens recently caught (May 2016 to August 2016) from a field site inhabited by *C. acutus* and *C. moreletii* (N = 83) illustrate morphological features of both species as described in Herrera et al (2012) and Hekkala et al (2015); it is almost becoming commonplace (particularly south of the Belize River) to find individuals not adhering to the standard morphological characteristics of the parental species (Tellez and Boucher, pers. obs.). It would seem that if conservationists are concerned about the loss of genetic integrity of American and Morelet's crocodiles, the preservation of key (nesting) habitat is essential.

Although the collection of scientific data is necessary in advancing any conservation efforts of the American Crocodile, acceptance and interest in the conservation of the species among communities is fundamental for the success of any current and future management program. Many Belizeans are unaware of the protection status of crocodiles, do not understand the possible important ecological role crocodiles serve in their environment in conjunction with the possible economic opportunity via ecotourism, or unaware of the knowledge to live in co-existence with species that are relatively shy and timid. The preliminary data from an on-going community perception survey about crocodiles in Belize suggests that the lack of educational outreach, sensationalized TV documentaries or shows, and the previous ideology of relocating non-problematic crocs (which ultimately subconsciously teaches fear and the lack of desire to co-exist with crocodiles) has resulted in wide-spread misguided information and false facts about the predators (Tellez, unpubl. data). The lack of tolerance has led to the continual harassment and illegal hunting of crocodiles as they are seen as vicious predators or pests. Key stakeholders (i.e. the Crocodile Research Coalition (CRC), The Belize Zoo, and the Belize Forest Department) are currently combating opportunistic killings or false beliefs through intensive crocodile educational outreach, which include festival and school presentations, radio and TV interviews, interactive social media posts, local internship and volunteer opportunities, and community involvement programs.

For example, Next Gen Croc initiated by the CRC in collaboration with the Forest and Marine Reserve of Caye Caulker (FAMRACC), is a crocodile monitoring program that mentors Ocean Academy high school students on Caye Caulker to conduct official monthly nocturnal eyeshine surveys in addition to monthly community outreach to educate locals and tourists about the American Crocodile, the environment, and adjacent wildlife. Students of Next Gen Croc are already proving themselves as local advocates for crocodile conservation, pioneering the establishment of a long-term American Crocodile monitoring program on the caye. We anticipate that outreach programs such as Next Gen Croc will motivate young conservationists to establish local initiatives, as well as build a strong foundation for the future stewards of conservation management in Belize. Given the logistical support received by the local communities and government for programs similar to Next Gen Croc, it would appear integrative management and mentorship programs will emerge as a new approach of conservation management in contrast to previous programs, which tentatively ignored community participation in local conservation efforts.

Similar to other wildlife species in threat of survival, the long-term management of American Crocodiles of Belize would likely benefit from ongoing conservation efforts, not simply a one-time positive intervention. Education and the re-establishment of cultural linkage between crocodiles and Belizeans could reignite pride in the species, further promoting a countrywide sentiment of species protection. For example, discussing the importance of crocodiles within the Maya culture (such as being the only animal recognized to connect the celestial, terrestrial and underworld, as well as being the first symbol of the Maya Calendar) has warranted further positive interest to learn more about crocodiles amongst communities and tourists, as well as stimulating tour guides and tour operators to take positive action towards crocodile conservation. Encouraging local participation can help identify a champion, one who can lead the conservation efforts for the American Crocodile in the perspective region. This is extremely important to gain further community support for wildlife conservation efforts. Lastly, an updated countrywide population survey is warranted to update the status of *C. acutus* in Belize, and reevaluate data deficient areas such as the mainland. It is unlikely that the population of American Crocodiles will ever reach its once historical abundance given the current threats of habitat destruction and pollution, however, stakeholders can work together to ensure the population remains stable while simultaneously mitigating local extirpation. Given the recent interest in crocodile management, rise in crocodile research, and collaborative efforts by various stakeholders and young conservationists, we believe Belize is entering a Second Renaissance of crocodile conservation that will be favorable for both *C. acutus* and local communities for generations to come.

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