NUI Galway
OÉ Gaillimh

The effects of Urbanisation and illegal feeding practices on the behaviour, body condition, and ecosystem health of wild Crocodylus acutus on Ambergris Caye, Belize.

Disappearing dinosaurs: Crocodiles of the Cayes.

Author: Gary Moscarelli (18353201)

Supervisor: Dr Kevin Healy

Zoology BS4

Zoology department School of Natural Sciences

Thesis submitted as part of the Bachelor (Hons.) of Science Degree

Contents:

Tables and figures

Tables:

Figures:

<u>The effects of Urbanisation and illegal feeding practices on the behaviour, body condition, and ecosystem health of wild *Crocodylus acutus* on Ambergris Caye, Belize.</u>

<u>Abstract:</u>

Urban development of natural areas along with illegal wildlife activities adversely effects our wildlife, with the increasing pace of development likely to increase the damage to our natural areas. Human development of the habitat of keystone species such as crocodiles not only effects the species in question, but also adversely effects the entire ecosystem function. This study aims to assess the impacts that illegal feeding practices and urbanisation has on crocodilian behaviour, body condition, and their surrounding ecosystem. The effect of unstructured illegal feeding practices involving *Crocodylus acutus* on Ambergris Caye, Belize along with the recent increase in deforestation and urbanisation on the island was investigated to assess its impacts on the present population of crocodiles and their surrounding ecosystem. Here we use data to provide results that highlight the impacts that illegal feeding accompanied with the uncontrolled development of the island has had on the behaviour and health of the crocodiles, as well as the possible negative implications for their surrounding ecosystem. Our results highlight the negative effect unregulated ecotourism and urban development have had on the behaviour and health of *Crocodylus acutus* and their wetland ecosystem. We found a complete change in human associated crocodile behaviour, and possible biological signs of poor environmental health. The study sheds light on the complexities of wildlife management involving large predators and we hope that this research will allow the implementation of better wildlife practices that will benefit the local economy, the local wildlife, and the ecosystem.

<u>Introduction:</u>

Ambergris Caye forms the southernmost extent of the Mexican Yucatán peninsula and is located approximately 0.8km from the Belize barrier reef, which is a UNESCO world heritage site (Sweetman et al., 2018). The proximity to these reef ecosystems has made the island the most important tourist destination in Belize, as well as the country's economic hub (Sweetman et al., 2018). San Pedro town is considered the epicentre of industry and tourism on the island and has seen a 432% increase in population between 2000-2017 (Statistical institute of Belize, 2017). This increase in population size and the rapid development of infrastructure across the island has caused an acceleration of deforestation, illegal wildlife activities, pollution, and landscape transformation within the last two decades (Steinberg, 2015). Mangrove forests, shrubland, low-land broad leaf dry forests, wetland, and littoral forests are the dominant ecosystem types of Ambergris Caye (Meerman and Sabido et al., 2001). This diversity of ecosystems, along with its proximity to the Mexican Yucatán peninsula to the North, means that Ambergris Caye is unique in its biodiversity when compared to other offshore Cayes e.g., Caye Caulker (Grimshaw and Paz, 2004). The island is home to many species otherwise only found on the mainland, including all 5 central American big cat species including jaguar and puma, and the endangered white lipped peccary (Grimshaw and Paz, 2004). Much of this biodiversity is now restricted to the far North of the island, within the Bacalar chico natural reserve. The accelerated destruction of the island's vegetation and coastal ecosystems by the tourist industry can lead to the degradation of adjacent coral reef ecosystems, due to the overproduction of sediment coupled with nutrient run-off (Bartley et al., 2014). This poses a major threat to the local economy, as it is almost entirely supported by the reef (WWF, 2022). Due to their position at the top of the food chain, many of these negative anthropogenic effects are exhibited in the wild population of *Crocodylus acutus* on the island, most notably in their behaviour, and the prevalence of the ectoparasite *Paratrichosoma* which is an environmental indicator.

Between 1996 and 2017 mangrove deforestation on Ambergris Caye accounted for almost 20% of all mangrove deforestation that occurred in Belize (Cherrington et al., 2020). This is concerning considering the island itself is only 4km wide and roughly 30km long (Guderjan, 1995). Mangroves offer important ecological services to coastal human habitations throughout Latin America as they provide protection against tropical storms (Mumby et al., 2004) and are critical to sustaining the fishing industry. Mangroves act as nurseys for many economically important fish species, with the biomass of several commercially important species more than doubling when their adult habitat is connected to mangrove systems (Mumby et al., 2004). Large untouched areas of mangroves also provide the habitat required to keep crocodiles and people away from each other. This space is essential to prevent our species having to share communal areas.

Mangroves represent important habitat for adult American crocodiles to hunt and reside in, as well as providing important refugia places for hatching and juvenile individuals (Balaguera-Reina et al., 2016). Hatchling American crocodiles have an extremely low survival rate due to their size (~0.50-0.70g at birth) with between 1-16% of individuals from a clutch surviving on average, depending on clutch size and geographic location (Briggs-Gonzalez et al., 2017). The thick intricate maze that the mangroves and their roots produce help hatchling crocodiles to avoid detection from predators, while simultaneously providing food sources for both young and adult individuals (Singh 2014).

The increased popularity of Ambergris Caye with holiday makers has also led to a spike in illegal wildlife activities on the Caye, most notably the illegal feeding of American crocodiles around the town of San Pedro (ACES Wildlife Rescue data, unpublished). American crocodiles are protected under Belizean constitution, meaning it is illegal to feed, capture, or harass these reptiles, with the possession or selling of American crocodile teeth, skin, bones, or meat also illegal under the wildlife protection act (Belize forest department, 2022). Different species of animals react differently to interactions with humans due to the development of situation specific responses (reference needed). These responses are formed from a combination of active learning and inherent behaviour that have been selected for (Whittaker and Knight 1998).

Learned responses that attract wildlife to people can be detrimental to the wild population, dangerous to the person attracting the animal, and puts future people visiting the area in danger of a conflict with the attracted species (Whittaker and Knight 1998). The responses wildlife has to interactions with humans can be classified into 3 main categories, "**attraction**", "**habituation**", and "**avoidance**" (Knight and Cole 1991). Attraction regarding interactions between humans and wildlife is defined as the strengthening of an animal's behaviour due to positive reinforcement and implies movement toward the stimuli (Knight and Cole 1991). This stimulus is most associated with humans supplying food to an individual organism or a population, but includes other stimuli such as shelter, or an altered habitat e.g., birds congregating at a bird bath (Knight and Cole 1991). Avoidance is the opposite of attraction and is an aversion or avoidance to negative consequences associated with human actions (Knight and Cole 1991). For example, Finnish grey wolves have learned to avoid roads and human settlements due to past human persecution, with studies showing on average that these organisms actively avoid human settlements by 1km and roads by 250m (Kaartinen et al., 2005). Habituation refers to a waning response to a repeated neutral stimulus, meaning that a habituated animal would ignore humans, or the human introduced stimuli when both are sharing the same environment (Knight and Cole 1991). The term habituation is commonly confused with attraction and is misused by many wildlife professionals (Whittaker and Knight 1998).

These behaviours can be expressed in organisms in several ways. For example, through active learning e.g., urban dwelling birds losing fear of humans who frequently feed them. Genetic selection for or against beneficial or harmful human stimuli across generations is another example of this expression of behaviour e.g., red tailed hawk populations near areas with a long history of humans hunting them with firearms were seen to be less aggressive and expressed more avoidance behaviours compared to populations closer to settlements with less history of persecution events (Knight et al., 1989). Evidence also exists that animals may culturally transmit learned behaviours in response to interactions with humans. Hamilton and Douglas-Hamilton (1975) recorded the unusually aggressive and nocturnal behaviour of a family of African elephants and used historical records to suggest the change in behaviour could be traced back to a persecution event in 1919. This aggressive and reclusive behaviour of the matriarch elephant along with the other adults of the group suggests that this was taught to them by their family members who were adults during the time of the persecution event, with those young individuals retaining this knowledge into maturity (Hamilton and Douglas-Hamilton 1975).

Conflicts between humans and *Crocodylus acutus* in Belize as well as across Latin America are tightly correlated with increased unstructured illegal feeding events carried out by local communities as a form of tourism (Lemos 2017). Although adult individuals of this species have the capability to grow upwards of 4 meters in length (Crocodile specialist group 1989), they do not typically attack humans or prey as large as us, and under natural circumstances will actively avoid humans when encountered (Lemos 2017). Feeding wild American crocodiles reduces aversion behaviours toward humans and instils attraction behaviour as individuals of a population begin to associate people in their environment as a food source (Lemos 2017). These feeding events have become commonplace across their neo-tropical range, with “crocodile bridge” in Costa Rica and the surrounding banks of the Tarcoles river becoming internationally recognised by tourists as a place where they can view wild crocodile feedings and achieve a close encounter (Lemos 2017). Sixty-two attacks from American crocodiles were reported in Costa Rica between 1990-2017, 35 being non-fatal, with 27 deaths occurring. Most of these attacks occurred during the day while people were by the water’s edge (Porras Murillo and Cambronero 2020). Crocodilians are the only reptile to possess a fully developed cerebral cortex (Pritz, 2015) which allows them to engage in sophisticated behaviours such as setting traps with tools while hunting (Dinets et al., 2013), navigating hundreds of kilometres to return to their original location post translocation efforts (Fukuda et al., 2019), as well having the ability to recognise voices of individual people, differentiating between aggressors e.g., poachers or scientists capturing them (Ron et al., 1998) as well as benefiters e.g., humans who feed them.

Unstructured feeding events are described as the intentional supply of food for wildlife with a dearth of management, informed supervision, or conservation initiative (Newsome et al., 2004). When applied to species which are apex predators, the problems that are created are magnified (Newsome et al., 2005). These problems include abnormal concentrations of individuals at the feeding site which can lead to spread of disease and increase in interspecific violence, the loss of natural behaviours of fed individuals e.g., foraging, predator avoidance, and an increase of inappropriate behaviour toward humans (Newsome et al., 2005).

The human-crocodile conflict that occurs on Ambergris Caye, Belize is centred around unstructured illegal feeding events (The Rufford Foundation, 2022). These events are increasing as humans continue to encroach on crocodile habitat and wish to capitalise on the alure associated with a close encounter with an apex predator (Lemos 2017). Feeding the local population of American crocodiles has created many negative implications for both the local community and the animals.

Paratrichosoma as an environmental indicator:

Ventral infection by the benign parasite *Paratrichosoma* was chosen as an indicator for the health of the crocodilian environment. This method of assessing the health of the crocodilian habitat was chosen due to several previous studies that have found a positive correlation between *Paratrichosoma* infection and healthy environmental conditions with relative levels of low pollution. Moravec and Vargas-Vazquez (1998) found a 100% prevalence of *Paratrichosoma* on members of *C.moreletii* found within the *Ria celestun biosphere reserve* in Yucatan, Mexico, Webb *et al.,* (1983) also found a 100% prevalence of the nematode when surveying *C.Johnstoni* from the pristine and protected McKinlay river in the Northern territory of Australia. In both mentioned examples populations were isolated from human development and anthropogenic pollution (Tellez et al., 2016). Previous studies of *Crocodylus acutus* habitat on Caye Caulker, Belize has also highlighted this positive correlation between *Paratrichosoma* and good environmental health. Caye Caulker is a smaller neighbouring island less than 7km south of Ambergris Caye, with the two islands sharing extremely similar environmental conditions and ecotypes. Caye Caulker has seen far less urbanisation, pollution, and anthropogenic development than Ambergris Caye, with the creation of a marine and forest protected reserve helping protect its natural integrity (Ellen M McRae 2004). (Tellez et al., 2016) found a 92% prevalence of the nematode (12 out 13 individuals infected) on individuals captured on Caye Caulker, while only 1 out of 13 individuals captured in the highly polluted and urbanised waterways of Ambergris Caye were found with the ectoparasite (see results section).

This study attempts to investigate how the rapid development and population increase of Ambergris Caye has affected the behaviour and body condition of *Crocodylus acutus*, as well as the effect this urbanisation has had on crocodilian habitat health. We also address solutions to these problems and suggest viable avenues through which wild crocodiles can be used ethically as a form of eco-tourism to help support local communities who share space with this species, as well as funding critical conservation efforts for *Crocodylus acutus.* We will explore how correct applications of eco-tourism with this species can provide a stable alternative source of employment to activities that are harmful to local wildlife, as in the past conflicts have arisen between local communities and international wildlife organisations (Negi and Nautiyal 2003). Many of our solutions have been adapted from various ethical and successful eco-tourism initiatives in Costa Rica where both local communities and the crocodile population have been able to benefit from the creation educational tours displaying the crocodiles and their environment, without the need to entice the organisms or alter their behaviour.

Materials and methods:

<u>Areas surveyed:</u>

The behavioural and morphometric data for this study was collected from the Placencia lagoon in the Stann Creek district of main-land Belize, and the island of Ambergris Caye. Ambergris Caye is a small island separated from the rest of Mexico's Yucatán peninsula by the narrow channel of *Bacalar Chico* (Guderjan, 1995). The island is roughly 30km long and 4km wide (Guderjan, 1995). Crocodile behaviour in response to humans was recorded at two locations on the island. **Location A)** was at a dock attached to a restaurant just north of San Pedro town (17.96179, -87.93451) where locals are known to feed the crocodiles as a form of tourism and to attract guests to the establishment (ACES wildlife rescue, unpublished). **Location B)** was situated to the far north of the island, within Ambergris Caye's natural reserve (18.153100, -87.892617). Capture surveys were carried out across the island to collect morphometric data on Ambergris Caye's crocodile population. These surveys were conducted throughout the waterways of San Pedro town, Mahogany Bay resort, Serena beach resort, the grand Belizean estates, and the San Pedro sewage ponds. These areas were selected due to their high encounter rate of crocodiles ranging from 8-18 individuals per kilometre (Miriam Boucher et al., 2021). Due to the varied and often human disturbed habitats the crocodiles of Ambergris Caye reside in, surveys were carried out in a variety of ways including on foot, by boat, or in golf carts.

<u>The Placencia lagoon:</u>
Capture surveys on the mainland were conducted in the flower camp area of the Placencia lagoon (16.52555, -88.37771). All capture surveys on the Placencia lagoon were conducted by boat. Placencia lagoon has a significantly lower human development rate than Ambergris Caye, exhibiting a more natural environment with a lower density of both crocodiles and people present (Cissell and Steinberg 2020). The Placencia lagoon was chosen as our control site due to its low levels of pollution, high levels of biodiversity and the lack of damage from deforestation compared to other areas of Belize (Wildtracks et al., 2017).

<u>Capture surveys:</u>

Due to crocodiles being crepuscular organisms, each capture survey began 15-30 minutes after sunset (Whitaker and Sivaraman, 2022). At the beginning of each survey GPS co-ordinates, salinity, water temperature and air temperature are recorded (Benitez *et al.*, 2011). These surveys were conducted on foot, by boat, or by golf cart depending on what the local terrain allowed. These surveys lasted between 3-6 hours, depending on the distance that had to be covered. Once a crocodile was spotted a size estimation was required to decide what the most effective method of capture will be (Benitez et al., 2011). All members of the survey team must keep speech to a minimum while the scientist capturing the animal communicates with the boat captain via hand signals only (Figure 1.1) (Benitez et al., 2011). If the animal is less than 1.2 meters in length, then the “hand grab” technique is most effective, with crocodiles over 1.2 meters requiring the use of a noose or catch pole (Figure 1.2) (Benitez et al., 2011). If the noose being employed is made from metal, then the crocodile must be secured around the neck, as attempting to place the metal noose over the top jaw can cause damage to the crocodile’s snout and eyes (Benitez et al., 2011). Once the animal is safely captured and secured, all morphometric data must be recorded as diligently and rapidly as possible to avoid damaging the health of the animal. Manual capture and restraint of crocodiles can cause dangerous increases in lactate, haematocrit, and haemoglobin levels in the blood, with captured individuals needing up to 8 hours of recovery time to return to normal functioning and behaviour (Franklin et al., 2003). The weight of the crocodile along with measurements of different features of the jaw, head, body, and tail were taken to compare the morphology of the different populations (Benitez et al., 2011). Close attention was taken when measuring the girth of the tail as this measurement is used universally as a measure of crocodilian body condition and general heath (Tellez et al., 2016). The animal is then flipped on its back and inspected for the presence of the parasite *Paratrichosoma* which is a benign nematode parasite that effects the epidermal skin on the ventral side of crocodilians (Tellez et al., 2016). Studies have shown the correlation between the presence of this nematode on crocodiles and a healthy environment (Marisa Tellez, 2016). The crocodile is then released back at the capture location ensuring all rope and tape has been removed. Abiotic data, time of capture and release, and GPS co-ordinates are also taken at the location of capture (Benitez et al., 2011).

This protocol was followed during capture surveys of the Ambergris Caye population as well as the control group living within the Placencia lagoon.

Figure 1.1: Hand signals to communicate with the boat captain (Benitez et al., 2011)***.***

Hand signals from left to right: “Go to the left”, “Encircle to the left”, “Go straight”, “Stop”, “Encircle to the left” “Encircle to the right”, “Go to the right”.

<u>Behavioural surveys:</u>

As previously mentioned in the *Areas surveyed* section, two locations were chosen to record the behavioural response of American crocodiles to human presence. **Group A** were a population *of Crocodylus acutus* in a mangrove cove subjected to illegal feeding and high levels of urbanisation in their environment (17.96179, -87.93451). These animals have been subjected to organised illegal feeding events by the local community for approximately 10 years as a form of tourism. **Group B** included a population of American crocodiles located in the Bacalar Chico natural reserve (18.153100, -87.892617); this population was chosen as a control group as the reserve has low levels of urbanisation and it is expected that the behaviour of the crocodiles in this region will be less impacted by human contact.

Group A surveys:

The behaviour of group A was surveyed twice, first on the 19th of August 2021, and again on the 22nd of August 2021. Each survey lasted 3 hours from 5pm-8pm. 5pm was chosen as the beginning of the survey, as this was the usual time the restaurant staff fed the crocodiles for the tourists. We asked a member of staff to lead us down to the location and "call" the crocodiles. Consistency in our arrival time, having a restaurant employee present, and our behaviour as "tourists" was essential as crocodiles remember patterns, voices, and can distinguish between humans that have fed them and humans that have harmed or attempted to capture them before (Augustine et al., 2012). Both surveys included the presence of both tourists and restaurant staff, with kitchen scraps being presented to the crocodiles at the first survey, but not at the second, with just our human presence and mangrove branches used as stimulus. Our research began by walking up the dock to emulate tourists being brought to the feeding location. We then splashed the water with branches to imitate food being dropped off the dock. We then stood and observed the crocodile's behaviour in response to our presence, splashing the water every few minutes with mangrove branches to simulate a usual feeding session. The responses of the crocodiles to our presence were recorded based off behavioural parameters in **table 1.1**. These observational parameters were closely adapted from the *List of characterized behaviour and description of activities observed for American Crocodiles (Crocodylus acutus) in Belize, Central America,* that was created by (Miriam Boucher et al., 2021).

Figure 1.2: Location A, feeding dock and associated restaurant (17.96179, -87.93451).

Table 1.1: (Miriam Boucher et al., 2021) Categorised *Crocodylus acutus* behaviour

Characterised behaviour:	**General categories of activities:**	**Description of activities:**
Agonistic:	Aggression:	• Negative behaviour (Competition for non-food items) • Chasing with aggressive intent • Physical altercation aggressive threat display e.g., HOTA (Head Oblique Tail Arch) • Jaw clap, tail wag.
Social:	Social signalling:	• Courting behaviour (dorsal rubbing, circling) • Submissive posturing (snout lift) • Alertness indicator (tail lift, back bob, inflated posture)
Maintenance:	Basking:	• On land, whole body exposed, • Partially withdrawn from water, • dorsal area exposed in water, • prolonged exposure of full dorsal surface.
	Foraging:	• Stalking prey • Striking out to capture prey • Lifting head to consume prey
	Submerging:	• Entire body concealed under surface of the water
	Surface:	• Head or body exposed floating stationary in the water
	Swimming:	• Locomotion in the water

<u>Group B surveys:</u>

The crocodile research coalition recorded the behaviour of *Crocodylus acutus* living within the Bacalar Chico natural reserve during a nocturnal eyeshine survey of the area on the 29th of June 2018 at the beginning of the wet season. It was vital to have observed both populations during the same weather season, as time of year can have an ~~massive~~ effect on the behaviour of this species (Miriam Boucher et al., 2021). Due to the crepuscular nature of this species the survey began at dusk (7pm) and ended at mid-night (Miriam Boucher et al., 2021). The West shore of the reserve was chosen as the survey area as it was easily accessible by boat and was known to have a significant population of American crocodiles. At the beginning of the survey air and water temperature was recorded, along with salinity and GPS co-ordinates. The boat moved along the river at a consistent pace of ~8mph with a member of the team at the bow of the boat using a spotlight to find members of the population. *Crocodylus acutus* as a species have a natural aversion and are wary of humans, so using a spotlight allows us to see the crocodiles from a distance at night, due to the bright red reflective glow that the tapetum lucidum within the crocodile's eye reflects (Olivier et al., 2004). Once a crocodile was spotted GPS co-ordinates were recorded, an estimation on its size, along with the type of environment it was in e.g., underneath mangroves, open water, etc. The crocodile was then approached at a consistent speed via boat until it evaded away. Evading was classified as submerging underwater or retreating away from the boat rapidly. The distance at which the crocodile retreated was then recorded.

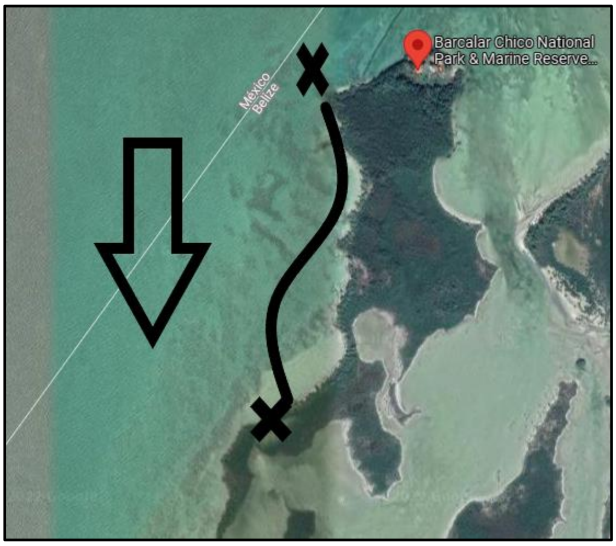


Figure 1.3 survey route of the Bacalar Chico natural reserve (18.153100, -87.892617):

Analysis of data:

Our data was analysed using RStudio version 4.1.1 (2021-08-10) software. When analysing the significance of the behavioural data that was collected general linear models were used as well as a two-tailed T-test. The general linear models were used to compare the two separate populations reactions to the presence of humans, which were then plotted for visual comparison. A two-tailed T-test was used when we compared the different behavioural responses of the same human attracted *Crocodylus acutus* population under different survey conditions. Survey A was carried out with the locals who regularly fed the crocodiles while supplying food, with survey B carried out without the food stimulus or the local individuals. When assessing the tail conditions of the Placencia lagoon and the Ambergris Caye populations a general linear model was also used to compare the two locations, with body-size controlled for.

Due to the lack of previous in-depth analysis on *Paratrichosoma* we analysed its prevalence to a presence absence degree, as previous studies have shown its presence correlates with low levels of pollution in an environment but no correlation with the quantity of infection or the relevance of which body part is infected has yet been made.

Results:

To assess the overall affect the rapid urbanisation and human population increase of Ambergris Caye has had on the population of *Crocodylus acutus,* we compared the population's behavioural data, body condition (Identified by measuring tail girth), and the prevalence of infection by the environmental indicator *Paratrichosoma* to a population living 158 kilometres south within the Placencia lagoon.

Prevalence of Paratrichosoma:

A total of 35 individual *Crocodylus acutus* were captured and inspected for the presence of Paratrichosoma, with 13 individuals captured on Ambergris Caye, and 22 individuals captured from the control site at the Placencia lagoon. All individuals deemed hatchlings (<50cm) were excluded from the survey as infection by the parasite to individuals of this age category is far less likely regardless of environmental conditions. Our observations found evidence of *Paratrichosoma* on **86.4% (19 out of 22)** of individuals caught within the Placencia lagoon, with the nematode only appearing on **7.7% (1 out of 13)** of individuals caught and inspected on Ambergris Caye. Evidence of *Paratrichosoma* was recorded via a presence/absence indicated by either yes or no.

Table 1.2:

Table representing the prevalence of the environmental indicator Paratrichosoma between the Ambergris Caye and Placencia lagoon populations.

Location:	**Size class:**	**Evidence of *Paratrichosoma:***
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Juvenile	No

San Pedro, Ambergris Caye	Adult	No
San Pedro, Ambergris Caye	Subadult	Yes
San Pedro, Ambergris Caye	Subadult	No
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Juvenile	No
San Pedro, Ambergris Caye	Adult	No
San Pedro, Ambergris Caye	Adult	No
San Pedro, Ambergris Caye	Juvenile	No
Placencia	Juvenile	Yes
Placencia	Adult	No
Placencia	Juvenile	No
Placencia	Juvenile	No
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Subadult	Yes
Placencia	Juvenile	Yes
Placencia	Adult	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Subadult	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Adult	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes
Placencia	Juvenile	Yes

Figure 1.4: *Prevalence of Paratrichosoma found on Crocodylus acutus: Ambergris Caye vs. Placencia lagoon*

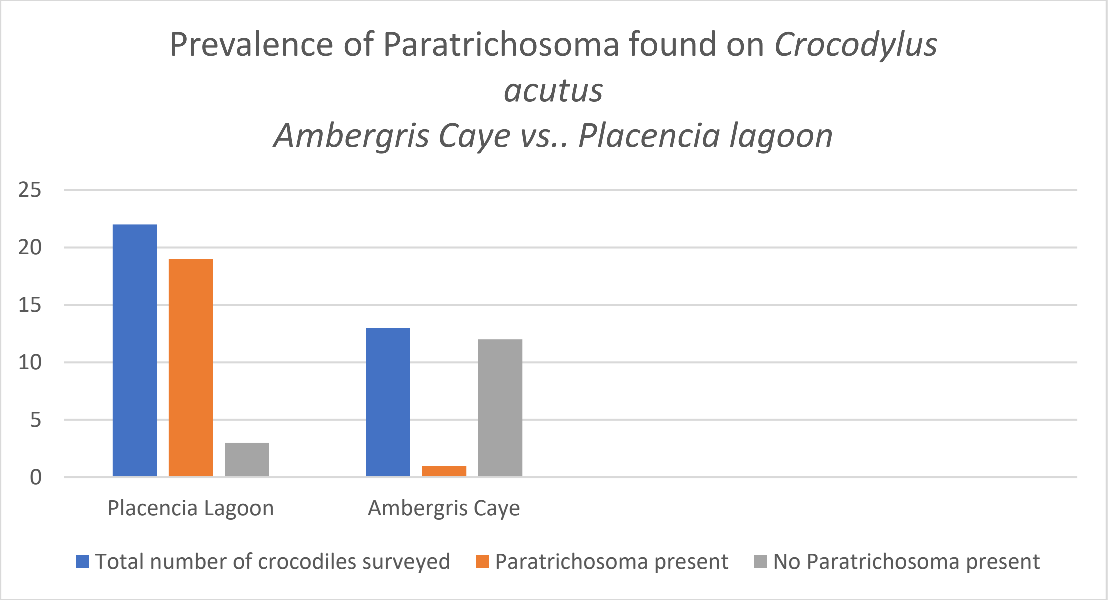


Figure 1.5: (Mckinlay river freshwater crocodile project, 2001)

Evidence of *Paratrichosoma* on ventral scales of a crocodile.

<u>Crocodylus acutus behavioural response to human presence:</u>

A total of 27 individual crocodiles were observed with their behaviour recorded across **Location A** and **Location B.** A total of 12 crocodiles were observed at location A, with 6 individuals observed during our first survey, and 6 observed during our second survey. 15 crocodiles were observed at location B within the Bacalar Chico natural reserve, with all data from location B recorded on the 29th of June 2018.

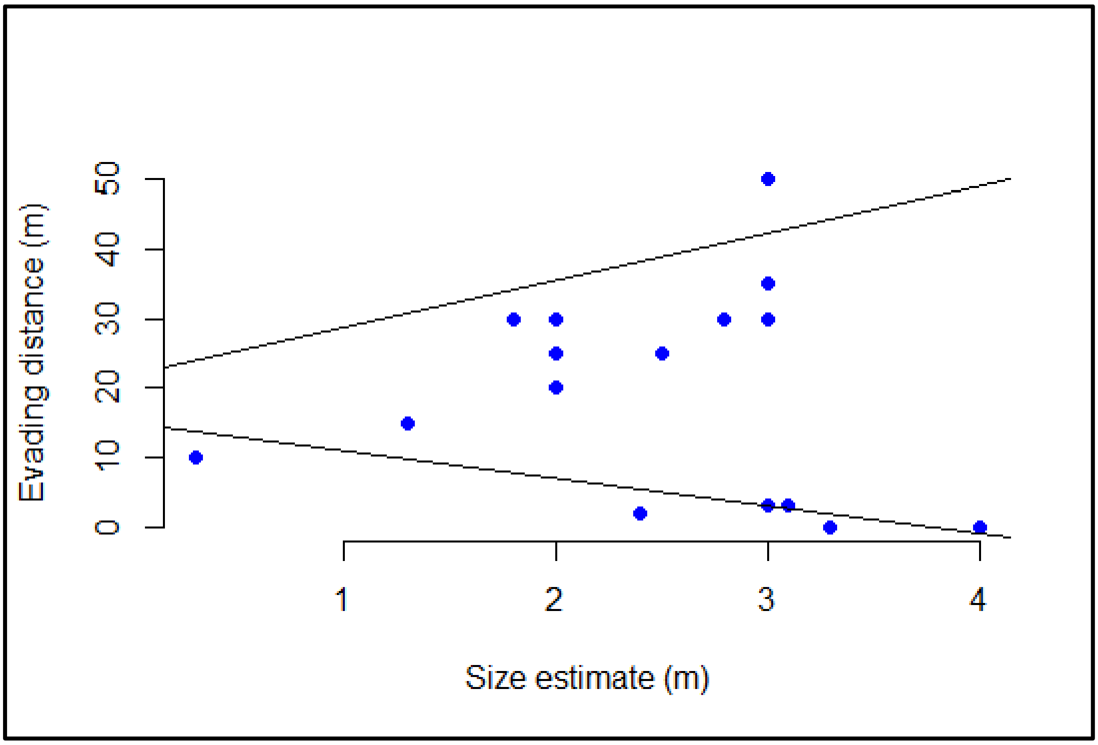
<u>Evading response to human presence:</u>

Our analysis using a general linear model revealed a significant difference between the distance (m) crocodiles at **location A** and **location B** allowed humans to approach/be present before evading the situation with **P=2.49e-06** ($p<0.05$).

Table 1.3: *The effect of variables on the aversion/fleeing behaviour of crocodiles under varying anthropogenic exposure.*

Variables:	Estimate:	Std error:	T-value	P value:
Intercept	17.239	4.781	3.605	0.00202
Size estimate	4.783	1.989	2.405	0.02712
Location	-27.038	4.003	-6.755	2.49e-06

Figure 1.6: *Graph representing the different behavioural responses of* ***population A vs population B*** *regarding human presence. Top line representing location B and the bottom-line representing location A.*



100% of individuals at **location B** over 2m in length did not allow researchers to approach within 30 meters of them once spotted, opting to submerge completely or evade rapidly in the opposite direction. While 100% of individuals at **location A** over 2m in length allowed human presence within 5 meters, with the largest individuals estimated to be over 3 meters long actively approaching the researchers. The feeding of these predators switched their response to people from aversion to attraction. A two tailed T-test showed that there was not a significant difference in the evading distance between survey 1 (food presented) and survey 2 (food not presented) of the fed population at **location A,** with **P= 0.6997.** This analysis was carried out to show that previously fed crocodiles keep their attraction behaviour toward humans even if future encounters with people don't involve food. When researchers at location A were present with the usual food source (scraps from the restaurant kitchen) the crocodiles approached quickly and visibly, swimming on the surface of the water with no intent to conceal their approach. When we returned to the site without food, the crocodiles approached slowly and fully submerged displaying the foraging tactic of stalking prey. Only breaking the surface to strike out at the mangroves being splashed by researchers to simulate a feeding event.

Behavioural activity population A vs population B:

The behaviours and activity patterns of the illegally fed, and the naturally foraging populations were compared to each other in response to human presence under the specific behavioural characteristics outlined in **Table 1.1** (Miriam Boucher et al., 2021). Below is a list of behavioural characteristics recorded from each separate population.

Category:	**Behaviour:**	**Description of activities:**
Agonistic	Interspecific aggression	• Chasing with intent • HOTA display (Head oblique tail arched)
Maintenance	Foraging	• Stalking humans on the dock • Striking out from ambush position • Lifting head to consume prey
Locomotion	Movement in response to stimulus (human presence)	• Swimming on the surface of the water toward stimulus • Floating on the surface, full body exposed • Submerging full body • Only head exposed
Social signalling	Non-aggressive interspecific communication	• Tail raised, body posture inflated, back raised

Table 1.4: Categorised behaviour Location A: Tipsy lobster dock (17.96179, -87.93451).

Category:	Behaviour:	Description of activities:
Agonistic	**Not observed**	**Not observed**
Maintenance	**Not observed**	**Not observed**
Locomotion	Movement in response to stimulus (human presence)	• Submerging full body • Swimming on surface of the water away from the stimulus • Only head exposed on surface of the water • Movement from shallow to deeper water
Social signalling	**Not observed**	**Not observed**

Table 1.5: Categorised behaviour Location B: Bacalar Chico natural reserve

Analysis of behavioural observations:

Population A displayed 10 different activities from all 5 behavioural categories. With locomotion in response to the stimulus (human presence) being the most observed behaviour (4 different behavioural observations) and foraging behaviours being the second most observed behaviour (3 different behavioural observations). **Population B** displayed 4 different activities from only 1 of the behavioural categories. Both populations displayed 4 unique locomotive responses to human presence, with **population A** displaying an *attraction* response to the stimulus while **population B** displayed an *avoidance* response.

Figure 1.7: *Crocodile exhibiting attraction behaviour toward researchers and tourists beside feeding location*

(Photo: Gary Moscarelli)

Tail girth as a measure of body condition:

The body condition of each population was assessed by measuring the girth of the widest part of the tail of each captured individual. The girth of the tail was compared to the total length of the animal to check for abnormalities in body condition. Although all individuals captured displayed similar healthy tail conditions for their respective length and assumed age category, our analysis using a general linear model showed there to be a significant difference between the tail circumference of the two populations, where **(P= >2e-16).** We theorise that the significant result may be due a disproportionate number of juvenile individuals captured at **location B** compared to **location A,** with this being further investigated in the *discussion* section of this paper.

Variables:	**Estimate:**	**Std error:**	**T-value:**	**P value:**
Intercept	-3.944775	0.544861	-7.24	8.71e-09
Total length	0.254472	0.005006	50.83	<2e-16

Table 1.6: *Comparing the effect of variables on the tail girth of crocodiles from Ambergris Caye vs Placencia lagoon*

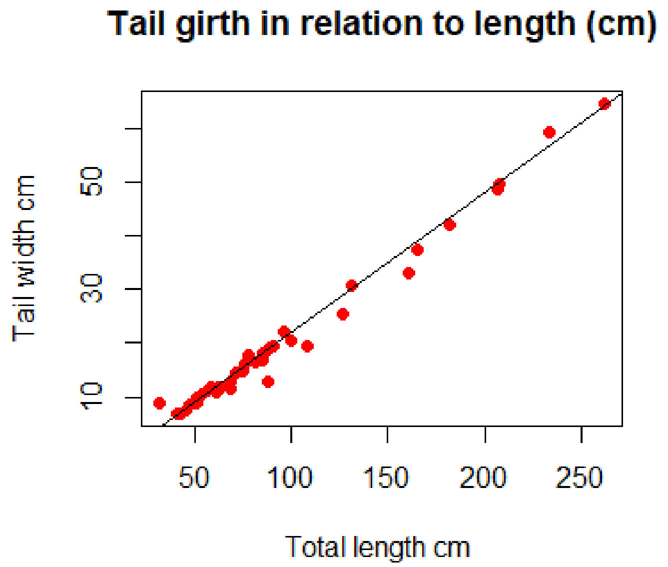


Figure 1.7: Body condition assessment Ambergris Caye vs Placencia lagoon

The linear model produced shows both populations displaying very similar correlations between tail width and total length. The adults captured on Ambergris Caye had an average length of 234.6cm and an average tail width of 57.5cm. Adults surveyed from the Placencia lagoon had an average length of 183.4cm with an average tail width of 41.5cm. There was a 51.2cm difference in the average length of the adults from the separate populations, with a 16cm difference in tail width.

Discussion:

Our study aimed to highlight the effect illegal feeding events have had on the behaviour of wild *Crocodylus acutus* living on Ambergris Caye Belize, as well as the possible negative effects the rapid urbanisation of the island has had on the health of the crocodiles and the surrounding ecosystem. Due to the broadness of our study, this research can act as a baseline for further work into the conservation of the ecosystems and organisms present on Ambergris Caye.

Paratrichosoma as an environmental indicator:

The results of our investigation into the prevalence of *Paratrichosoma* among individuals living on Ambergris Caye and our control population within the Placencia lagoon supports the hypothesis that the presence of the nematode is indicative of a healthy ecosystem (Tellez et al., 2016). When comparing the prevalence of *Paratrichosoma* to 4 different crocodilian environments the only limiting factor of the ectoparasites presence seems to be the level of anthropogenic disturbance in the area, with the nematode species being equally as prevalent in crocodilians in freshwater habitats in Australia as they are in crocodilians in high salinity coastal habitats in Central America (Webb et al 1983) (Tellez et al., 2016) (Tellez et al., 2017). But even though the results are promising more research into the effectiveness of the ectoparasite as an environmental indicator is needed. Research has also suggested that infection by *Paratrichosoma* may also be influenced by the activity patterns of the organism and not just the environment they reside in, so further research into the parasite is needed (Charruau et al., 2017). Another improvement to our study would be the detail in which we examined the parasites infecting individuals. We recorded the prevalence of *Paratrichosoma* only to a “Presence/absence” degree on the crocodiles examined and due to the limited research on this topic I would recommend future researchers to also record the infection location on the body as well as the quantity of infections on each individual crocodile.

Crocodylus acutus behavioural response to human presence:

In our analysis on the effect that unstructured feeding events have on the behavioural response of *Crocodylus acutus* to the presence of humans, we found that American crocodiles living in a rural setting exhibit avoidance behaviours to the presence of humans and will evade away or submerge when approached within 30 metres. This response to humans makes *Crocodylus acutus* a great candidate species for co-existence in areas where their range overlaps with human settlement. Other crocodilian species of similar size such as *C.porosus* in Australia and across the Indo-pacific cause difficult wildlife management issues due to their lack of fear of people and their aggressive predisposition toward humans in their environment (Fadzlidee Bin Asmat 2015). We found that when American crocodiles are exposed to frequent unstructured feeding events their behaviour toward people is significantly changed. We observed 2 unique interspecific agnostic behaviours, and 4 human directed agnostic behaviours on both survey trips of the fed population living behind the restaurant in San Pedro town. The interspecific aggressive behaviours included chasing with aggressive intent to remove individuals from the feeding area, and individuals exhibiting the HOTA (head oblique tail arched) aggression display to one another. The aggressive behaviour toward people on the dock included striking out from an ambush position, approaching directly and quickly on the surface of the water, exhibiting the HOTA display, and stalking individuals on the dock. These behaviours are in complete contrast to the behaviour of the population surveyed away from human interaction within the Bacalar Chico natural reserve. The Bacalar Chico population exhibited 4 unique behavioural responses to human presence, all of which can be categorised as avoidance behaviours. These included Submerging full body, swimming on surface of the water away from the stimulus, retreating to mangroves with only head exposed above the water, and movement from shallow to deeper water.

Interestingly, we found a significant difference in the behaviour of the human fed population depending on the people present on the dock and their prior relationship with the crocodiles. During our first survey of this population the usual restaurant staff were present and were feeding the crocodiles for tourists. The crocodiles approached quickly on the surface of the water and exhibited boisterous behaviour with no attempt to conceal their presence or their approach. When we returned without the restaurant staff the crocodiles adopted stalking techniques to approach and we were only aware of their presence as they struck out of the water in response to us splashing mangrove branches. On both occasions we observed interspecific agnostic behaviour. The behaviour of the crocodiles toward individuals who did not usually feed them was extremely concerning considering tourists frequent the dock often and have been observed dangling their feet over the side.

The continued feeding occurring at **study site A** has led to altered behaviour of the crocodiles and the display of semi-domesticated behavioural patterns (**see supplementary data 1 for video of attraction behaviour)**. The population of adult individuals at our study location had lost their natural fear of humans and instead displayed aggressive, boisterous, and exuberant behaviours towards people who visited the low wooden dock. With similar behaviour being expressed by all previously fed crocodiles regardless of the food incentive being present at the time. The urbanised and polluted location of these illegal feeding sites has possible negative implications for the health and body condition of this population. The sites proximity to several restaurants, resorts, and an illegal waste dump has caused the area to become incredibly polluted, with vast volumes of macro-plastics and other waste products distributed throughout the environment. Ventral infection by the benign parasite *Paratrichosoma* was chosen as an indicator for the health of the crocodilian environment.

Human-wildlife conflicts can be incredibly complex by nature and include a range of religious, social, and economic facets (Dickman, 2010). These issues are amplified when the animal in question is a large predator such as a crocodile (García-Grajales and Buenrostro-Silva, 2019). Although education is an important tool in any situation involving human-wildlife conflict, in situations like the unstructured feeding events in San Pedro it is not enough. The owners of the restaurant see economic value in feeding the crocodiles as it draws more tourists to his restaurant and increases cash flow. We suggest that local wildlife organisations support the restaurant owner by educating the staff on the species and the surrounding environment to allow for structured viewing tours to be carried out from the dock, replacing the dangerous unstructured feeding events. This would allow the restaurant to advertise legal ecotourism to visitors of the island and continue to reap the economic benefits of the crocodiles without endangering the public. Costa Rica is an example of the utilisation of crocodile ecotourism for both economic and wildlife conservation benefits (Lemos 2017). Structured crocodile tourism on the Tarcoles river produced approximately 5,292,073.81 USD in indirect sales for the local community in 2014, with a further 4,039,751.00 USD produced from directly from structured crocodile tourism (Lemos 2017). Showing members of the local community that crocodiles can have sustainable economic value leads to less poaching, habitat destruction, and illegal wildlife activities from occurring (Lemos 2017). Creating the opportunity for local people earn a living from structured wildlife tourism practices would stop the illegal feedings and boost the local economy.

Although our results were significant, I believe the validity of our results could have been improved by increasing the number of individual populations we observed. Again, due to limitations on our budget and time we were only able to observe and record the behaviour of two separate *Crocodylus acutus* populations and I believe researchers looking to further investigate the effect of unstructured feeding on this species should attempt to observe more naturally foraging control populations.

Investigating body condition of *Crocodylus acutus* Ambergris Caye vs Placencia lagoon:

The body condition of the crocodiles residing within location A and location B was assessed by measuring their tail girth. Tail girth was chosen as an indicator of body condition as tail thickness is widely used as an indication of crocodilian health (Squires et al., 2019). Although our linear model displayed a significant difference in the tail girth of individuals between the two locations, we deduced this was caused by the unequal spread of the size classes sampled between both populations. All individuals from both populations displayed healthy tail conditions, with the significant result likely coming from an excess of juvenile individuals captured from the Placencia lagoon compared to the larger individuals caught on Ambergris Caye. While we did not find any differences in measures of health between the populations, future investigations into concentrations of heavy metals in the caudal scutes of individuals would be a far better indication of organism health as well as environmental stability. Pollutants present in apex predators such as crocodilians serve as a indicator for the level of pollution within other species living in that environment due to bioaccumulation (Berger 2014). Bioaccumulation is a process where pollutants are accumulated within an organism due to eating other polluted organisms or uptake of substances through their environment, with the uptake rate of the pollution being higher than the organism's ability to remove the substance (Berger 2014).

Berger (2014) investigated the concentrations of heavy metals in *Crocodylus acutus* on Ambergris Caye to assess the effect that unregulated dumping and industrial development has had on the crocodiles and their ecosystem. Their studies found high concentrations of Al, Cu, Pb, As, and Se in the scute samples of crocodiles of all size classes on the island. Al was found in its highest concentrations within both the adult and juvenile populations of crocodiles ($24945.9<x<48194.8$ng/g), followed by Cu ($4698.9<x<169044.1$ ng/g) (Berger 2014). Previous studies on the effects of heavy metal pollution on crocodiles in Latin America has shown that high levels of these substances can have negative implications for crocodilian survivorship, growth, and reproductive viability (Cedillo-Leal et al., 2018). These results show that the pollutants entering the ecosystem of Ambergris Caye are being absorbed by crocodiles of all size classes of the environment.

Conclusion:

The situation that crocodile populations face on Ambergris Caye is concerning but not unique to the conservation challenges faced by crocodiles globally. The natural behaviour that *Crocodylus acutus* exhibits towards human presence makes them a fantastic candidate for co-existence throughout their neo-tropical range. Local communities altering their behaviour via unstructured feeding events will lead to negative consequences for both crocodiles and the safety of visitors and community members alike. Crocodiles are a critical component to the functioning and productivity of their environment, and similarly a healthy and productive ecosystem is critical for the good health and development of crocodiles. The conservation of this species should be intrinsically linked to the conservation of their wetland biomes. Crocodiles are an enchanting species, that capture the imagination of millions of people globally. The alure of seeing these charismatic beasts in their natural environment should be capitalised on both by local communities and in-situ wildlife conservation organisations to garner funding and attention to the conservation of these animals, while also supporting the local economy.

Although potentially a threat to human safety if interacted with incorrectly, the benefits of crocodiles to local communities far out way the negatives. Crocodiles ensure the upkeep of healthy fish populations (Van der Ploeg et al., 2011), remove many pest species, and can greatly improve the economic state of a community or region (Lemos 2017). For all these reasons, as well as their critical role in the wetland habitats as ecosystem engineers (USGS 2004) I believe the rapid development of Ambergris must be slowed, with important areas of crocodile habitat identified and protected. Infrastructure and education must also be provided to local communities to allow them to avail of the benefits of structured crocodile tourism, and thus reducing the incidence of illegal unstructured feeding events.

Figure 1.8: *Fed wild American crocodile*

Bibliography:

1. Guderjan, T., 1995. **Maya Settlement and Trade on Ambergris Caye, Belize**. *Ancient Mesoamerica*, 6, pp.147-159.

2. Miriam Boucher, Marisa Tellez, and James T. Anderson 2021. **Activity Budget and Behavioural Patterns of American Crocodiles (Crocodylus acutus) in Belize.** *Herpetological Conservation and Biology* 16(1):86–94.

3. Cissell, J. and Steinberg, M., 2020. **Human Landscape Modification in Placencia, Stann Creek District, Belize: Possible Implications for Crocodile Hybridization**. *Journal of Latin American Geography*. Pages etc

4. Whitaker, N. and Sivaraman, C., 2022. **Behavior in a captive family group of Siamese Crocodiles (Crocodylus siamensis) at the Madras Crocodile Bank Trust near Chennai, India**. *Reptiles & Amphibians*, 29(1), pp.71-75.

5. Jauregui G, Herrara O, Naranjo A, Benitez-Diaz H**. Programa de Monitoreo del Cocodrilo de Pantano (Crocodylus moreletii) México-Belice-*Guatemala*** *Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO)* ISBN: 978-607-7607-53-3

6. Dr Tellez M, Boucher M, Kohlman K. **Population status of the American Crocodile (Crocodylus acutus) in Caye Caulker, Belize.** *Mesoamericanherpetology*.com

7. Franklin, C., Davis, B., Peucker, S., Stephenson, H., Mayer, R., Whittier, J., Lever, J. and Grigg, G., 2003. **Comparison of stress induced by manual restraint and immobilisation in the estuarine crocodile,crocodylus porosus**. *Journal of Experimental Zoology*, 298A (2), pp.86-92.

8. Cherkiss, M., Fling, H., Mazzotti, F. and Rice, K., 1969. **Counting and Capturing Crocodilians**. *EDIS, 2005(1).*

9. Augustine L, Baumer M. **Training a Nile crocodile to allow for collection of blood at the wildlife conservation society's Bronx Zoo.** *Herpetological Review 43(3):432-435 2012.*

10. Ogden, J., 1978**. Status and Nesting Biology of the American Crocodile, Crocodylus acutus, (Reptilia, Crocodilidae) in Florida**. *Journal of Herpetology*, 12(2), p.183.

11. Tisdell C, Wilson T, and Nantha H S. **Australian Tropical Reptile Species: Ecological Status, Public Valuation and Attitudes to their Conservation and Commercial Use.** *Economics, ecology, and the environment. Working paper number 16, 2004.*

12. Olivier, F., Samuelson, D., Brooks, D., Lewis, P., Kallberg, M. and Komaromy, A., 2004. **Comparative morphology of the tapetum lucidum (among selected species).** *Veterinary Ophthalmology*, 7(1), pp.11-22.

13. Sweetman, B., Cissell, J., Rhine, S. and Steinberg, M., 2018. **Land Cover Changes on Ambergris Caye, Belize: A Case Study of Unregulated Tourism Development.** *The Professional Geographer*, 71(1), pp.123-134.

14. Statistical institute of Belize, **Abstract of statistics 2017 Pdf.**

15. Meerman, J. C., and W. Sabido. **Central America Ecosystems Map: Belize.** *CCAD/World Bank/Programme for Belize*, 2001.

16. Grimshaw T, Paz G. **The revised Bacalar Chico National Park and Marine Reserve management plan.** *Green reef environmental institute, San Pedro Town, Belize.*

17. Kroon, F., Schaffelke, B. and Bartley, R., 2014. **Informing policy to protect coastal coral reefs: Insight from a global review of reducing agricultural pollution to coastal ecosystems.** *Marine Pollution Bulletin*, 85(1), pp.33-41.

18. **ACES Wildlife Rescue**. Non-profit organization permitted by the Belize Forest Department and dedicated to the conservation and protection of Belize's native wildlife and their critical habitats. *Info@acesbelize.com / 623-7920 / ACES wildlife rescue.com*

19. **Wildlife Protection Act 1981. (**Act number 4 of 1981) *An Act to provide for the conservation, restoration and development of wildlife, for the regulation of its use and for all matters connected therewith.*

20. Cherrington, E., Griffin, R., Anderson, E., Hernandez Sandoval, B., Flores-Anderson, A., Muench, R., Markert, K., Adams, E., Limaye, A. and Irwin, D., 2020. **Use of public Earth observation data for tracking progress in sustainable management of coastal forest ecosystems in Belize, Central America.** *Remote Sensing of Environment*, 245, p.111798.

21. Mumby, P., Edwards, A., Ernesto Arias-González, J., Lindeman, K., Blackwell, P., Gall, A., Gorczynska, M., Harborne, A., Pescod, C., Renken, H., C. C. Wabnitz, C. and Llewellyn, G., 2004. **Mangroves enhance the biomass of coral reef fish communities in the Caribbean.** *Nature*, 427(6974), pp.533-536.

22. Briggs-Gonzalez, V., Bonenfant, C., Basille, M., Cherkiss, M., Beauchamp, J. and Mazzotti, F., 2017. **Life histories and conservation of long-lived reptiles, an illustration with the American crocodile (Crocodylus acutus)**. *Journal of Animal Ecology*, 86(5), pp.1102-1113.

23. Balaguera-Reina, S., Venegas-Anaya, M., Sánchez, A., Arbelaez, I., Lessios, H. and Densmore, L., 2016. **Spatial Ecology of the American Crocodile in a Tropical Pacific Island in Central America**. *PLOS ONE*, 11(6), p.e0157152.

24. Whittaker D, Knight R, 1998. **Understanding wildlife responses to humans.** *Wildlife Society Bulletin 1998, 26(2):312-317*

25. Knight, R, Cole, D.N, 1991. **Effects of recreational activity on wildlife in wildlands.** *Transactions of the North American Wildlife and Natural Resources Conference (USA) ISSN : 0078-1355.*

26. Kaartinen, S., Kojola, I. & Colpaert, A. 2005: **Finnish wolves avoid roads and settlements**. — *Ann Zool. Fennici 42: 523-532*

27. Douglas Hamilton I., O, Douglas-Hamilton 1975**. Among the elephants.** *Collins and Harville, London, England*.

28. Lemos, A**. Measuring the Economic Value and Social Impact of Crocodile Tourism in Tarcoles, Costa Rica (2017).** *FIU Electronic Theses and Dissertations. 3329.* https://digitalcommons.fiu.edu/etd/3329

29. _Porras Murillo, L. and Cambronero, E., 2020. **Analysis of the Interactions Between Humans and Crocodiles in Costa Rica.** *South American Journal of Herpetology*, 16(1), p.26.

30. Pritz, M., 2015. **Crocodilian Forebrain: Evolution and Development.** *Integrative and Comparative Biology*, 55(6), pp.949-961.

31. Ron, S., Vallejo, A. and Asanza, E., 1998. **Human Influence on the Wariness of Melanosuchus niger and Caiman crocodilus in Cuyabeno, Ecuador.** *Journal of Herpetology*, 32(3), p.320.

32. SINGH, L. A. K. (2014): **Forty Years' Saga of Mangrove and Biodiversity Conservation Launched from Crocodile Conservation.** Summary of Chairman's address at Seminar-cum-Workshop on Sustainable Coastal Zone Protection through Mangrove Management in Odisha. 6-7 September 2014. *Council of Cultural Growth and Cultural Relations, Cuttack, Odisha, and Ministry of Earth Sciences, Government of India, New Delhi.*

33. Newsome, D., Lewis, A., & Moncrieff, D. 2004. **Impacts and Risks Associated with Developing, but Unsupervised. Stingray Tourism at Hamelin Bay, Western Australia.** International Journal of Tourism Research, 6, 305-232.

34. Newsome, D., Dowling, R., & Moore, S. 2005. **Wildlife Tourism.** *Channel View Publications, Clevedon.*

35. Negi, C. S., & Nautiyal, S. (2003). **Indigenous peoples, biological diversity and protected area management-policy framework towards resolving conflicts.** *International Journal of Sustainable Development and World Ecology, 10 (2), 169-179.*

36. Dinets, V., Brueggen, J. and Brueggen, J., 2013. **Crocodilians use tools for hunting.** *Ethology Ecology & Evolution*, 27(1), pp.74-78.

37. Fukuda, Y., Webb, G., Manolis, C., Lindner, G. and Banks, S., 2019. **Translocation, genetic structure and homing ability confirm geographic barriers disrupt saltwater crocodile movement and dispersal.** *PLOS ONE*, 14(8), p.e0205862.

38. Webb, G., Manolis, S. and Buckworth, R., 1983. **Crocodylus johnstoni in the McKinlay River Area N. T, V.* Abnormalities and Injuries.** *Wildlife Research*, 10(2), p.407.

39. Tellez M, Arevalo B, Paquet-Durand I, and Heflick S**. Population status of Morelet's Crocodile (Crocodylus moreletii) in Chiquibul Forest, Belize.** *Mesoamerican Herpetology 8 March 2017 | Volume 4 | Number 1*

40. Charruau, P., Pérez-Flores, J. and Labarre, D., 2017. **Skin parasitism by Paratrichosoma recurvum in wild American crocodiles and its relation to environmental and biological factors.** *Diseases of Aquatic Organisms*, 122(3), *pp.205-211.*

41. FADZLIEE BIN ASMAT M. **AGONISTIC BEHAVIOUR IN CAPTIVE ADULT SALTWATER CROCODILE, CROCODYLUS POROSUS** *MARINE SCIENCE PROGRAMME FACULTY OF SCIENCE AND NATURAL RESOURCES UNIVERSITI MALAYSIA SABAH* 2015.

42. Dickman, A., 2010. **Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict.** *Animal Conservation, 13(5), pp.458-466.*

43. García-Grajales, J. and Buenrostro-Silva, A., 2019. **Assessment of human–crocodile conflict in Mexico: patterns, trends, and hotspots areas.** *Marine and Freshwater Research*, 70(5), p.708.

44. World Wildlife Fund. 2022. **Making the financial case for protecting Belize's barrier reef.** [online] Available at: *<https://www.worldwildlife.org/stories/making-the-financial-case-for-protecting-belize-s-barrier-reef> [Accessed 7 March 2022].*

45. Squires, M., Godahewa, A., Dalaba, J., Brandt, L. and Mazzotti, F., 2019. **Have you seen a skinny alligator in South Florida?**. *EDIS, 2019(6), p.3.*

46. van der Ploeg, J., Cauillan-Cureg, M., van Weerd, M. and Persoon, G., 2011. **'Why must we protect crocodiles?' Explaining the value of the Philippine crocodile to rural communities.** *Journal of Integrative Environmental Sciences*, 8(4), pp.287-298.

47. García-Grajales, J. and Buenrostro-Silva, A., 2019. **Assessment of human–crocodile conflict in Mexico: patterns, trends and hotspots areas.** *Marine and Freshwater Research*, 70(5), p.708.

48. Cedillo-Leal, C., Cienfuegos-Rivas, E. and Escobedo-Galván, A., 2018. High Levels of Heavy Metals in Scutes and Eggs of Morelet's Crocodiles (Crocodylus moreletii) from Northeast Mexico. *The Southwestern Naturalist*, 63(1), p.71.

49. Rufford.org. 2022. *Cherie Renee Chenot-Rose - American Crocodile, Crocodylus Acutus, Population and Habitat Viability Assessment and Conservation in Ambergris Caye, Belize - The Rufford Foundation*. [online] Available at: <https://www.rufford.org/projects/cherie-renee-chenot-rose/american-crocodile-crocodylus-acutus-population-and-habitat-viability-assessment-and-conservation-in-ambergris-caye-belize/> [Accessed 21 March 2022].