Morelet's Crocodile (*Crocodylus moreletii*) is a medium-sized crocodylian found from Tamaulipas, Mexico, southward to Belize and Guatemala. Once propelled to the brink of extinction by overharvesting and poaching, protective measures for its conservation have allowed populations in certain areas to recover. Information on the status of this species in southern Belize was lacking, and the following article describes a monitoring survey conducted in Chiquibul Forest, Cayo District, Belize. © Miriam Boucher

Mesoamerican Herpetology
www.mesoamericanherpetology.com
Eagle Mountain Publishing, LC
www.eaglemountainpublishing.com
OPEN ACCESS

Population status of Morelet's Crocodile (*Crocodylus moreletii*) in Chiquibul Forest, Belize

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Abstract: We conducted a population survey of *Crocodylus moreletii* in Chiquibul Forest, Cayo District, Belize, in April, June, and July of 2016. Of the 162 individuals observed (encounter rate = 3.6 crocodiles/km), we classified 22 as yearlings (13%), 45 as juveniles (28%), 19 as subadults (12%), 27 as adults (17%), and 49 as eyeshine only (30%). The sex ratio of *C. moreletii* in Chiquibul Forest illustrates a strong female bias (0.29:1). The distribution of subadults and adults did not differ significantly among the rivers surveyed, although we found a higher abundance of yearlings and juveniles along the Macal River. The prevalence of the cutaneous parasite *Paratrichosoma* sp. was high (79%), and the overall calculations of body index (K) suggest a healthy population of *C. moreletii* in Chiquibul Forest. Given the data collected in this study, in conjunction with past research of *C. moreletii* in Belize, we suggest that the population in Chiquibul Forest is unique given its isolation, and that appropriate conservation management plans are warranted to protect this population's genetic and ecological integrity.

Key Words: Conservation management, crocodile demographics, habitat monitoring, mark-recapture survey, nest survey, nocturnal eyeshine survey, *Paratrichosoma* sp.

Resumen: Realizamos un censo de población de Cocodrilo de Pantano (*Crocodylus moreletii*) en La Selva de Chiquibul, Distrito de Cayo, Belice en abril, junio, y julio de 2016. Avistamos 162 cocodrilos (tasa de encuentro = 3.6 cocodrilos/km). La población de cocodrilos estuvo conformada por 22 crías (13%), 45 juveniles 28%, 19 subadultos (12%), 27 adultos (17%) y 49 (30%) se identificaron como solos ojos. La proporción de sexos en La Selva de Chiquibul muestra un fuerte sesgo hacia las hembras (0.29:1). La distribución de subadultos y adultos no fue significamente diferente entre los ríos, pero se encontró una mayor abundancia de crías y juveniles en el Río Macal. El parásito *Paratrichosoma* sp. tuvo una prevalencia alta (79%), y el calculo del índice corporal (K) sugiere una población de *C. moreletii* sana en La Selva de Chiquibul. Con los datos obtenidos en este proyecto y las investigaciones pasadas de *C. moreletii* en Belice, sugerimos que esta población es única por su aislamiento, y que se necesitan planes de manejo de conservación adecuados para proteger la integridad genética y ecológica de esta población.

Palabras Claves: Censos de nidos, Censos nocturnos, demografía de cocodrilos, marcaje captura-recaptura, monitorio del hábitat, *Paratrichosoma* sp., plan de manejo para la conservación

Citation: Tellez, M., B. Arevalo, I. Paquet-Durand, and Shawn Heflick. 2017. Population status of Morelet's Crocodile (*Crocodylus moreletii*) in Chirquibul Forest, Belize. Mesoamerican Herpetology 4: 8–21.

Received: 27 January 2017; **Accepted:** 21 February 2017; **Published:** 30 March 2017.

INTRODUCTION

Morelet's Crocodile (*Crocodylus moreletii*) is one of two crocodile species that occur in Belize, and which primarily inhabits freshwater lakes, rivers, and wetlands (Ross, 1998). In the early to mid-1900s, overharvesting and poaching of *C. moreletii* throughout its range (Belize, Guatemala, and Mexico) propelled the species toward extinction (Frost, 1974; Platt and Thorbjarnarson, 2000). With the implementation of the Belize Wildlife Protection Act of 1981, populations began to recover as a result of the new legal status, but still were considered vulnerable to extinction (Thorbjarnarson, 1992). The IUCN/Species Survival Commission–Crocodile Specialist Group (CSG) prioritized the gathering of baseline data in the mid-1990s to determine the population of *C. moreletii* in Belize. The data collected from surveys conducted only in northern Belize illustrated a recovering population of *C. moreletii* from past overexploitation (Platt and Thorbjarnarson, 2000). Based on this survey data, as well as the abundant data accrued from Mexico, *C. moreletii* currently is listed as Least Concern in the IUCN Red List, and as Appendix II in the Convention on International Trade in Endangered Species of Flora and Fauna (CITES). The current IUCN assessment and the CITES status of *C. moreletii*, however, highly depend on continued research and management programs to implement the appropriate conservation plans, and thus the population stability of this species is "conservation dependent" (Ross, 1996).

The population ecology and status of *C. moreletii* in northern Belize has been well documented (Platt et al., 2010), but the status of this crocodylian species in southern Belize remains data deficient, particularly in Chiquibul Forest, Cayo District. Historical and current observations and information provided by local people indicate a stable and isolated population of *C. moreletii*, but the actual demographics of the population are unknown. The population of *C. moreletii* in Chiquibul Forest presents an interesting topic for investigation given the lack of human encroachment and encounters in this region, as well as in the amount of undeveloped habitat; such variables are rare in modern crocodylian studies.

The purpose of this study was to obtain baseline data on the population status of *C. moreletii* in Chiquibul Forest, in order to foster a local conservation program for the species. Our goals included: (1) to collect demographic data on *C. moreletii* via eyeshine and capture surveys; (2) to monitor the habitat; (3) to conduct nest surveys; and (4) to examine individuals for presence of the external parasite *Paratrichosoma* sp.

MATERIAL AND METHODS

Study Area

Chiquibul Forest covers an area of 176,999 ha, and is comprised of three protected areas: Chiquibul National Park (106,838 ha); Chiquibul Forest Reserve (59,822 ha); and Caracol Archeological Reserve (10,339 ha). Because of its rich biodiversity, Chiquibul Forest is recognized at the national and international levels as a key biodiversity conservation area. Meerman and Sabido (2001) identified 17 different natural ecosystems within Chiquibul Forest, all variants of Tropical Broadleaf Forest, except for a pine forest ecosystem. The climate of the region is subtropical, with a marked dry season from February to June, and a rainy season coinciding with the hurricane season that occurs from July to November (Salas and Meerman, 2008). Cretaceous limestone forms the parent rocks found in the western half of the forest, while Permian meta-sediments are dominant on the east (Cornec, 2003). Volcanic deposits are present on the extreme southern portion of the longitudinally oriented main divide, the backbone of the Maya Mountains. The soils generally are derived from limestone and are fertile compared to those in other tropical areas, but Wright et al. (1959) classified the soils on the steeper limestone slopes as skeletal. Primarily limestone, much of the hydrology is subterranean, except for principal waterways such as the Raspaculo, Monkey Tail, and the Chiquibul rivers. The Chalillo Dam was completed and commissioned in September of 2005. The dam has a height of 49.5 m and is located 12 km downstream of the confluence of the Macal and Raspaculo rivers. Its construction resulted in the creation of an artificial lake with a total surface area of 9.53 km^2 (including the existing 1.5 km^2 of the river), and extends for approximately 20 km up the Macal River and 10 km up the Raspaculo River. At full supply the maximum depth of the reservoir is 35 m, and it contains a storage capacity of 120.3 million m^3. The Chalillo Dam is designed to work in conjunction with two other existing dams (Mollejon and Vaca) located downstream from the Macal River, and it has a power generating capacity of 7.3 MW (ESL Management Solutions Limited, 2006).

Survey Methods

We conducted surveys from 1 to 3 April, 21 to 24 June, and 14 July 2016 to obtain baseline data for the *Crocodylus moreletii* population in Chiquibul Forest, for initiating a crocodile conservation program led by the co-managers of Chiquibul Forest: Friends for Conservation and Development (FCD) in collaboration with the Crocodile Research Coalition (CRC). This inaugural step to create a conservation program also included training for the FCD research team.

We used canoes during the April surveys along the Raspaculo River, and a 40 hp motorboat along the Macal and Raspaculo rivers and in Chalillo Lake during the June and July surveys (Fig. 1). We conducted habitat monitoring (HM) and nest surveys (NS) during the day to facilitate the description of the habitat and to identify crocodile nests, following Sánchez Herrera et al. (2011). We performed nocturnal eyeshine surveys (NES) and capture and mark surveys (CMS) at night using a 200,000-candle power spotlight and LED headlamps. We did not conduct the NES and CMS surveys during the same nights because of the following reasons: (1) the velocity must remain at a constant speed; and (2) the NES should be conducted with minimal noise, i.e., the capture of crocodiles can adversely effect observing individuals for the NES (Sánchez Herrera et al., 2011). We recorded survey routes and GPS location points of crocodile sightings, capture, and nests with a Garmin eTrex 30x.

Habitat Monitoring

We examined the habitats along the Raspaculo and Macal rivers on 1 April and 24 June of 2016, to assess the current and future environmental or anthropogenic threats to the *C. moreletii* habitat. We described the following major components as presented in Sánchez Herrera et al. (2011): (1) types of water; (2) types of habitats; (3) state of the natural vegetation (on a scale from 1 to 10; 1 = poor); (4) predominant human activity; and (5) pollution in the water (i.e., trash and chemical drainage).

Nocturnal Eyeshine Surveys

Our census data for *Crocodylus moreletii* began with nocturnal eyeshine surveys (NES). We recorded the average beginning and ending air temperature as 25.7ºC and 24.0ºC and the average beginning and ending water temperature as 28.5ºC and 28.0ºC, respectively, during four nights of the NES, between 1901 and 2156 h. Upon sighting a crocodile, we recorded the GPS coordinates and the distance of the sighting from the boat (m). We also classified individuals into size categories based on total length (TL) as hatchlings (TL < 50 cm), juveniles (51 cm–100 cm), subadults (101 cm–150 cm), adults (TL > 151 cm), and as "eyeshine only" if the TL could not be determined (Platt and Thorbjarnarson, 2000; Sánchez Herrera et al., 2011).

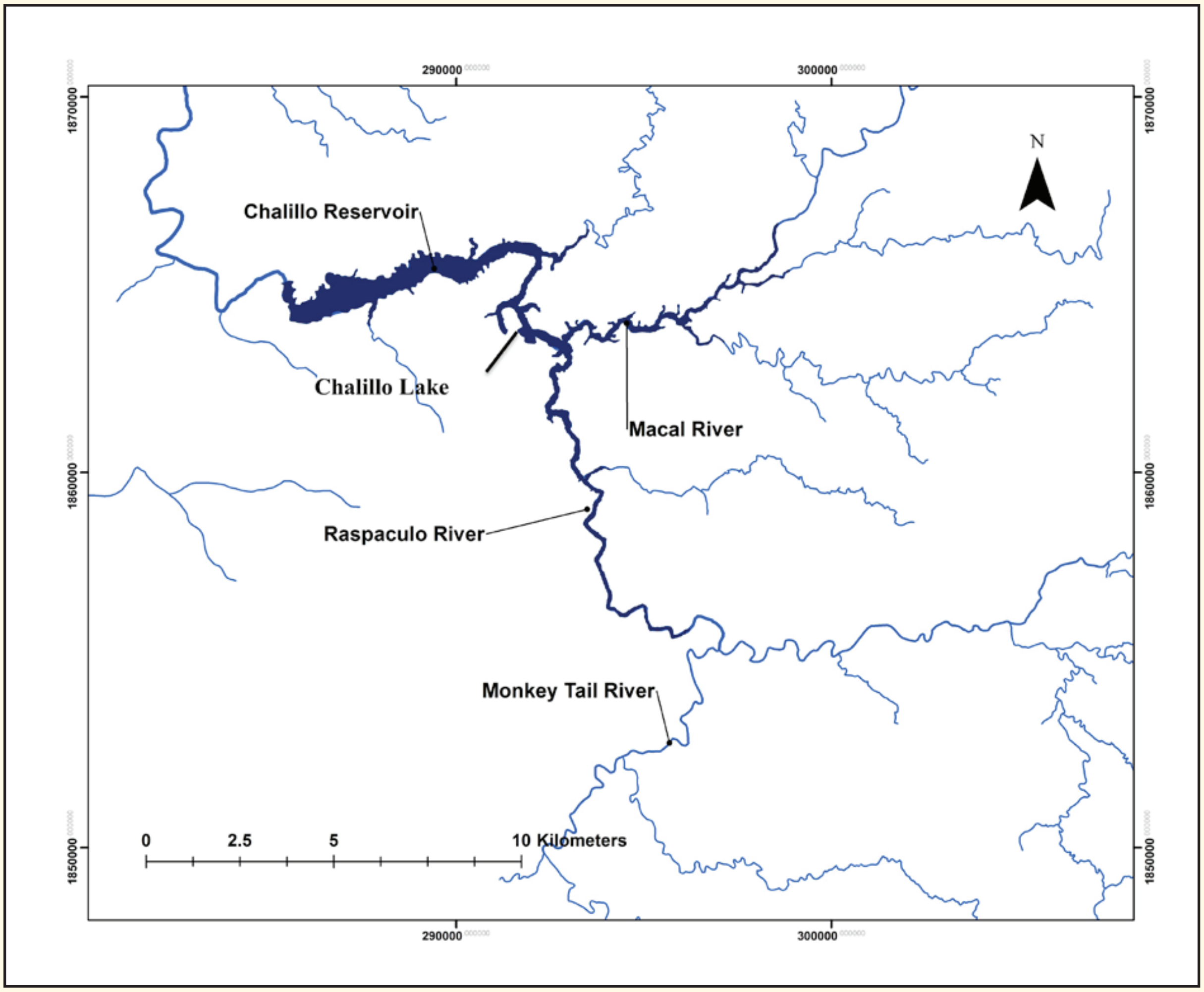

Fig. 1. Map of Chiquibul Forest, Cayo District, Belize, and survey routes.

Capture and Mark Surveys

We recorded the average air and water temperatures as 23.1ºC and 27.7ºC, respectively, during the four nights of the CMS on the Macal and Raspaculo rivers. We captured the *Crocodylus moreletii* by hand or catchpole, and recorded the following morphometric data: head length; snout length; cranial width; maxillary width; pre-maxillary width; TL; snout–vent length; tail width; sex; and body mass. We also examined individuals for the presence of *Paratrichosoma* sp., a nematode identified by its cutaneous zigzagging trails, which infects the epidermal skin on the ventral side of crocodiles (Ashford and Muller, 1978; Tellez and Paquet-Durand, 2011). The parasite causes no pathology, and infected individuals are known to recover (MT, unpublished). After collecting the morphometric and parasite data, we marked individuals with a specific numerical code identifying the species and region (i.e, Chiquibul). We tagged crocodiles > 100 cm TL with a metal inter toe tag in which the numerical identification matched the numerical scute clip of the individual. The tail scute clips were preserved for future genetic and eco-toxicology studies. After collecting the data and scute clippings, we released crocodiles at the site of capture.

Nest Surveys

Nest surveys are important because they help identify the characteristics of the reproducing population, such as estimating its abundance, and particularly that of reproducing females (Sánchez Hererra et al. 2011). Nest surveys, therefore, can be an important tool for conservation management, as they can complement and strengthen information on the viability of a population and what conservation efforts should be implemented, in conjunction with eyeshine surveys, and capture and mark surveys (Sánchez Hererra et al. 2011). We conducted nest surveys during the day on 22 and 24 June by boat, as well as through personal communication with the Scarlet 6 Biomonitoring Team who were conducting bird surveys in Chiquibul at the time of our study. Upon locating a nest, we recorded the following: (1) the presence of a female; (2) the primary vegetation used for the mound nest; (3) the minimum distance from the center of nest to the nearest shore of the body of water; (4) the percentage of shade the nest likely receives during the day; (5) the temperature of the nest; and (6) the diameter, height, and depth of the nest. The opening of a nest greatly enhances predation of the eggs. Thus, following the suggestion of Sánchez Hererra et al. (2011) we did not completely uncover the nests to remove the eggs for measurements, as the nests we identified had been covered especially well and were not under any environmental threat of being destroyed (i.e., flooded due to its closeness to the water, desiccation, etc.). We revisited the nests three days after we examined them, to determine if they had been disturbed as a result of our original visit.

Statistics

We calculated Fulton's Condition factor (K) for 17 of the juvenile *Crocodylus moreletii* we captured, to determine the overall condition and health of the crocodiles in Chiquibul Forest (Zweig, 2003), and to examine how their condition might differ between the Macal and Raspaculo rivers. We did not record the body mass for nine of the captured crocodiles, and omitted three subadults from our K analysis so as not to affect the overall results. To assess their condition of health, we divided the range of scores for juveniles into the following four arbitrary ranks, as Fulton's K does not have a standard biological condition score: low; low to average; average to high; or high (Zweig, 2003; Rice, 2004).

To identify the relative density of *C. moreletii* in Chiquibul Forest, we calculated the encounter rate as described in Platt and Thorbjarnarson (2000). We tested against the null hypothesis of a 1:1 sex ratio in Chiquibul Forest with a chi-square test, in addition to to testing for a 1:1 sex ratio between the Macal and Raspaculo rivers. We also tested the observed size distribution of crocodiles within Chiquibul Forest against the null hypothesis of an even distribution of size cohorts with a chi-square test, in addition to testing the variation of size distribution within the Macal River, Raspaculo River, and Chalillo Lake. We omitted Eyeshine Only (EO) from the statistical examination of size class distribution among and within our three primary field sites. We performed the above statistical analyses on Program R (2012), and all analyses were considered significant at $P < 0.05$.

RESULTS

Our study in Chiquibul Forest primarily included surveys along rivers, as well as in a few streams and creeks in areas with steep banks. Because of the presence of natural debris, we could not survey too far along the streams and creeks, and thus many times spotted crocodiles in places where they could not be easily captured. The predominant vegetation consisted of water lilies (40%), grassland (40%) tule marsh (18%), and human modification (i.e., campsites, 2%). Human activities are minimal in this national park, and primarily consist of few national and international researchers, FCD rangers and a research team, and poachers from Guatemala (MT and FDC rangers, pers. comm.). The state of the natural vegetation appeared healthy and pristine (recorded as 10) and we had several encounters with local wildlife, e.g., Fer-de-Lance (*Bothrops asper*), Scarlet Macaws (*Ara macao*), Baird's Tapirs (*Tapirus bairdii*), Margays (*Leoprdus wiedii*), and Jaguars (*Panthera onca*). We did not encounter signs of pollution, but in September of 2015 the Belize Ministry of Health issued a public advisory warning people in villages around the Macal River to avoid the consumption of fish, because of high levels of mercury resulting from dam sedimentation (Ministry of Health, 2015). To date, we are unaware of the mercury levels or other heavy metal concentrations in the Macal or Raspaculo rivers. We collected tissue samples from the captured crocodiles for future analysis, which might help reveal the current levels of heavy metals in Chiquibul Forest.

During four nights of the NES we encountered a total of 162 *Crocodylus moreletii* along a 44.2 km route (encounter rate = 3.6 crocodiles/km, Table 1). Of the 162 crocodiles observed, we classified 22 as yearlings (13%), 45 as juveniles (28%), 19 as subadults (12%), 27 as adults (17%), and 49 as eyeshine only (30%). The distribution of yearlings and juveniles was significantly higher in the Macal River ($\chi^2 = 10.0$, $df = 2$, $P < 0.001$; $\chi^2 = 10.8$, $df = 2$, $P < 0.005$), whereas that of adults did not differ significantly in distribution among Chalillo Lake, and the Macal and Raspaculo rivers ($\chi^2 = 0.38$, $df = 2$, $P > 0.05$). The distribution of subadults in the Raspaculo River was marginally significant relative to the other field sites ($\chi^2 = 6.19$, $df = 2$, $P = 0.05$). Size-class distributions differed significantly within the Macal River ($\chi^2 = 12.63$, $df = 3$, $P < 0.006$) and Macal Watershed ($\chi^2 = 9.03$, $df = 3$, $P < 0.03$), with juveniles more abundant in the Macal River and subadults more abundant in Chalillo Lake. Size-class distributions in the Raspaculo River did not differ significantly ($\chi^2 = 7.24$, $df = 3$, $P > 0.05$) (Fig. 2).

Table 1. Data on nocturnal eyeshine, and capture and mark surveys on *Crocodylus moreletii* conducted in Chiquibul Forest, Cayo District, Belize, in April and June of 2016.

Date	Location	Distance Surveyed	Crocodiles Encountered	Encounter Rate
1 April	Raspaculo River	4.4 km	16	3.6
2 April	Raspaculo River	1.2 km	11	9.2
3 April	Raspaculo River	4.2 km	2	0.5
21 June	Raspaculo River	9.7 km	48	4.9
22 + 23 June[a]	Raspaculo River	4.7 km	12	2.6
23 June	Macal River	7.3 km	35	4.7
24 June	Macal River	7.3 km	14	1.4
14 July	Macal River (open watershed)	5.4 km	24	4.4
Totals		**44.2 km**	**162**	**3.6 crocodiles/km**

[a]Given the heavy rainfall on the night of June 22, in which the survey was conducted for 30 min, the capture survey continued on the night of June 23. We began the capture survey on 23 June at the location in which the survey ended on 22 June.

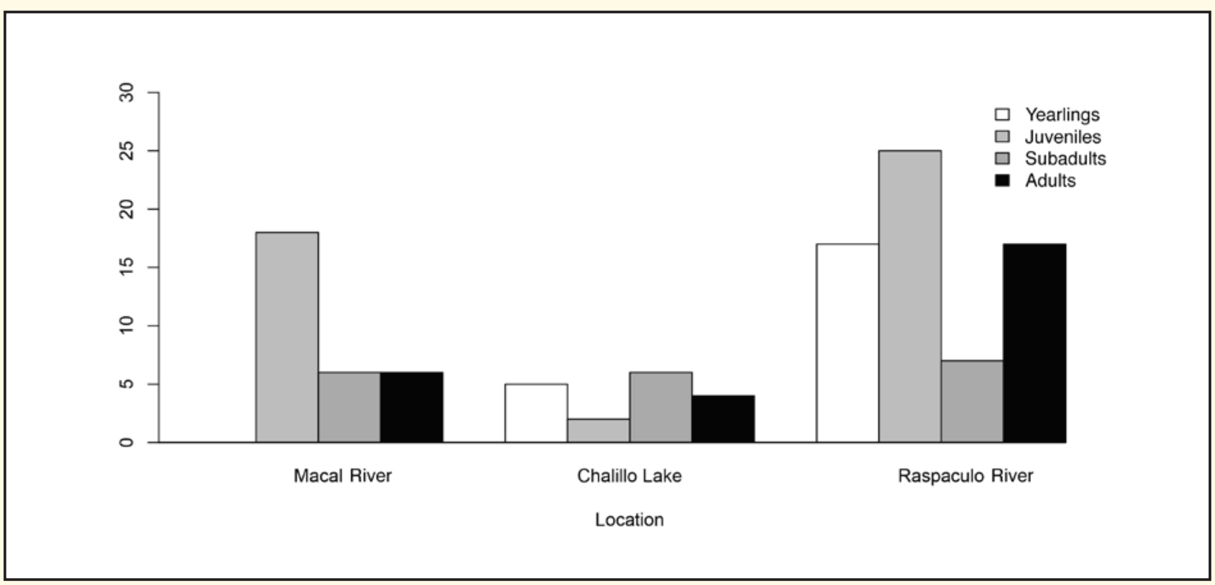

Fig. 2. Distribution of *Crocodylus moreletii* size cohorts among the Macal River, Chalillo Lake, and the Raspaculo River in Chiquibul Forest, Cayo District, Belize.

The collection of morphometric data was derived from 29 captured *C. moreletii* (Fig. 3), for which we determined the sex of 22 individuals (seven small juveniles could not be reliably sexed). The sex ratio of *C. moreletii* in Chiquibul Forest illustrates a significant difference from 1:1 ($\chi^2 = 6.55$, $df = 1$, $P < 0.01$) with a strong female bias (0.29:1; Fig. 4). The sex ratios between the Macal and Raspaculo rivers were not significant ($\chi^2 = 0$, $df = 1$, $P > 0.05$). From the above captures, we successfully obtained the body mass of 10 juveniles and one subadult from the Macal River, and seven juveniles and two subadults from the Raspaculo River. We found that the average body mass of juveniles and the subadult from the Macal River was more than that of the juveniles and subadults from the Raspaculo River (juveniles: 2.2 ± 0.4 vs. 0.97 ± 0.6; subadults: 0.97 ± 0.6 vs. 3.0 ± 0.0), respectively.

Upon visual inspection, the 29 individuals captured showed a good body condition (particularly when examining the neck and tail girth), with minor injuries or a few scars evident from presumed intra- or interspecific competition or conflict. A high prevalence of the captured *C. moreletii* exhibited infections of *Paratrichosoma* sp. (79%), concentrated primarily from the cloaca to the tail, on the neck, and on the lower jaw. All of the non-infected individuals ($n = 6$) were identified as small juveniles that ranged in size from 51.3 cm to 71.1 cm. The condition scores for the juvenile *C. moreletii* ranged from 1.2 to15.8 (Table 2). The *C. moreletii* from the Raspaculo River showed a lower mean body condition than those from the Macal River (2.5 vs. 3.7), but the overall K suggests a relatively healthy population of crocodiles in Chiquibul Forest.

Table 2. Futon's condition score (K) range and assigned ranks for juvenile *Crocodylus moreletii* captured in the Raspaculo and Macal rivers in Chiquibul Forest, Cayo District, Belize.

Quartile	K	Condition Rank
1st	1.2–2	Low
2nd	2.1–2.3	Low to Average
3rd	2.4–2.6	Average to High[a]
4th	3.2–15.8	High[b]

[a]Average mean K in Raspaculo River ($n = 7$): 2.5
[b]Average mean K in Macal River ($n = 10$): 3.7

In total, we only found two *C. moreletii* nests—one on the Macal River and the other on the Raspaculo River (Table 3). Some nests likely escaped detection due to the thick vegetation in some areas along both rivers. The nest located along the Macal River appeared to be a multi-year nest site, evidenced by the presence of old material and the nest diameter height (S. Heflick, pers. comm.); FCD rangers confirmed having observed this nest site in previous years. No female was present during our nest surveys, and tracks of the rear feet were not found so we could estimate the length of nesting female (Platt et al., 2008). Dry leaves and grass were the primary substrate used to construct the nest mounds, with 0% shade coverage and an average distance of 20 m from the shore.

Table 3. Description of the two *Crocodylus moreletii* nests discovered along the Raspaculo and Macal rivers in Chiquibul Forest, Cayo District, Belize.

Location	Nest Diameter (cm)	Nest Depth (cm)	Nest Material	Distance from Shore (m)	Nest Temperature (ºC)
Raspaculo River	252	32	Dry leaves	30	30.4
Macal River	285.5	59	Dry leaves and grass	10	28.7

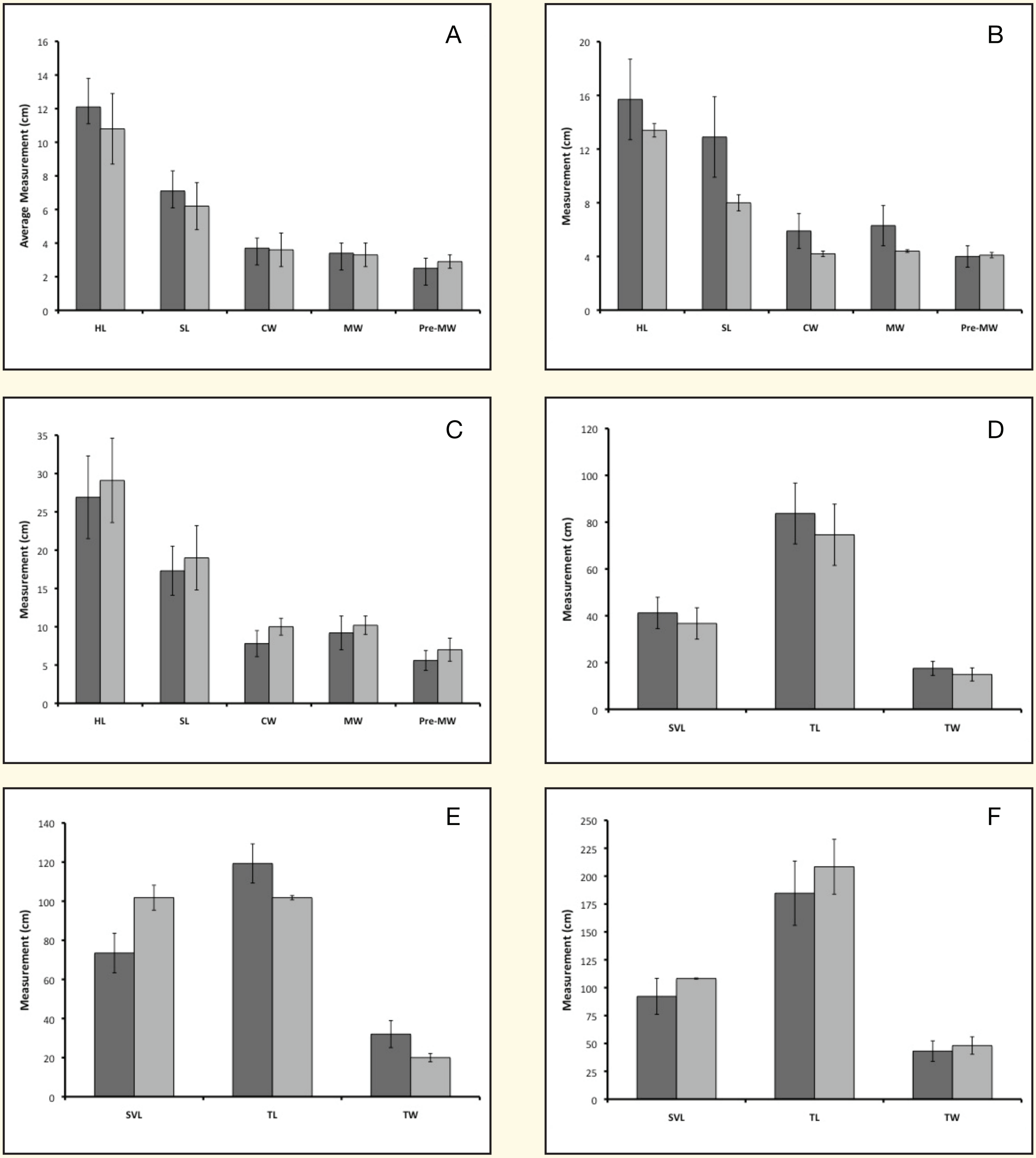

Fig. 3 Mean average morphometric (± SD) data of captured *Crocodylus moreletii* separated in size class cohorts, river systems, and morphometric data (head and body measurements): (A) juvenile head measurements; (B) subadult head measurements; (C) adult head measurements; (D) juvenile body measurements; (E) subadult body measurements; and (F) adult body measurements. Abbreviations are as follows: HL = head length; SL = snout length; CW = cranial width; MW = maxillary width; Pre–MW = pre-maxillary width; SVL = snout–vent length; TL = total length; and TW = tail width. Dark gray bars indicate crocodiles captured in the Macal River, and light gray bars indicate crocodiles captured in the Raspaculo River.

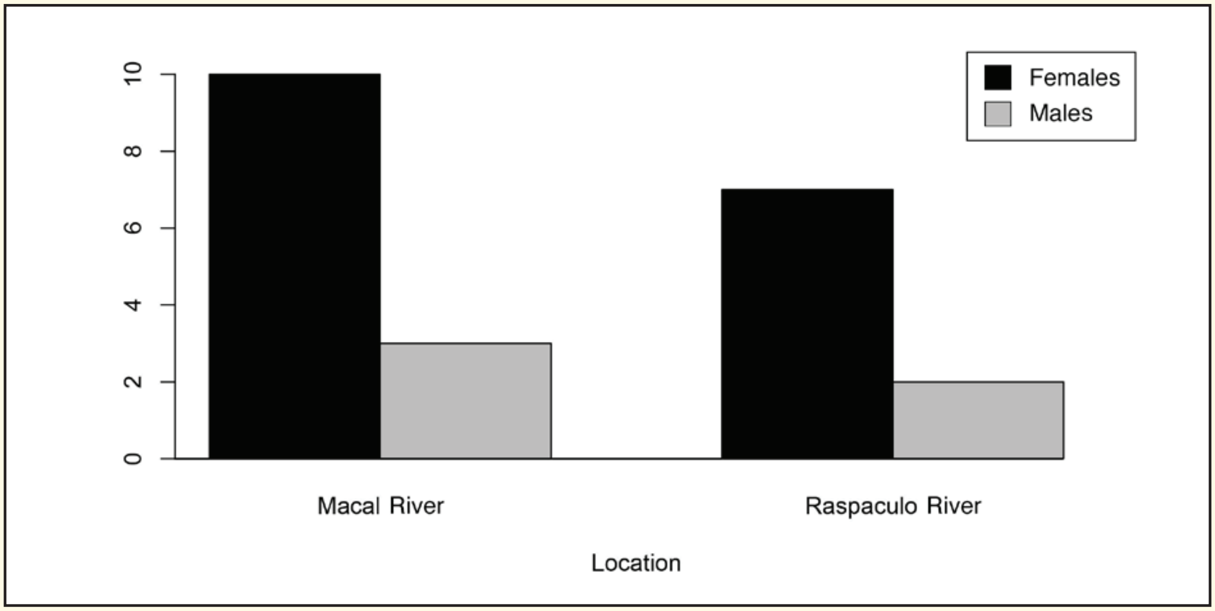

Fig. 4. Sex ratio distribution of *Crocodylus moreletii* between Macal and Raspaculo rivers in Chiquibul Forest, Cayo District, Belize.

DISCUSSION

Our study confirms a relatively abundant and healthy population of *Crocodylus moreletii* along the Macal and Raspaculo rivers in Chiquibul Forest. We found that yearlings, juveniles, and smaller subadults primarily inhabit dense vegetation along the riverbanks or within creeks or streams, whereas large subadults and adults prefer open water in rivers or riverbanks (not necessarily with dense vegetation). Prey availability and preference can influence habitat distribution among size cohorts (Chabreck, 1966; Tucker, 1996; Delany and Abercrombie, 1986), but this may hold little significance in Chiquibul Forest. During our surveys, we observed an overabundance of frogs along the riverbanks and open waters of the Raspaculo River (particularly in March), in addition to fish of various sizes. During the time of our investigation, food availability did not appear to be a limiting factor in streams, creeks, or rivers. Currently, we can only assume that prey consumed throughout the ontogenetic dietary shifts in *C. moreletii* in this environment is similar to that reported in previous studies (Pérez-Higareda et al., 1989; Platt et al., 2006), as data on predator-prey interaction is lacking in this system. Hence, based on our observations (and previous observation by FCD rangers) we suggest that frogs and fish are the primary sources of prey for juveniles, subadults, and adults in Chiquibul Forest, and presume that the location of prey does not have a prominent influence on crocodile distribution among the size cohorts because of the abundance of prey in the various habitats. Instead, we suggest that protection from potential terrestrial predators (egrets, herons, and jaguars) and larger aquatic predators (large fish or crocodiles), or the aversion of territorial aggression from larger crocodiles, likely influences smaller individuals to inhabit areas with dense vegetation in order to camouflage (i.e., residing in creeks, streams, or in densely-vegetated areas along riverbanks). Large fish, in addition to the possibility of preying upon small mammals that swim in rivers, likely influence the predatory behavior of larger subadult and adult crocodiles in open water. Additional dietary and behavioral observations are warranted in Chiquibul Forest to further understand the diet and behavioral ecology of this population of *C. moreletii*.

We observed a wide range of size classes, similar to those in reports from the Macal River in 2001 and 2002 (Stafford et al., 2003). Size distribution among the size classes within the Macal and Raspaculo rivers did not differ significantly, yet the abundance of yearling and juvenile crocodiles in the Macal River was significantly higher than in the Raspaculo River. These data perhaps suggest that both rivers provide viable habitat and suitable food for crocodiles throughout stages of their life history, as well as with annual nesting and hatching success (presuming the gradual incline of SVL of smaller individuals reflects annual growth). The higher abundance of yearlings and juveniles observed along the Macal River, however, might result from the higher proportion of streams and creeks along this river that provide prime habitat for smaller individuals. As previously mentioned, streams and creeks generally contained more dense vegetation than found along the banks of the primary river system, which a higher number of smaller individuals use for protection from larger individuals and/or predators. Thus, the higher abundance of yearlings and juveniles found along the Macal River likely reflects the increase of habitat space in which smaller individuals can evade or hide from predators, as well as a possible lower rate of predation compared to that in the Raspaculo River (which has lower amount of prime habitat for smaller crocodiles). Further research into the ecology of *C. moreletii* in Chiquibul Forest might help reveal cryptic details to further understand the differences of biotic and abiotic factors on the survival rate of smaller individuals.

The population of *C. moreletii* in Chiquibul Forest appeared healthy and yielded an overall high body condition score, which may reflect a stable and healthy environment. Crocodiles in Chiquibul Forest possibly do not undergo as much stress (which can affect body mass and K) as those from populations with limited prey due to over-fishing or such human perturbations as pollution, habitat loss, and harassment (Rice, 2004). Thus, isolation or minimal contact from human influences, in addition to an overabundance of prey sources, perhaps significantly contributes to the high body condition score and overall health observed in this population. The fact that few scars and only minor injuries were observed among the 29 captured individuals suggests low intraspecific competition within this system. These results are similar to those in a previous population study along the Macal River in 1995 (Stafford et al., 2003), but our finding contrasts observations of *C. moreletii* in other populations in Belize (MT, pers. observ.). Scars, bite marks, or missing limbs appear to be a common occurrence as a result of competition for habitat, breeding mates, or food (Somaweera et al. 2013; Cedeño-Vázquez et al. 2016). Nonetheless, we witnessed three occurrences of cannibalism within a 24 h period along the Macal River (Tellez et al., *In Press*). All of the cannibalized crocodiles were females around 1.5 m TL (we retrieved all three carcasses from the predatory crocodile). Cannibalism is common among crocodylians (Cedeño-Vázquez et al. 2016), but the rate of cannibalism for *C. moreletii* in Chiquibul Forest is unknown. Interestingly, we observed few injuries among the captured crocodiles, but our observation of cannibalism provides evidence of intraspecific conflict within this population.

The nematode *Paratrichosoma* sp. is non-virulent, and the zigzag cutaneous trails of infected individuals are known to subside (Ashford and Muller, 1978; MT, unpublished). In contrast to previous findings, we found a 79% prevalence of *Paratrichosoma* sp. infection. Previous reports of *Paratrichosoma* sp. on the Macal River identified the parasite on only two yearling crocodiles (Stafford et al., 2003), but we did not identify the infection on any yearlings or small juveniles. The life cycle of *Paratrichosoma* sp. is still unknown, but preliminary data and hypotheses suggest that the nematode can infect its crocodylian host via trophic transmission or cutaneous penetration (Buenviaje et al., 1998; Tellez and Paquet-Durand, 2011). Given the contrasting data from the previous and current study, trophic transmission does not seem like a primary route of infection given the varying diets of yearlings and small juveniles, compared to those of larger animals (Tucker et al., 1996, 2007; Platt et al., 2006). Alternatively, perhaps the life cycle of this species of *Paratrichosoma* is monoxenous (i.e., one host in the life cycle) and directly infects this population of *C. moreletii* through cutaneous penetration. Female *Paratrichosoma* excrete their eggs into the external environment from the crocodylian epidermis (Ashford and Muller, 1978). Once eggs are released into the external environment, abiotic cues likely signal the larvae to hatch, and the parasite then endures a free-living stage until contact with its definite host. Given the possibility that this population of *Paratrichosoma* sp. may include a free-living stage, juveniles become exposed to various abiotic fluctuations that can affect their infection success and geographic distribution (Combes, 2003). Thus, the increasing prevalence of this parasite in Chiquibul Forest may reflect environmental changes that have favored the expansion of *Paratrichosoma* sp. into various microhabitats within the river systems. The above hypotheses cannot be conclusive, however, given the small data set provided by Stafford et al. (2003), in addition to the paucity of information on the *Paratrichosoma* sp. life cycle. Further research into the distribution and prevalence fluctuations of *Paratrichosoma* sp. might provide cryptic details about past and current environmental changes in Chiquibul Forest.

We found a female biased population of *C. moreletii* in Chiquibul Forest, which to our knowledge is the first reported for this species in Belize, and throughout its range (Platt, 1996; Platt and Thorbjarnarson, 2000; Stafford et al., 2003; Cedeño-Vazquez et al., 2006; Platt et al., 2009). Previous studies report a male biased population of *C. moreletii* in Belize, with minimal deviation from 1:1, which is similar to other congeneric populations (Platt and Thorbjarnarson, 2000; Stafford et al., 2003; Platt et al., 2009; Platt et al., 2011 and references within). The *C. moreletii* population in Chiquibul Forest, however, appears to deviate significantly from the 1:1 ratio (0.29:1). We excluded yearlings and small juveniles from our sex ratio calculations, because of the difficulty of sexing and to prevent misidentification of their sex. Additionally, our captures were random, and thus we assume unbiased sampling of males and females. Our finding could result from low ambient temperatures (the air temperature is relatively lower in Chiquibul Forest, compared to that in other areas within the range of *C. moreletii* in Belize) affecting the nest temperatures (Hutton, 1987; Belize by NaturaLight, 2016). The sex of crocodylians is temperature-dependent, with low nest temperatures (28ºC–31ºC) producing females and higher temperatures (32ºC–34) producing males (Lang, 1994). Although we only found two nests, the average temperature for both was 29ºC, which theoretically would produce a female biased clutch. No shade covered either mound nest, and thus because of the exposure to direct sunlight perhaps the top layer of eggs incubated at a higher temperature, with the majority of the eggs incubating at a lower temperature. Years of this pattern might have led to the female biased sex ratio we observed. The difference in growth rate and survivorship between males and females also could affect the population sex ratios (Thorbjarnarson, 1997; Lance et al., 2000), but more data needs to be accrued before assuming that variation in average total size and survival capability between male and female crocodiles influenced our sampling bias.

The two nests we found shared similar characteristics to hose found in other populations of *C. moreletii* in Belize (Platt et al., 2008). The nest located on the Macal River was smaller in depth and diameter compared to the one on the Raspaculo River, but we could not determine if this was a reflection of female size (Alvarez del Toro, 1974). Larger females generally construct the largest nest mounds, but since no females were present during our nest surveys we cannot assume that a larger female constructed the nest on the Raspaculo River. The Raspaculo River nest, however, appeared to have been used the previous year, as evidenced by the presence old vegetation on the bottom of the nest, as well as the height of the nest. Thus, we presume that the same individual was re-using this nest site, which might reflect previous years of hatching success. Even though both nests were constructed on elevated sites, the Macal River nest might have been smaller given its construction on a steep slope. Unlike all of the *C. moreletii* nests found in northern Belize (Platt et al., 2008), this nest was not constructed on a solid substrate, but on soft soil and on a steep slope. The distance of this nest from the water reflects its elevation, as it was located rather close to the water's edge. The site of both nests apparently indicates that the females chose the location to minimize the risk of early flooding or the water levels rising, and also constructed close enough to the water's edge to guard the nests from predators (Platt et al., 2008). Interestingly, both nests are located within the watermark level of annual flooding, and thus during the rainy season nests are inundated and compacted by the weight of the water and erosion. As a result of Hurricane Earl, which affected Belize on 4 August 2016, the water levels in Chiquibul Forest rose drastically, and earlier than expected in Chiquibul Forest. The FCD rangers confirmed that both nests were destroyed by the hurricane, which likely also destroyed other nests we did not find. Perhaps some nests hatched a few weeks earlier, given that the hatching season for *C. moreletii* is from mid-August to mid-September, but to date we have no confirmed sighting of a hatchling from the past nesting year.

The construction of the Chalillo Dam in 2005 motivated many environmentalists to express their concerns about the impact the dam on local wildlife as a result of back-flooding, and particularly on the survival of *C. moreletii* nests (Stafford et al., 2003). Our observations illustrate a thriving population of *C. moreletii* that have adapted to the environmental changes caused by the dam. The wide distribution of crocodiles of varying sizes attests to multiple years of successful hatching since the dam was constructed.

In summary, the population of *C. moreletii* in Chiquibul Forest appears to be stable in a relatively healthy environment. Presumably, future research and annual surveys will provide significant data for the local conservation and management of this unique population, especially since it likely represents one of the few remaining genetically pure populations of *C. moreletii* in Belize (Ray et al., 2004). Hybridization between *C. moreletii* and *C. acutus* is common in areas of sympatry (Cedeño-Vázquez et al., 2008; Rodriguez et al., 2008; Pacheco-Sierra et al., 2016), and the discovery of *C. acutus* haplotypes further inland in typical *C. moreletii* habitat in Belize illustrates the loss of genetic integrity due to introgression (Ray et al., 2004; Hekkala et al., 2016). The continued isolation of *C. moreletii* in Chiquibul Forest provides a protective barrier for the genetic integrity of this population, as well as from anthropogenic influences (i.e., pollution, habitat loss, harassment, indiscriminate killing). The FCD in partnerships with the Belize Forest Department (BFD) and the Belize Defense Force (BDF) are in a continuous struggle to protect the biodiversity of Chiquibul Forest from poachers crossing the Belize–Guatemala border. Data on the extent of crocodile poaching in Chiquibul Forest is lacking, however, and presumed to be minimal compared with those for other wildlife (e.g., Scarlet Macaws). Nonetheless, given the decimated populations of *C. moreletii* along the southern Belize–Guatemala border (MT, pers. observ.), and the rise of crocodile poaching further inland in Belize, future conservation and management plans of this unique *C. moreletti* population in Chirquibul Forest should include the implementation of strategies to minimize crocodile poaching.

Acknowledgements.—We thank Yoni Moralez, Valerie Garcia, Miriam Boucher, Andrew Austin, the Friends for Conservation and Development rangers, and the Belize Wildlife Referral and Clinic for their assistance with the field research. We also are grateful to the Belize Forest Department for their continual support in furthering crocodile research, conservation, and management. Our appreciation also goes out to Luis Sigler and Valerie Garcia for their thoughtful reviews of the manuscript.

Literature Cited

AMEC E & C Services Limited. 2001. Macal River Upstream Storage Facility Environmental Impact Assessment. (https://journal.probeinternational.org/2001/08/31/macal-river-upstream-storage-facility-environmental-impact-assessment/)

Alvarez del Toro, M. 1974. Los Crocodylia de Mexico (Estudio Comparativo). Instituto Mexicano de Recursos Naturales Renovables, A.C., México, D.F., Mexico.

Ashford, R. W., and R. Muller. 1978. *Paratrichosoma crocodylus* n. gen. sp. (Nematoda: Trichosomoididae) from the skin of the New Guinea Crocodile. Journal of Helminthology 52: 215–220.

Belize by NaturaLight (2016) Facts about Belize. (www.belizenet.com/overview/facts-about-belize; accessed 18 November 2016).

Buenviaje, G. N., P. W. Ladds, and Y. Martin. 1998. Pathology of skin diseases in crocodiles. Australian Veterinary Journal 76: 357–363.

Cedeño-Vázquez, J. R., D. Rodriguez, S. Calme, J. P. Ross, L. D. Densmore, and J. B. Thorbjarnarson. 2008. Hybridization between *Crocodylus acutus* and *Crocodylus moreletii* in the Yucatan Peninsula: I. Evidence from mitochondrial DNA and morphology. Journal of Experimental Zoology Part A: Ecological Genetics and Physiology 309: 661–673.

Cedeño-Vázquez, J. R., Ross, J. P. and S. Calmé. 2006. Populaiton status and distribution of *Crocodylus acutus* and *C. moreletii* in southeastern Quintana Roo, Mexico. Herpetological Natural History 10: 17–30.

Chabreck, R. H. 1966. Methods of determining the size and composition of Alligator populations in Louisiana. Proceedings of the 20th Annual Conference of the Southeast Association of Game and Fish Commission 20: 105–112.

Combes, S. 2003. Parasitism: The Ecology and Evolution Intimate Interactions. The University of Chicago Press, Chicago, Illinois, United States.

Cornec, J. H. 2003. Provisional Geological Map of Belize, 1:175,000. Privately published, Belize.

Delany, M. F., and C. L. Abercrombie. 1986. Alligator food habits in northcentral Florida. The Journal of Wildlife Management 50: 348–353.

Frost, M. D. 1974. A Biogeographical Analysis of Some Relationships between Man, Land, and Wildlife in Belize (British Honduras). Unpublished Ph.D. dissertation, Oregon State University, Corvallis, Oregon, United States.

Hekkala, E. R., S. G. Platt, J. B. Thorbjarnarson, T. R. Rainwater, M. Tessler, S. W. Cunningham, C. Twomey, and G. Amato. Integrating molecular, phenotypic and environmental data to elucidate patterns of crocodile hybridization in Belize. Royal Society Open Science 2: 150409.

Hutton, J. M. 1987. Incubation temperatures, sex ratios and sex determination in a population of Nile Crocodiles (*Crocodylus niloticus*). Journal of Zoology 211: 143–155.

Lance, V. A., R. M. Elsey, and J. W. Lang. 2000. Sex ratios of American Alligators (Crocodylidae): male or female biased? Journal of Zoology 252: 71–78.

Lang, J. W., and H. V. Andrews. 1994. Temperature dependent sex determination in crocodilians. Journal of Experimental Zoology 270: 28–44.

Meerman, J. C., and W. Sabido. 2001. Central American Ecosystems: Mapping Project: Belize. Programme for Belize, Belize City, Belize. 88 pp.

Ministry of Health, Belize. 2015. Mercury in Fish in the Macal River. (www.health.gov.bz/www/general-health/866-mercury-in-fish-from-the-macal-river; accessed 28 November 2016).

Pacheco-Sierra, G., Z. Gompert, J. Domínguez-Laso, and E. Vázquez-Domínguez. 2016. Genetic and morphological evidence of a geographically widespread hybrid zone between two crocodile species, *Crocodylus acutus* and *Crocodylus moreletii*. Molecular Ecology 25: 3,484–3,498.

Pérez-Higareda, G., A. Rangel-Rangel, H. M. Smith, and D. Chiszar. 1989. Comments on the food and feeding habits of Morelet's Crocodile. Copeia 1989: 1,039–1,041.

Platt, S. G. 1996. The Ecology and Status of Morelet's Crocodile in Belize. Unpublished Ph.D. dissertation, Clemson University, Clemson, South Carolina, United States.

Platt, S. G., T. R. Rainwater, J. B. Thorbjarnarson, A. G. Finger, T. A. Anderson, and S. T. Murry. 2009. Size estimation, morphometrics, sex ratio, sexual size dimorphism, and biomass of Morelet's Crocodile in northern Belize. Caribbean Journal of Science 45: 80–93.

Platt, S. G., T. R. Rainwater, J. B. Thorbjarnarson, and D. Martin. 2011. Size estimation, morphometrics, sex ratio, sexual size dimorphism, and biomass of *Crocodylus acutus* in the coastal zone of Belize. Salamandra 47: 179–192.

Platt, S. G., T. R. Rainwater, J. B. Thorbjarnarson, and S. T. McMurry. 2008. Reproductive dynamics of a tropical freshwater crocodilian: Morelet's Crocodile in northern Belize. Journal of Zoology 275: 177–189.

Platt, S. G., L. Sigler, and T. R. Rainwater. 2010. Morelet's Crocodile *Crocodylus moreletii*. Pp. 79–83 *In* Crocodiles: Status Survey and Conservation Action Plan. 3rd ed. IUCN/SSC Crocodile Specialist Group, Darwin, Australia.

Platt, S. G., and J. Thorbjarnarson. 2000. Status and conservation of the Morelet's Crocodile, *Crocodylus moreletii*, in northern Belize. Biological Conservation 96: 21–29.

R Development Core Team. 2012. R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna Austria. (www.R-project.org/).

Ray, D. A., J. A. Dever, S. G. Platt, T. R. Rainwater, A. G. Finger, S. T. McMurry, M. A. Batzer, B. Barr, P. J. Stafford, J. McKnight, and L. D. Densmore. 2004. Low levels of nucleotide diversity in *Crocodylus moreletii* and evidence of hybridization with *C. acutus*. Conservation Genetics 5: 449–462.

Rice, A. M. 2004. Diet and condition of American Alligators (*Alligator mississippiensis*) in three central Florida lakes. Unpublished MSc. thesis. University of Florida, Gainesville, Florida, United States. (http://ufdcimages.uflib.ufl.edu/UF/E0/00/43/67/00001/rice_a.pdf).

Rodriguez, D., J. R. Cedeño-Vázquez, M. R. Forstner, and L. D. Densmore. 2008. Hybridization between *Crocodylus acutus* and *Crocodylus moreletii* in the Yucatan Peninsula: II. Evidence from microsatellites. Journal of Experimental Zoology Part A: Ecological Genetics and Physiology 309: 674–686.

Ross, J.P. 1996. Application of the new IUCN Criteria to crocodilian status evaluation. Pp. 499–504 *In* Crocodiles: Proceedings 13th Working Meeting of Crocodile Specialist Group. IUCN–The World Conservation Union, Gland, Switzerland.

Ross, J. P. 1998. Crocodiles: Status Survey and Conservation Action Plan. 2nd ed. IUCN/SSC Crocodile Specialist Group, Gland, Switzerland.

Salas, O., and J. C. Meerman. 2008. Chiquibul National Park Management Plan 2008–2013. 191 pp.

Sánchez Herrera, O., G. López Segurajáuregui, A. García Naranjo Ortiz de la Huerta, and H. Benítez Díaz. 2011. Programa monitoreo del Cocodrilo de Pantano (*Crocodylus moreletii*) México-Belice-Guatemala. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, México, D.F., Mexico.

Stafford, P. J., S. T. McMurry, T. R. Rainwater, D. A. Ray, L. D. Densmore, and B. Barr. 2003. Status of Morelet's Crocodile (*Crocodylus moreletii*) in the Macal River watershed, Belize. Herpetological Bulletin 85: 15–23.

Somaweera, R., M. Brien, and R. Shine. 2013. The role of predation in shaping crocodilian natural history. Herpetological Monographs 27: 23–51.

Tellez, M., S. Heflick, M. Boucher, and A. Austin. *In Press*. Cannibalism in *Crocodylus moreletii* in Chiquibul Forest, Belize. Herpetological Review.

Tellez, M., and I. Paquet-Durand. 2011. Nematode infection of the ventral scales of the American Crocodile (*Crocodylus acutus*) and Morelet's Crocodile (*Crocodylus moreletii*) in southern Belize. The Helminthological Society of Washington 78: 378–381.

Thorbjarnarson, J. 1997. Are crocodilian sex ratios female biased? The data are equivocal. Copeia 1997: 451–455.

Thorbjarnarson, J. B., H. Messel, F. W. King, and J. P. Ross. 1992. Crocodiles: An Action Plan for their Conservation. IUCN–The World Conservation Union, Gland, Switzerland.

Tucker, A. D., C. J. Limpus, H. I. McCallum, and K. R. McDonald. 1996. Ontogenetic dietary partitioning by *Crocodylus johnstoni* during the dry season. Copeia 1996: 978–988.

Tucker, A. D., C. J. Limpus, K. R. McDonald, and H. I. McCallum. 2007. Growth dynamics of freshwater crocodiles (*Crocodylus johnstoni*) in the Lynd River, Queensland. Australian Journal of Zoology 54: 409–415.

Wright, A. C. S., D. H. Romney, R. H. Arbuckle, and V. E. Vial. 1959. Land in British Honduras. Colonial Research Publications No. 24.

Zweig, C. L. 2003. Body condition index analysis for the American Alligator (*Alligator mississippiensis*). Unpublished MSc. thesis, University of Florida, Gainesville, Florida, United States. (http://ufdcimages.uflib.ufl.edu/UF/E0/00/08/36/00001/zweig_c.pdf).

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