POPULATION STATUS AND DISTRIBUTION OF *CROCODYLUS ACUTUS* AND *C. MORELETII* IN SOUTHEASTERN QUINTANA ROO, MÉXICO

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Abstract. We conducted spotlight surveys and a mark-recapture program from February–October 2002 to determine the population status of the American and Morelet's crocodiles (*Crocodylus acutus* and *C. moreletii*, respectively) in southeastern Quintana Roo, México. We detected 645 crocodiles (46 *C. acutus*, 599 *C. moreletii*) along 205.2 km of survey route. *Crocodylus acutus* occurred in coastal saltwater habitats, and *C. moreletii* inhabited freshwater systems. In brackish creeks located in northern Chetumal Bay, *C. moreletii* occurred syntopically with *C. acutus*. The *C. acutus* population was largely composed of subadults (53.1%), followed by adults (34.3%), and juveniles (6.25%); whereas *C. moreletii* was equally represented by subadults (27.9%), juveniles (27.6%), and adults (25.9%), while hatchlings and yearlings constituted only 9.0% and 9.4%, respectively. Encounter rates for *C. acutus* were lower than for *C. moreletii* (0.13–2.69 and 0.87–7.57 crocodiles/km, respectively). Population sex ratio was not significantly different from parity for *C. moreletii*. At present, there are no major threats to the continued survival of Morelet's crocodile in the study area. On the other hand, the small population of *C. acutus* is threatened by accidental drowning in fishing nets and future development of nesting habitat for tourism.

Resumen. De febrero a octubre de 2002 realizamos censos nocturnos y un programa de marcaje-recaptura, para determinar el estado poblacional de *Crocodylus acutus* y *C. moreletii* en el sureste de Quintana Roo, México. Obtuvimos en total 645 registros (46 para *C. acutus* y 599 para *C. moreletii*) en 205.2 km recorridos. *C. acutus* ocurrió en hábitats con agua salada de la franja costera y *C. moreletii* en sistemas dulceacuícolas, pero ambas ocurren en sintopía en los canales de agua salobre localizados al norte de la Bahía de Chetumal. La población de *C. acutus* está compuesta principalmente por subadultos (53.1%), seguidos por los adultos (34.3%), y jóvenes (6.25%); mientras que la de *C. moreletii* está igualmente representada por subadultos (27.9%), jóvenes (27.6%), y adultos (25.9%), y los neonatos y crías de un año constituyen sólo el 9% y 9.4%, respectivamente. Las tasas de encuentro para *C. acutus* fueron más bajas que las de *C. moreletii* (0.13–2.69 y 0.87–7.57 cocodrilos/km, respectivamente). La proporción de sexos en la población de *C. moreletii* no fue diferente de 1:1. Actualmente no existen amenazas mayores para *C. moreletii*. Por el contrario, la baja población de *C. acutus* enfrenta amenazas como el ahogamiento accidental en redes de pesca y el futuro desarrollo turístico sin planeación en el hábitat de anidación.

Key Words. México; Coastal wetlands; Conservation status; *Crocodylus acutus; C. moreletii.*

There are 23 species of crocodilians in the world (Ross 1998; Britton 2004), of which 13 are recognized as threatened by the International Union for Conservation of Nature and Natural Resources (IUCN 2004). The American crocodile (*Crocodylus acutus*) is widespread in the neotropics and occurs on the Atlantic and Pacific coasts from México to South America, as well as in the Caribbean islands of Cuba, Jamaica, Haiti, and the southern tip of Florida, USA (Thorbjarnarson 1989). Morelet's crocodile (*C. moreletii*) occurs in the Atlantic and Caribbean lowlands of México, Guatemala, and Belize (Ross 1998). Both species occur sympatrically in coastal wetlands throughout the range of *C. moreletii* (Platt and Thorbjarnarson 1997; Platt et al. 1999). The American crocodile is classified as vulnerable, and Morelet's crocodile is considered a lower risk species, listed as "conservation dependent" on the IUCN red list (Ross 1996). The international trade of both species is banned (Ross 1998).

The general distribution of both species is well known in México. The American crocodile is found along the Pacific coastal plain, and the Grijalva and Usumacinta Rivers, offshore islands, and coastal mainland habitats of the eastern and northern Yucatán peninsula. Morelet's crocodile occurs primarily in freshwater wetlands through the Gulf of México coastal plain and the Yucatán Peninsula (Lazcano-Barrero 1990). Nonetheless, little has been published on the conservation status of both species (Casas-Andreu 1995), and studies on the status of wild populations of Mexican crocodilians are urgently needed for the development of successful conservation strategies (Ross 1998).

In the past, over-harvesting by commercial skin hunters depleted wild crocodile populations around the world (Thorbjarnarson 1988). In México, crocodiles were protected by a ban on hunting enforced by the Dirección General de Pesca (Casas-Andreu and Guzmán 1970). The low numbers of skins from the wild entering the trade by 1970 indicated crocodile populations were depleted (Álvarez del Toro 1974). To allow populations to increase, a permanent ban was established in 1970 by the Secretaría de Industria y Comercio (Casas-Andreu 1995).

According to local inhabitants, the hunting ban established in the 1970s was respected in the state of Quintana Roo only from the early 1980s. Although there are no available data for Quintana Roo on historical crocodile abundance, anecdotal information from three former crocodile hunters (*lagarteros*) from Xcalak Village and Chetumal City, indicate that populations were healthy (occasionally 75 skins harvested by one person per night). In addition, Domínguez-Laso (2002) reported from 200–900 crocodiles per year were killed in the Sian Ka´an Biosphere Reserve area, according to anecdotal information provided by four former *lagarteros* from Felipe Carrillo Puerto and nearby villages.

In contrast, both species were nearly extirpated in neighboring Belize by the late 1960s, but recent surveys suggest that *C. moreletii* populations are recovering (Platt 1996; Platt and Thorbjarnarson 2000*a*; Mazzotti 2002). However, there is little data to suggest that recovery of *C. acutus* populations has occurred (Platt and Thorbjarnarson 2000*b*). Although little information is currently available regarding the status of wild populations in Quintana Roo, it appears that viable populations of Morelet's crocodile now occur in the Sian Ka´an Biosphere Reserve (Merediz 1999*a*; Domínguez-Laso 2002) and other areas of the State. Comprehensive survey data for both species in Southeastern Quintana Roo are lacking and population status remains unknown (Cedeño-Vázquez 1999).

The objective of this study was to assess the population status of the American and Morelet's crocodiles in Río Hondo, Chetumal Bay, and surrounding locations in southeastern Quintana Roo, México. We determined the distribution, habitat use, abundance, and population structure of both species in this area.

MATERIALS AND METHODS

Study Area

Location. We conducted this study in the southeastern portion of Quintana Roo State, México along the border with Belize (Fig. 1). Chetumal Bay is a brackish lagoon system (Suárez et al. 1991) with extensive mangrove wetlands. Chetumal Bay is connected to some creeks, the Guerrero Lagoon, and the Río Hondo, which forms the border between México and Belize. Chetumal Bay, declared a natural reserve "Manatee Sanctuary" in 1996, and the Río Hondo, its main tributary, are located in the Mesoamerican terrestrial ecoregion (Mittermeier et al. 1999) and belong to the Meso-american Biological Corridor (Ramírez 2003), a critical area for the conservation of biodiversity. This area is a karstic plain with abundant freshwater wetlands, which generally contain water year-round, although levels tend to fluctuate (Platt 1996).

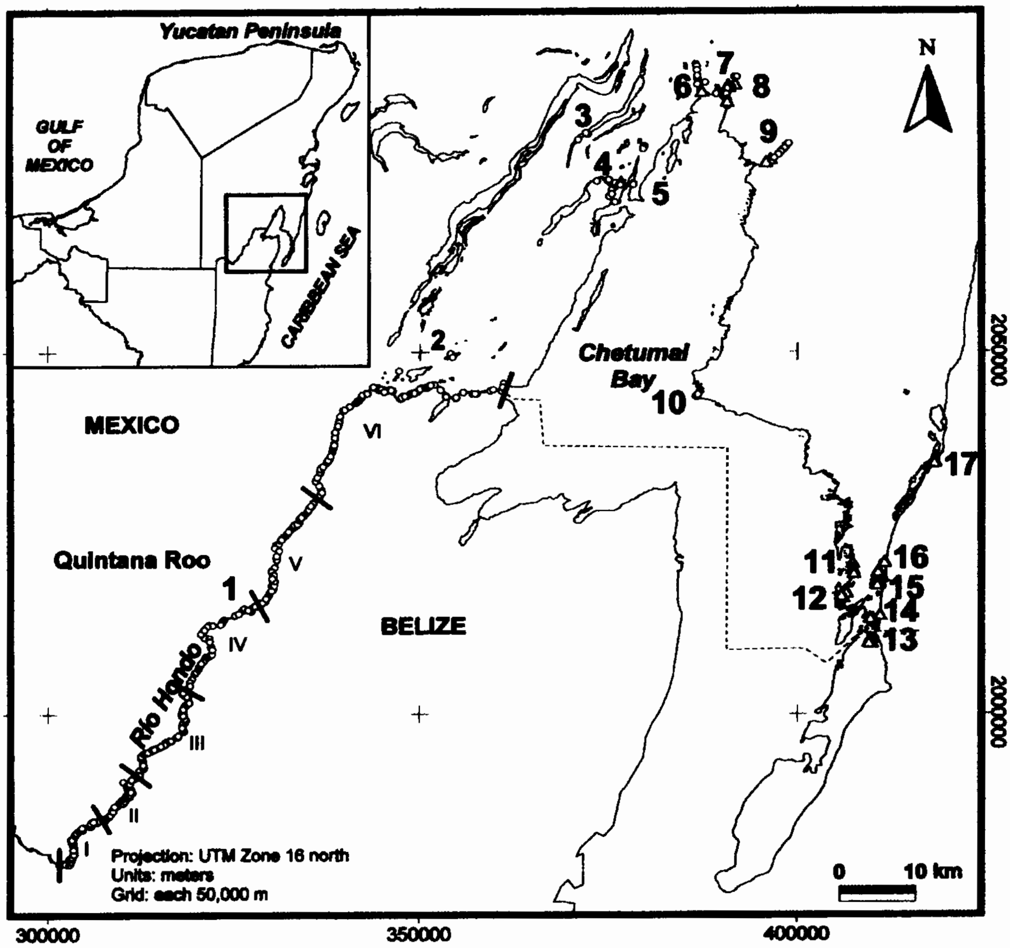

Figure 1. Map of study area showing the distribution of American (triangles) and Morelet's (circles) crocodiles, and locations of spotlight surveys conducted from February to October 2002. Locations are labeled numerically as 1—Río Hondo (México-Belize), 2—Tres Ríos swamp, 3—Chile Verde lagoon, 4—Laguna Guerrero stream-creeks, 5—Río Cacayuc, 6—Chac Chilí creek, 7—Jas creek, 8—Río Creek, 9—Siete Esteros creek, 10—Punta Calentura, 11—La Aguada, 12—Canecax lagoon, 13—Bacalar Chico (México-Belize), 14—Canal Zaragoza, 15—Cementerio lagoon, 16—Xcalak lagoon, and 17—Río Huach lagoon. Place names are in accordance with topographical maps and local names. Dotted line in Chetumal Bay denotes international boundary.

Survey areas. For survey purposes, we divided the Río Hondo into six sections (Fig. 1). Section lengths were established on the basis of the number of hours spent during the first survey. Sections IV and VI were longer than sections I, II, III, and V owing to less sinuosity, with a wider watercourse allowing faster travel, and lower encounter rates. Emergent vegetation such as *Nymphaea ampla* is present in some sections, particularly at the mouth of tributary creeks. Shoreline vegetation of sections I–III on Río Hondo was dominated by primary and second-growth dense forest, characterized by trees (*Bucida buceras*, *Manilkara zapota*, *Metopium brownei*), shrubs (*Chrysobalanus icaco*), palms (*Roystonea regia*, *Chamaedorea* sp., *Sabal mexicana*, *Bactris mexicana*), and the Cyperacea *Schoenoplectus erectus*. Trees (*Bucida buceras, Pachyra acuatica*), red mangrove (*Rhizophora mangle*), and dense sawgrass (*Cladium jamaicense*) with palms (*Acoelorrhaphe wrightii*) dominate the shoreline on sections IV–VI. The remainder of the study area was mangrove wetlands (swamps, creeks, lagoons and small bays) dominated by red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*), buttonwood (*Conocarpus erecta*), and the palm *Acoelorrhaphe wrightii*, and often dense stands of sawgrass (*Cladium jamaicense*) and spikerush (*Eleocharis* spp.). Emergent vegetation such as *Nymphaea ampla*, turtle grass (*Thalassia testudinum*), and manatee grass (*Syringodium filiforme*) were present in some sections of creeks and lagoons. Water salinities ranged from 1–40 parts per thousand (ppt), depending on location.

Habitat classification. For comparative purposes habitat was classified as follows:

Creeks.—These habitats contain water flowing into Chetumal Bay throughout the year, although some creeks are reduced in depth in the late dry season. The Canal Zaragoza (a man-made channel) and Bacalar Chico canal, which connect the Caribbean with Chetumal Bay, were also included in this habitat.

Small bays.—These are bays not more than 500 m wide; they are heavily vegetated by sawgrass and red mangrove.

Lagoons.—Lagoons are shallow water systems (< 1 m in depth) on karstic substrate. They generally occur in coastal areas and are surrounded by mangrove vegetation.

Swamp.—Swamps are wetlands dominated by red mangrove vegetation, occurring within a labyrinth of open water.

River.—The only river considered herein, the Río Hondo (with a depth of about 8 m), contains flowing water throughout the year.

Survey Methods

We located potential crocodile habitat using satellite imagery, aerial photographs, and 1:50,000 scale topographical maps from the Instituto Nacional de Estadística, Geografia e Informática (INEGI). Survey localities were selected based on accessibility to vehicles and boats. We conducted daylight reconnaissance surveys along proposed survey routes to determine feasibility, locate possible hazards, and characterize habitat. A team of two observers, one scribe, and a boat driver conducted the surveys. Two to four spotlight counts were conducted at most locations to achieve a greater degree of precision (low standard error; Messel et al. 1981) and to account for seasonal variation. We conducted systematic nocturnal surveys at 17 locations (Fig. 1) from February–October 2002, using a 4.27 m aluminum boat by its 15 hp outboard engine, or by paddling along the shoreline. Crocodiles were located with a handheld spotlight (100 W power), a 12 V Q-Beam spotlight (400,000 lux), and 4.5 V headlights. Distance from shoreline and boat speed varied according to habitat type. A distance of 50 m from the shoreline was maintained, when permitted by water depth in shallow coastal lagoons and small bays, and boat speed was less than 10 km/h. In rivers, canals, and creeks, the boat was centered and maneuvered at idle speed, allowing observers to illuminate both banks. Spotlight counts were conducted along established survey routes to estimate crocodile densities in each location (King et al. 1994). This technique has been used to census populations worldwide and yields a relative index of the total population, because not all crocodiles present are observed during the survey (Bayliss 1987; King et al. 1990). Relative indices are powerful when survey techniques are standardized (Bayliss 1987). To maintain similar conditions, we conducted surveys on nights without moonlight, approximately 20–30 min after sunset to ensure sufficient darkness to detect eye shine (Messel et al. 1981). Surveys were not conducted under adverse conditions, such as winds > 15 knots (27.8 km/h), rain, or fog, all of which substantially limit visibility and bias counts (Woodward and Marion 1978). Due to the length of the Río Hondo, we sampled different sections throughout most of the night (2000–0530 h). Sampling on the Río Hondo throughout most of the night did not generate any bias as assessed by an Analysis of Variance (ANOVA) that compared observed densities during the different hours of the night against a null model of equal distribution (F = 2.22; df = 4; P = 0.07).

Because both *C. acutus* and *C. moreletii* occur sympatrically in coastal habitats (Platt and Thorbjarnarson 2000*b*), individuals were captured whenever possible to verify species identification. When this was not possible, species determination was based on differences in head shape, a characteristic readily apparent during spotlight surveys (Platt et al. 1999). Morelet's crocodile has a broad, compact head, whereas the American crocodile has a relatively narrower head (Brazaitis 1973). Although studies from southern Belize (Platt and Thorbjarnarson 1997; Platt et al. 1999; Hekkala 2004; Ray et al. 2004) indicate some hybridization and morphological similarity between these species, in our study area correct visual identification of crocodiles was verified on captured animals (19 *C. acutus*, 168 *C. moreletii*) using subcaudal scalation. This is the best diagnostic character for recognition of these two species (Platt 1996), and the presence of irregular intrusions among the caudal scales is diagnostic for *C. moreletii* (Brazaitis 1973; Ross and Ross 1974). We recorded the following data for each crocodile observed: time, Global Positioning System (GPS), salinity (measured with a previously calibrated VISTA A366ATC hand refractometer on a scale of 0– 100 ppt), air and water temperature, habitat type (river, creek, lagoon, small bay, swamp), and shoreline vegetation. Based on total length (TL) we used the following classes (Platt and Thorbjarnarson 2000*b*) for *C. acutus*: hatchlings (TL < 30 cm), yearlings (TL = 30.1 to 60 cm), juveniles (TL = 60.1 to 120 cm), subadults (TL = 120.1 to 180 cm), or adults (TL >180 cm). For Morelet´s crocodile, we used the following classes (Platt and Thorbjarnarson 2000*a*): hatchlings (TL < 30 cm), yearlings (TL = 30.1 to 50 cm), juveniles (TL = 50.1 to 100 cm), subadults (TL = 100.1 to 150 cm), or adults (TL > 150 cm). Crocodiles were approached as closely as possible to estimate total length (TL). When TL could not be determined, crocodiles were classified as "eye shine only." Size estimations were collected by either JRCV or Alejandro Villegas on all surveys to reduce interobserver bias. The sighting fraction and encounter rates (crocodiles/km) excluding hatchlings, were calibrated when data from more than one survey were acquired, following Messel et al. (1981). The sighting fraction (P), or percentage of the total population sighted during a spotlight count, is estimated by $P = 1 - (s^2/m)$, where s is the standard deviation and m the mean of the total counts. When s is higher than 1/3 of the mean value, P is obtained using the superior limit (sl) of the counts: $P = m/sl$. Once P is known, the observed values are corrected as follows: corrected values $cv = (sl*100)/P$. Finally, cv are transformed to absolute encounter rates as number of crocodiles per km (croc/km). We compared encounter rates for both species using a two-tailed Student t-test, excluding locations with single surveys.

From captured animals we recorded TL, snout–vent length (SVL), and rostral length (RL) with a flexible plastic tape or calipers to the nearest 0.1 cm. With the exception of hatchlings, all captured crocodiles were sexed by cloacal examination (Brazaitis 1968; Magnusson 1982). We marked animals by both attaching numbered metal toe tags and clipping tail scutes in a coded pattern (Platt and Thorbjarnarson 1997), and then released them.

When crocodiles could not be approached closely to estimate TL by direct observation, we estimated it based on the rostral length (RL, distance between the eye and the tip of the snout in cm; TL = 10 x RL ± 2.5; L. Sigler pers. comm. 2002). A Chi-Square analysis compared size-class distributions of *C. moreletii* within each habitat against a null model of equal distribution (this was not performed for *C. acutus* because of limited data). Observed sex ratios of *C. moreletii* were tested against a null hypothesis of a 1:1 sex ratio using the Chi-Square statistic with the Bonferroni correction to alpha for multiple comparisons (μ/n: $0.05/n$; $df = 1$; Zar 1999). The small number of captures precluded analysis of sex ratio for *C. acutus*. Finally, we performed a one-way ANOVA to detect differences in abundance between species in response to water salinity.

RESULTS

Distribution

A total of 46 American crocodiles and 599 Morelet's crocodiles were observed, our results indicated that both species were widely distributed in the study area (Fig. 1). We found both species in five brackish creeks (2–12 ppt) located in northern Chetumal Bay. In this area we captured three individuals showing a discrepancy between the subcaudal scalation and head characters; two of them were assigned to *C. moreletii* and one to *C. acutus*, following Platt (1996). This suggests hybridization is occurring between the two species in the study area as observed in coastal populations from Belize (Hekkala 2004; Ray et al. 2004). *Crocodylus moreletii* was found in freshwater habitats (1–4 ppt) such as Río Hondo, Tres Ríos Swamp, and Chile Verde Lagoon, whereas *C. acutus* occurred in coastal habitats where salinity was higher (14–40 ppt). An ANOVA indicated a statistically significant difference ($P < 0.05$) in water salinity at sighting/capture locations between *C. acutus* and *C. moreletii*, with a mean of 28.2 ± 12.8 ppt ($n = 46$) and 2.5 ± 2.0 ppt ($n = 599$), respectively. However, there was no significant difference ($P > 0.05$) in water salinity in the brackish creeks where the two species occurred syntopically.

Size Class Structure and Habitat Use

The *C. acutus* population was mainly composed of subadults (53.1%, $n = 17$), followed by adults (34.3%, $n = 11$), and juveniles (6.25%, $n = 2$). We found only one hatchling and one yearling, both were at Cementerio Lagoon. All size classes

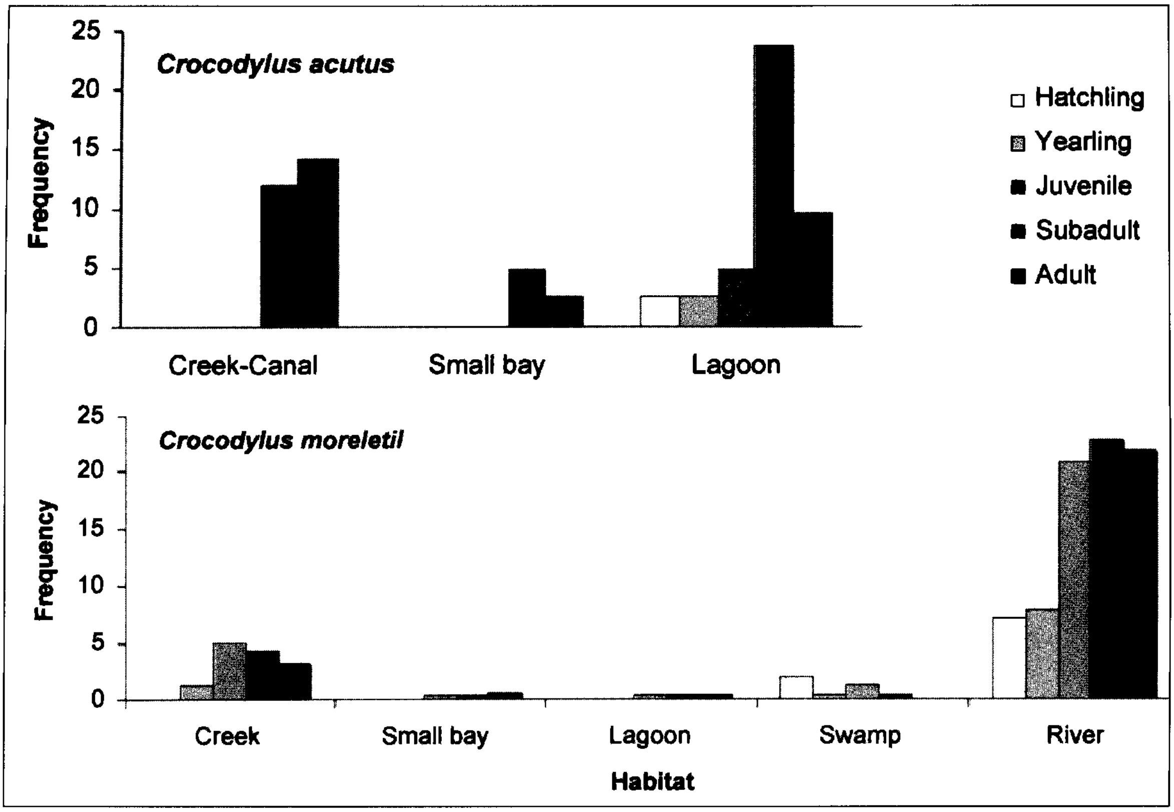

Figure 2. Size class distribution of American (*Crocodylus acutus*) and Morelet's (*C. moreletii*) crocodiles by habitat type.

were present in lagoon habitat, whereas only subadults and adults occupied the creek-canal and small bay habitats (Fig. 2).

The population of *C. moreletii* was equally represented by subadults (27.9%, *n* = 86), juveniles (27.6%, *n* = 85), and adults (25.9%, *n* = 80). Hatchlings and yearlings constituted only 9% (*n* = 28) and 9.4% (*n* = 29) of the population, respectively. All size classes were present in river habitat; all size classes except hatchlings were found in creeks; adults were not recorded in swamp habitat; and few crocodiles of any size class occurred in small bay and lagoon habitats (Fig. 2).

Sixty three percent (*n* = 29) of American crocodiles were found in shallow lagoons, 30% in creeks (*n* = 14), and 6.5% in small bays (*n* = 3). *C. acutus* was not recorded in swamp and river habitats. Most Morelet's crocodiles (87.6%, *n* = 525) were observed in rivers and creeks (8.3%, *n* = 50), while the remainder 4.1% (*n* = 24) occurred in other habitats (swamp, small bay, and lagoon; Table 1).

The size class distribution of *C. moreletii* was significantly different from a model of equal distribution only in swamp habitat ($\chi^2 = 53.3$, $P < 0.05$), where hatchlings and juveniles were more abundant than expected (Table 2).

Encounter Rates

We conducted a total of 65 surveys totalling 205.2 km. Encounter rates for *C. moreletii* were greater than those of *C. acutus* ($t = 2.58$, $P = 0.02$), and ranged from 0.13–2.69 croc/km (mean = 0.96, *SD* = 0.78) for *C. acutus* and from 0.23–7.57 croc/km (mean = 2.40, *SD* = 1.92) for *C. moreletii* (Table 3).

TABLE 1. Distribution of American (*Crocodylus acutus*) and Morelet's (*C. moreletii*) crocodiles observed during spotlight surveys of different habitat types.

Habitat Type	*C. acutus*	*C. moreletii*
Creek-canal	14	50
Small bay	3	8
Lagoon	29	3
Swamp	0	13
River	0	525
Total	46	599

TABLE 2. Distribution of Morelet's crocodile size classes by habitat type. Values presented as the total number of crocodiles observed followed by frequency (%) within each habitat. Size classes are hatchlings (TL < 30 cm), yearlings (TL = 30.1–50 cm), juveniles (TL = 50.1–100 cm), subadults (TL = 100.1–150 cm), and adults (TL >150 cm).

Habitat	Hatchlings	Yearlings	Juveniles	Subadults	Adults	χ^2
Creek	0 (0.0)	5 (10)	14 (28)	17 (34)	14 (28)	3.1^{NS}
Small bay	0 (0.0)	0 (0.0)	3 (37.5)	1 (12.5)	4 (50)	2.9^{NS}
Lagoon	0 (0.0)	0 (0.0)	1 (33.3)	1 (33.3)	1 (33.3)	0.5^{NS}
Swamp	6 (46.1)	1 (7.7)	4 (30.7)	2 (15.4)	0 (0.0)	53.0 **
River	22 (4.2)	44 (8.4)	145 (27.6)	150 (28.6)	164 (31.2)	0.3^{NS}

^{NS}not significant; $^{**}P < 0.001$

Sex Ratio

We captured 19 American and 168 Morelet's crocodiles during this study, and determined the sex of 17 (eight males: nine females) and 145 (84 males: 61 females), respectively. Two adult female *C. acutus* found dead (possibly due to entanglement in fishing nets) in Chetumal Bay between 2001 and 2002 were not included. The overall sex ratio for *C. moreletii* was not significantly different from 1:1 (corrected $P > 0.01$; critical $\chi^2_{0.01}$, 1 = 6.635; Table 4).

DISCUSSION

Distribution

Our results confirm the sympatric distribution

TABLE 3. Encounter rates for American (*Crocodylus acutus*) and Morelet's (*C. moreletii*) crocodiles observed in southeastern Quintana Roo, México. Location numbers and names are according to Fig. 1. Numbers in parentheses correspond to encounter rates including hatchlings.

Location		Distance (km)	Encounter Rate (crocodiles/km)		
			C. acutus	*C. moreletii*	
1. Río Hondo	Section I	14.5	_	3.60	
	Section II	14.5	_	2.60	
	Section III	13	_	4.70	
	Section IV	19	_	2.70	
	Section V	16	_	1.72	(3.00)
	Section VI	35	_	2.31	(3.00)
2. Tres Ríos swamp		1	_	7.57	(12.12)
3. Chile Verde lagoon		13	_	0.23	
4. Laguna Guerrero stream-creeks		9.5	0.21	1.20	
5. Río Cacayuc		15	_	0.66	
6. Chac Chili creek		4.5	0.44	1.30	
7. Jas creek		4.2	0.72	1.44	
8. Río Creek		4.5	0.67	1.11	
9. Siete Esteros creek		7.5	0.13	0.87	
10. Punta Calentura		1	_	4.00	
11. La Aguada		8	1.51	_	
12. Canecax lagoon		4.5	2.69	_	
13. Bacalar Chico		3.7	1.01	_	
14. Canal Zaragoza		1.5	1.33	_	
15. Cementerio lagoon		5.3	2.01 (1.93)	_	
16. Xcalak lagoon		3.5	0.57	_	
17. Río Huach lagoon		6.5	0.31	_	

TABLE 4. Sex ratios for American (*Crocodylus acutus*) and Morelet's (*C. moreletii*) crocodiles in the study area.

Size Class (cm)	Males	Females	Sex Ratio	χ^2
Crocodylus acutus				
120.1–180	6	7	1:1.1	–
> 180	2	2	1:1	–
Total	8	9	1:1.1	–
Crocodylus moreletii				
30.1–50	19	9	2.1:1	3.6^{NS}
50.1–100	33	22	1.5:1	2.2^{NS}
100.1–150	18	16	1.1:1	0.1^{NS}
> 150	14	14	1:1	0.0^{NS}
Total	84	61	1.3:1	3.6^{NS}

^{NS}not significant

of *Crocodylus acutus* and *C. moreletii* in coastal wetlands of southeastern Quintana Roo. Sympatry of *C. acutus* and *C. moreletii* has also been documented in other coastal wetlands of Quintana Roo, such as Sian Ka´an Biosphere Reserve (Lazcano-Barrero 1990; Merediz 1996; Domínguez-Laso 2002) and Nichupté Lagoon (M. Lazcano-Barrero, pers. comm. 1999). Elsewhere sympatry has been reported by Powell (1972), Campbell (1972), Abercrombie et al. (1982), Meerman (1992), Platt and Thorbjarnarson (1997), and Platt et al. (1999).

Sympatry of *C. moreletii* and *C. acutus* may be due to the rapid recovery of the *C. moreletii* populations following past over-exploitation, resulting in the species invading and occupying coastal habitats formerly dominated by *C. acutus* (Platt 1996). *Crocodylus acutus* was harvested intensively for its skin before the 1980s and, after widespread depletion of that species, Morelet's crocodiles may have dispersed into mangrove habitats, thereby inhibiting the recovery of *C. acutus* populations (Platt 1996). This possibly may explain differences in current abundance between these two species in the area around Chetumal Bay. Patterns of abundance may also be due to aggressive interactions and resource competition (Platt, pers. comm). Our findings generally agree with those of Campbell (1972), who worked along the eastern coast of México, and reported very few *C. acutus*, but found *C. moreletii* was common. Abercrombie et al. (1982) found only *C. moreletii* in coastal areas in Belize. Platt and Thorbjarnarson (1997) found that although *C. moreletii* is generally considered a freshwater species, it occurred in salinities as high as 22 ppt, whereas *C. acutus* was extremely rare in mainland coastal habitats. We noted *C. moreletii* in salinities between 2 and 12 ppt around Chetumal Bay, which indicates its tolerance to brackish conditions.

Our observations indicate that both species prefer vegetated shorelines and few individuals frequent open water. Smaller individuals, including hatchlings, were mostly observed in densely vegetated shorelines, particularly among the tree and shrub branches located over water, as well as among red mangrove roots. This is probably why few smaller crocodiles were observed in surveys. In this study, only four *C. moreletii* and two *C. acutus* were recaptured in the second or third survey session, and all were juveniles and subadults that remained in the vicinity of the previous capture, suggesting site fidelity (Lang 1987). However, additional research is needed to monitor movements and dispersal dynamics of *C. acutus* and *C. moreletii*.

Size Class Structure and Habitat Use

The size class distribution that we observed for *C. acutus* is consistent with that of a recovering population, due to the rarity of large adults. Except for juveniles, our results are similar to populations in Belize, which consisted of 39.1% subadults, 36.5% adults, and 24.2% juveniles (Platt and Thorbjarnarson 2000*b*). Lower numbers of juveniles and hatchlings in our study area could be due to sampling bias; smaller crocodiles often remain concealed within mangrove vegetation and escape detection during surveys (Messel et al. 1981). The presence of one yearling and one hatchling located in red mangrove shoreline at Cementerio Lagoon in

April and October, respectively, indicates that at least one female has been reproductively active, although we did not find any evidence of nesting. However, predation on eggs or hatchlings may be affecting nesting success and survival rates. In addition, lack of fresh water in coastal locations could reduce survival of hatchlings and limit juvenile recruitment, if they experience severe osmotic stress (Platt and Thorbjarnson 2000*b*).

Size class distribution for *C. moreletii* in the study area was composed of similar proportions of subadults, juveniles and adults. It could not be determined if lower numbers of yearlings (9%), and hatchlings (9.4%) was due to sighting bias or reflects an actual distribution. This differs from the size class distributions in Sian Ka´an Biosphere Reserve (Merediz 1999*b*) and northern Belize (Platt 1996), where juveniles were more abundant (48% and 49.5%, respectively). Recruitment is possibly higher in our study area than in Sian Ka´an and northern Belize. However, when separately considering the age structure for each habitat type, Platt (1996) found juvenile proportions up to 76.1% in alluvial lagoons, which function as important nursery habitats, but were not surveyed in our study. Once juveniles in alluvial habitats are removed from the Belize data, size class distributions are very similar between river and creek habitats in Belize and our study area.

Encounter Rates

Our sampling efforts were concentrated in areas of open water during the nesting season of both species. Thus our encounter rates should be considered conservative because animals in vegetated habitats are likely to be overlooked during spotlight surveys. The dwarf mangrove and sawgrass swamps surroundings Río Hondo, Tres Ríos swamp, and Chetumal Bay were not studied. Thus, habitats associated with juveniles and adult nesting females were under represented, so we expect the actual population to be larger in the area, particularly for the more abundant *C. moreletii*. Additionally at two sites only one survey was conducted, and in Jas and Siete Esteros creeks, we recorded only the individuals located in the main channel due to the labyrinthian nature of these systems.

Encounter rates for *C. acutus* in other regions tend to be higher in lacustrine and riverine habitats, and lower in coastal swamps (Platt and Thorbjarnarson 2000*b*). High encounter rates reported for some regions indicate the presence of healthy populations; however, in most parts of its historic range, low encounter rates are common (Table 5), and the species exists only in small scattered and isolated populations (King et al. 1982). Encounter rates are higher for some locations we surveyed such as Canecax and Cementerio lagoons, La Aguada, and Canal Zaragoza, but at other sites, encounter rates are similar to those reported in Belize (Platt and Thorbjarnarson 2000*b*). For instance, on Ambergris Cay, Belize, Platt (1995) reported encounter rates ranging from 0.18–0.73 croc/km. In an adjacent area of México (Bacalar Chico), we found only 1.01 croc/km, suggesting little change in abundance during a seven year period. Low encounter rates for the

TABLE 5. Encounter rates reported for spotlight surveys of American crocodile (*Crocodylus acutus*).

Location	Encounter Rate (crocodiles/km)	Habitat	Reference
México, Quintana Roo	0.13–2.69	Coastal	This study
México, Quintana Roo	0.23–1.01	Coastal	Domínguez-Laso (2002)
México, Quintana Roo	1.10–13.9	Cay/Atoll	Charruau et al. (2005)
Cuba	10.4–33.3	Coastal	Rodríguez-Soberón (2000)
USA, Florida	0.00–0.29	Coastal	Cherkiss (1999)
Belize	0.01–0.02	Coastal	Platt and Thorbjarnarson (2000*b*)
Belize	0.43–0.94	Cay/Atoll	Platt and Thorbjarnarson (2000*b*)
Honduras	0.06–0.7	Coastal/River	King et al. (1990)
Costa Rica	19.1	River	Sasa and Chaves (1992)
Venezuela	0.24–3.89	River	Seijas (1986, 1988)
Haiti	6.3	Lake	Thorbjarnarson (1988)
Republica Dominicana	18.9–25	Lake	Thorbjarnarson (1989)

American crocodile in our study area may reflect a combination of past over-exploitation, habitat quality, and competition between the two species (Platt and Thobjarnarson 2000*b*).

In general, encounter rates of *C. moreletii* are much greater than those for *C. acutus*. In the El Petén region, Guatemala, Lara (1991) reported from the former species 1.05–5.91 croc/km of shoreline in three lakes, whereas Castañeda-Moya (2001*a*) documented a mean of 1.12 croc/km and 5.66 croc/km in rivers and closed-water systems (ponds locally called *aguadas*), respectively. Castañeda-Moya (2001*b*) reported the highest encounter rates (11–12.28 croc/km) in lagoons and ponds in Guatemala. In coastal habitats of Campeche, Yucatán, and Quintana Roo in the Yucatán Peninsula, Sigler (2002) reported 1.0–14 crocs/km. In lagoons and creeks of Sian Ka´an Biosphere Reserve, Domínguez-Laso (2002) reported 0.06–6.49 croc/km. In Belize, encounter rates ranged from zero to 18.88 croc/km, depending on habitat type and location, with the highest encounter rates occurring in alluvial lagoons (Platt and Thorbjarnarson 2000*a*). Most encounter rates in the present study are low to moderate. Platt (1996) surveyed two sections of the Río Hondo between 1992 and 1994: 8.6 km upstream (section I in this study), and 12 km in the mouth of the river (final part of section VI in this study), and encountered 1.40 croc/km, and 0.15 croc/km in each of the sections, respectively. We estimated an encounter rate of 2.38 croc/km in section I, and 3.10 croc/km in section VI, suggesting a population increase eight years later. Finally, the low encounter rates of *C. moreletii* we found in mangrove habitats are very similar to values reported from Belize (Platt and Thorbjarnarson 2000*a*).

Sex Ratio

Although male-biased populations of *C. acutus* have been reported (Thorbjarnarson 1988, 1989; Charruau et al. 2005), we documented sex ratio parity, which is the most common for this species (Kushlan and Mazzotti 1989; Moler 1991; Cherkiss 1999; Platt and Thorbjarnarson 2000*b*; Domínguez-Laso 2002). Little sex ratio data exist for wild populations of *C. moreletii*, and the few available data are contradictory. Merediz (1999*b*) and Domínguez-Laso (2002) observed no significant difference from parity in the Sian Ka´an Biosphere Reserve, whereas Platt (1996), Rainwater et al. (1998), and Platt and Thorbjarnarson (2000*a*) found populations in Belize to be strongly male-biased. Our data agree with those collected in northern Belize, particularly among juveniles (though they were not significantly different from 1:1). Differences between Sian Ka´an and our study area and northern Belize might be due to differential mortality or differences in habitat selection between sexes (Thorbjarnarson 1997). For instance, in Belize at New River Lagoon sex ratio was 1:7 (female:male) whereas at Gold Button Lagoon it was 1:1 (S.G. Platt, pers. comm. 2003). If females inhabit interior swamps, a male biased sex ratio would be result if the surveys are conducted in open water systems (Merediz 1999*b*).

Conclusion

The current conservation status of both species in the study area is similar to that reported by Platt and Thorbjarnarson (2000*a,b*) for Belize. In the absence of over-hunting and habitat loss, *C. moreletii* appears secure. This is not the case for American crocodile, as populations remain low at most locations. Furthermore, the rarity of juveniles and hatchlings in the area suggests diminished recruitment (Platt and Thorbjarnarson 2000*b*). Recovery of *C. moreletii* in the area is probably attributable to the early age at which females attain sexual maturity (7–8 yr). Also *C. moreletii* does not require specialized nesting habitat (e.g., sand beaches) like *C. acutus* (Platt 1996). Moreover, much crocodile habitat consists of inaccessible, heavily vegetated marshes and swamps as in northern Belize, and currently, hunting pressure is minimal in the study area. The hunting ban probably has allowed populations to increase since the early 1980s. There are less than 25 local fishermen in the area, who occasionally use monofilament gill fishing nets that may be a source of mortality by incidental entanglement (Platt and Thorbjarnarson 2000*b*). Opportunistic killing of crocodiles also occurs occasionally in the vicinity of human settlements where crocodiles are perceived as a threat. While it is difficult to evaluate mortality from these sources, the loss of even a few crocodiles, especially adult females, can have a significant negative impact in small populations (Platt and Thorbjarnarson 2000*b*). Furthermore, exposure to environmental contaminants, especially pesticides, could represent a long-term threat to population viability. The Río Hondo, which drains to Chetumal Bay, is bordered by sugarcane fields in both Belize and México, and high levels of organochlorine pesticide have been found in *C. moreletii* eggs from northern Belize (Rainwater et al. 1998; Wu et al. 2000). In Chetumal Bay, organochlorine pesticides, heavy metals, and hydrocarbons have been found at low levels (Álvarez-Legorreta 2001). Although effects remain unknown, long-term exposure to these or similar contaminants could negatively impact the populations of aquatic organisms (Álvarez-Legorreta 2001) including crocodilians. In Florida (USA), environmental contaminants are believed responsible for declines in *Alligator mississippiensis* (Woodward et al. 1993; Guillette et al. 1994).

Habitat loss in the study area is not considered a threat due to the low human population density. Quintana Roo has the lowest population density of any state in México (22 people/km^2) and most of the population lives in the northern region (INEGI 2000). However, tourist development in the coastal fringe could be a major threat for the American crocodile, particularly if sand beaches used for nesting habitat by *C. acutus* are developed. Proposed developments should be evaluated with regards to potential nesting habitat for crocodiles before building permits are issued as suggested by Platt and Thorbjarnarson (2000*b*) for the coastal zone of Belize.

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