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Evaluation of Crocodilian Populations Along the Bita River (Vichada, Colombia)

Felipe Parra-Torres[1,4], Rafael A. Moreno-Arias[2], and Olga L. Montenegro[3]

[1]Programa de Maestría en Ciencias-Biología, Departamento de Biología, Universidad Nacional de Colombia, Bogotá, D.C., Colombia

[2]Grupo de biodiversidad y Sistemática Molecular, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, D.C., Colombia

[3]Grupo en Conservación y Manejo de Vida Silvestre, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, D.C., Colombia

[4]Corresponding author; email: mfparrat@unal.edu.co

***Abstract*.—We studied spatial and temporal variation of presence, abundance and population structure of crocodilian species along Bita River in Colombia and evaluated the conservation status of the Orinoco Crocodile (*Crocodylus intermedius*) along this river. We conducted night counts along eight transects of the river in three seasons, and we observed two species, the Spectacled Caiman (*Caiman crocodilus*) and Dwarf Caiman (*Paleosuchus palpebrosus*). In spite of intense searching, we did not find *C. intermedius* in the area, suggesting that the species is either at a very low density or has become locally extinct in this river. We counted a maximum of 626 individuals, 548 of which we identified as *C. crocodilus*, 25 as *P. palpebrosus*, and 53 we could not identify to species. We estimated mean encounter rate as 3.1 individuals/km for *C. crocodilus* and 0.5 individuals/km for *P. palpebrosus*. Sightings of *C. crocodilus* were not distributed homogeneously among seasons, nor along the river. In contrast, sightings of *P. palpebrosus* did not vary among seasons. Population structure of *C. crocodilus* varied between dry and early rainy seasons, with classes I (≤ 50 cm total length) and II (50.1–120 cm total length) being less frequently seen during the dry season. In general, crocodiles in classes I and II were the most abundant of the size classes during all sampling seasons. The population structure of *P. palpebrosus* was skewed toward adults over 80 cm total length.**

Key Words.—Caiman crocodilos; *Crocodylus intermedius*; Orinoquia region; *Paleosuchus palpebrosus*

Evaluación de las Poblaciones de Cocodriliaos a lo Largo del Río Bita (Vichada, Colombia)

***Resumen.*—Estudiamos la variación espacial y temporal de la presencia, abundancia y estructura poblacional de las especies de cocodrilianos a lo largo del río Bita en Colombia y evaluamos el estado de conservación del Cocodrilo del Orinoco (*Crocodylus intermedius*) a lo largo del río. Realizamos recorridos nocturnos a lo largo de ocho transectos en el río y en tres temporadas climáticas, y observamos dos especies, la Babilla (*Caiman crocodilus*) y el Cachirre (*Paleosuchus palpebrosus*). A pesar del esfuerzo de muestreo, no encontramos a *C. intermedius* en el área, sugiriendo que la especies se encuentra en muy bajas densidades o se ha extinguido localmente en este río. Contamos un máximo de 626 individuos, 548 fueron identificados como *C. crocodilus*, 25 como *P. palpebrosus*, y para 53 no pudimos identificar la especie. Estimamos la tasa promedio de encuentro en 3.1 individuos/km para *C. crocodilus* y 0.5 individuos/km para *P. palpebrosus*. Los avistamientos de *C. crocodilus* no se distribuyendo homogéneamente entre temporadas, ni a lo largo del río. En contraste, los avistamientos de *P. palpebrosus* no variaron entre temporadas. La estructura poblacional de *C. crocodilus* varió entre la temporada seca e inició de precipitaciones, en las clases I (≤ 50 cm de longitud total) y II (50.1–120 cm de longitud total) siendo menos frecuentes de observar durante la estación seca. En general, los cocodrilianos de las clases I y II fueron los más abundantes durante todas las temporadas de muestreo. La estructura poblacional de *P. palpebrosus* fue sesgada hacia adultos de más de 80 cm de longitud total.**

Palabras Clave.—Caiman crocodilos; *Crocodylus intermedius*; *Paleosuchus palpebrosus*; Región Orinoquia

Introduction

Colombia has the greatest crocodilian richness in the world with two families, four genera, and six species (Morales-Betancourt et al. 2013), four of which are distributed in the Orinoco Basin, and one of them, *Crocodylus intermedius* (Orinoco Crocodile), is listed as Critically Endangered (CR) by the International Union for the Conservation of Nature (IUCN). This species is also included in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; Crocodile Specialist Group [CSG] 1996; Castaño-Mora 2002). The remaining three species, the Spectacled Caiman (*Caiman crocodilus*), Dwarf Caiman (*Paleosuchus palpebrosus*), and Smooth-fronted Caiman (*P. trigonatus*) are listed as Low Concern (LC) and included in CITES Appendix II (Castaño-Mora 2002; Morales-Betancourt et al. 2013). Current threats to crocodiles include increased hunting for meat consumption and illegal skin trade, habitat destruction, incidental catching drowning in fishing nets, and disturbance from an increase in river traffic (Morales-Betancourt et al. 2013). Assessing the effects of these threats on crocodilian species in Colombia is difficult, especially in the Orinoco region where information about population structure and abundance as well as their temporal and spatial variation is very limited.

Consequently, a priority exists in Colombia for addressing crocodilian population status to generate effective management and conservation strategies (Morales-Betancourt et al. 2013). In the Orinoco region, some studies suggest a population decline in *C. intermedius* (Lugo 1996; Ardila-Robayo et al. 2001; Seijas et al. 2010; Espinosa-Blanco and Seijas 2012; Babarro 2014). Other studies show that variation in spatial and temporal abundance of crocodile populations are related to fluvial dynamics and amount of lentic water bodies affecting available habitat. Likewise, interaction among crocodilian species results in spatial segregation and differential habitat use (Seijas 1986; Llobet and Seijas 2003; Pacheco-Álvarez 2009; Espinosa-Blanco and Seijas 2010; Moreno et al. 2014), and in some cases negative correlations between species abundances are found (Seijas 1996; Llobet and Seijas 2003). There is a need for population monitoring and conservation strategies for the Critically Endangered *C. intermedius* in areas of Colombia and Venezuela. Areas in these countries have been recognized as conservation units for the species based on published information related to population status, habitat conditions, density of nearby human populations, and implementation of conservation actions (Balaguera-Reina et al. 2017).

The Bita River in Colombia is within the historical distribution of *C. intermedius* (Medem 1981), although it was not included as a conservation unit for the species (Balaguera-Reina et al. 2017), mainly due to lack of information on local crocodilian populations and habitat characteristics. This river, however, has great conservation potential for *C. intermedius* because its surrounding area has a relatively low human density (Peñuela and Rodríguez 2014). Moreover, the Colombian Ministry of Environment has declared this river and its wetlands as a Ramsar site (Convention on Wetlands; Ministerio de Ambiente y Desarrollo Sostenible Decreto No. 1235 de 2018; https://www.minambiente.gov.co/images/normativa/app/decretos/1b-DECRETO%201235%20DE%202018.pdf) of international importance. Given the potential of the Bita River for conservation and management initiatives related to *C. intermedius* and other crocodilians, the objective of this study was to evaluate crocodilian abundance, population structure, and temporal and spatial variation along this river, as well as interactions among species. We aimed to generate the necessary information for designing strategies that favor long term crocodilian conservation on the Bita River.

Materials and Methods

Study area.—We studied crocodilians in the Bita River, located in eastern Colombia, in the department of Vichada, municipalities of La Primavera and Puerto Carreño (Fig. 1). This river is part of the Orinoco River Basin and is located on the non-flooding Colombian Llanos (Instituto Geográfico Agustín Codazzi 1999). The Bita River Basin covers approximately 8,384 km^2 and flows approximately 664 km towards the Orinoco River (Peñuela and Rodríguez 2014). The area is characterized by a mean annual temperature of 28.9° C, mean annual relative humidity of 70%, and mean annual rainfall of 2,366 mm (Peñuela and Rodríguez 2014). The rainfall regime is unimodal and bi-seasonal, with a dry season from December to April and a rainy season from April to November. Maximum and minimal rainfall values occur June-July and January-February, respectively (Peñuela and Rodríguez 2014).

Sampling of crocodilian populations.—To obtain information about crocodilian populations, we made three field trips to the Bita River between June 2016 and April 2017, covering the highest rainfall (June-July 2016), lowest rainfall (January 2017) and, the beginning of the rainfall (March 2017) seasons. During each of these field trips, we sampled the river using eight 10-km long transects along the river channel (Fig. 1). All transects were separated from each other by approximately 85 km and they were located along the river from upstream (T1) to downstream (T8; Fig. 1). Across the three sampling seasons, we sampled 880 km of nocturnal surveys and 1,586 km of diurnal surveys.

During each fieldtrip, we traveled along each transect two nights in a row and twice every night to detect crocodilians by observing eye shine using a hand-held

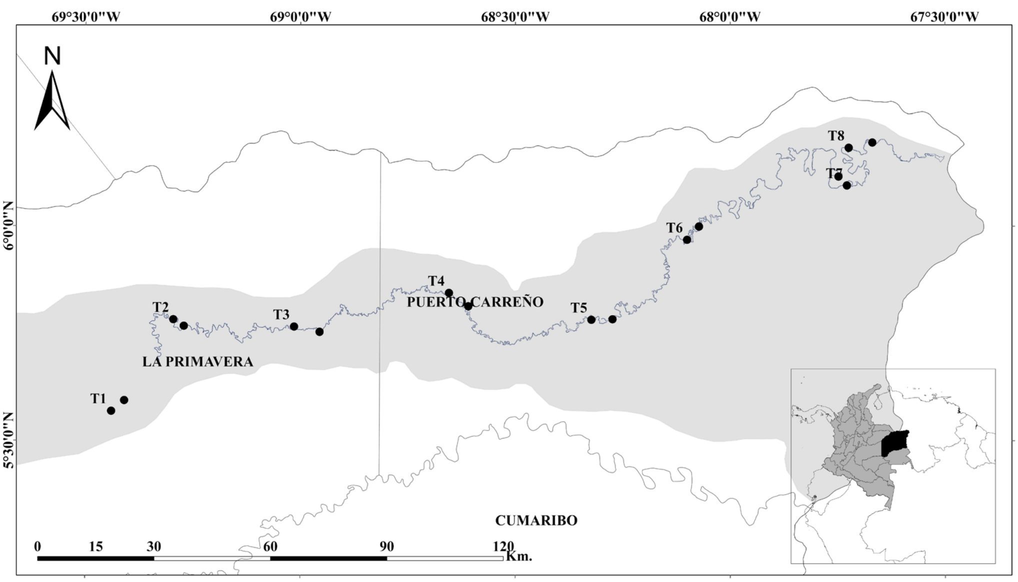

Figure 1. Bita River basin (gray), the Bita River (blue), and the location of transects (T) used for sampling crocodilian populations in this study in eastern Colombia (inset). Closed black dots indicate the start and end of each transect.

spotlight lanterns (900 lumens; Chabreck 1966). We traveled transects between 1830 and 0200 in a wooden boat 8 m long with a 15-horsepower outboard motor at a maximum speed of 8 km/h. To minimize the effect of outboard motor traffic on behavior and detectability of crocodilians, we allowed one hour to elapse between survey periods on a given night. Finally, in the river sections between transects, we made day trips between 0545–1600 at a maximum speed of 20 km/h to increase search effort. To identify crocodilians and estimate body size of each detected individual, we approached the animal as closely as possible to examine diagnostic morphological characteristics. When such proximity was not enough for identification, we recorded the sighting as Eyes Only (EO).

Abundance and population structure.—We estimated population abundance of each crocodilian species for each sampling season and each transect using the following equations proposed by King et al. (1990) and Juan Sánchez-Ramírez (unpubl. report):

$$EP = MNI * CF$$

where EP is the estimated population, MNI the maximum number of individuals observed in a transect,

$$CF = 100 / VF$$

where CF the correction factor, VF the visible fraction, and

$$VF = ((\text{Mean IO} / 2 * SD + \text{Mean IO}) * 1.05) * 100)$$

where Mean IO the mean number of individuals observed during the four survey transects, and SD its standard deviation. Encounter rate (ER) of each species, in each transect and each sampling season was calculated as EP/km traveled. We estimated ER to compare our results with those of other studies of crocodilians in the region.

For population structure of *C. crocodilus*, we recognized four size classes based on total length [TL] as proposed by Ayarzagüena (1983) and Velasco and Ayarzagüena (1995): (1) Class I = < 50 cm TL; (2) Class II = 50.1–120 cm TL; (3) Class III = 120.1– 180 cm TL; and (4) Class IV = >180.1 cm TL. For population structure of *P. palpebrosus*, although Botero-Arias (2007) suggested size classes with 10 cm intervals, we separated size classes every 30 cm of body size, from 80–210 cm TL because we estimated sizes from sightings instead of captures. We evaluated temporal and spatial variation in population abundance for each species by comparing encounter rate among sampling seasons and among transects.

We evaluated differences in encounter rates among seasons by means of a Kruskal-Wallis test, differences in encounter rate among transects in each sampling season using a Friedman test, and differences in population size structure among sampling seasons using a Chi-square homogeneity test. To examine possible associations among species abundances, we used a Spearman correlation between the encounter rates of each species. Correlations were examined for each sampling season and for each transect. We used encounter rates because this variable has been used previously with other crocodilian species (Seijas 1996; Llobet and Seijas 2003). For all tests, $\alpha = 0.05$.

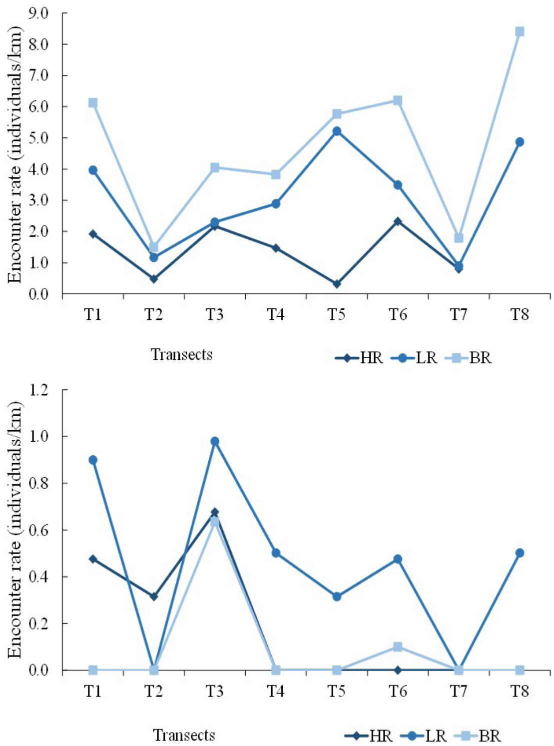

Figure 2. Mean encounter rates (individuals/km) of Spectacled Caiman (*Caiman crocodilus*) and Dwarf Caiman (*Paleosuchus palpebrosus*) in different transects along the Bita River, eastern Colombia. The acronyms HR = highest rainfall, LR = lowest rainfall, and BR = beginning rainfall seasons.

Results

We only detected two species of crocodilians, *C. crocodilus* and *P. palpebrosus*, during surveys and recorded 628 crocodilians during all sampling events. Of these, 548 (87.26%) were identified as *C. crocodilus*, 25 (3.98%) as *P. palpebrosus*, and 55 (8.76%) as EO. During the highest rainfall season, we detected 38 *C. crocodilus*, four *P. palpebrosus*, and four EO, but during the lowest rainfall season, we recorded 188 *C. crocodilus*, 16 *P. palpebrosus*, and 18 EO. At the beginning of the rainfall season, we found 322 *C. crocodilus*, five *P. palpebrosus*, and 31 EO (Table 1).

We found *C. crocodilus* during all seasons and in all transects, but the species was more abundant in the middle and lower part of the Bita River, in transects 6 (2.3 individuals I/km), 5 (5.2 I/km) and 8 (8.4 I/km) and during the beginning of the rainfall season. We also found *P. palpebrosus* during all sampling seasons, but its presence was not constant in all transects. This species was most abundant in the upper part of the river in transect 3 (0.7 I/km; 1.0 I/km; 0.6 I/km) and during the lowest rainfall season (Table 1). Abundance of *C. crocodilus* was not distributed homogeneously among seasons ($H = 8.98$; df = 2; $P = 0.011$), nor along the river ($X^2 = 11.57$; df = 6, $P = 0.038$; Fig. 2). We found no significant differences in abundance of *P. palpebrosus* among seasons ($H = 0.784$; df = 2; $P = 0.671$). Also, the abundance of this species was not homogeneously distributed among transects (Fig. 2), and its presence in transects was different from that observed for *C. crocodilus* (Table 1).

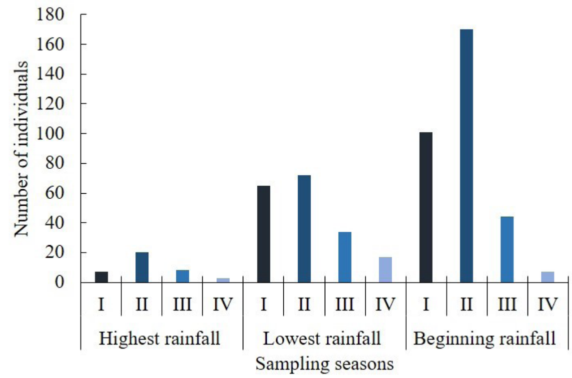

Figure 3. Number of observed individual Spectacled Caiman (*Caiman crocodilus*) within each size class during three sampling seasons along the Bita River, Vichada, Colombia.

In general, for *C. crocodilus*, individuals in size classes I and II were the most frequently observed (Fig. 3). The population structure of this species varied among seasons, particularly between the lowest rainfall and beginning of rainfall seasons ($X^2 = 19.05$; df = 3; $P < 0.001$) with classes I and II being less frequent during the lowest rainfall. For *P. palpebrosus*, the 25 individuals we found on the Bita River were all adult size Class III. These animals were both small (> 80 cm long) and large adults (Fig. 4). We did not find a significant correlation between the ERs of *C. crocodilus* and *P. palpebrosus* ($P = 0.454$).

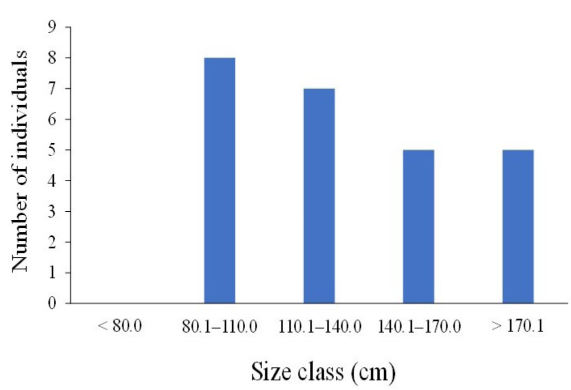

Figure 4. Number of observed individual Dwarf Caiman (*Paleosuchus palpebrosus*) within each size class along the Bita River, Vichada, Colombia.

Table 1. Maximum number (n) of observed individuals, visible fraction (VF), estimated population (EP), and encounter rate (EC) of Spectacled Caiman (*Caiman crocodilus*) and Dwarf Caiman (*Paleosuchus palpebrosus*) along Bita River, Vichada, Colombia, at different sampling seasons and transects.

		Caiman crocodilus				*Paleosuchus palpebrosus*			
Season	Transect	n	VF	EP	EC	n	VF	EP	EC
Highest rainfall	T1	7	36.4	19.2	1.9	1	21.0	4.8	0.5
	T2	1	21.0	4.8	0.5	1	31.7	3.2	0.3
	T3	7	32.3	21.7	2.2	2	29.6	6.8	0.7
	T4	11	74.8	14.7	1.5	—	—	—	—
	T5	1	31.7	3.2	0.3	—	—	—	—
	T6	7	30.1	23.2	2.3	—	—	—	—
	T7	4	50.2	8.0	0.8	—	—	—	—
Lowest rainfall	T1	35	88.2	39.7	4.0	3	34.8	8.6	0.9
	T2	8	68.5	11.7	12	—	—	—	—
	T3	19	82.5	23.0	2.3	7	71.5	9.8	1.0
	T4	25	86.6	28.9	2.9	2	39.9	5.0	0.5
	T5	35	67.1	52.2	5.2	1	31.7	3.2	0.3
	T6	31	88.7	34.9	3.5	1	21.0	4.8	0.5
	T7	6	67.1	8.9	0.9	—	—	—	—
	T8	29	59.5	48.8	4.9	2	39.9	5.0	0.5
Beginning Rainfall	T1	58	94.7	61.3	6.1	—	—	—	—
	T2	12	79.9	15.0	1.5	—	—	—	—
	T3	39	96.2	40.5	4.1	4	63.0	6.3	0.6
	T4	31	81.0	38.3	3.8	—	—	—	—
	T5	44	76.3	57.7	5.8	—	—	—	—
	T6	62	100.0	62.0	6.2	1	100.0	1.0	0.1
	T7	13	72.6	17.9	1.8	—	—	—	—
	T8	63	74.9	84.1	8.4	—	—	—	—

Discussion

***Presence of* C. intermedius.**—Despite extensive sampling effort, *C. intermedius* was not observed in the Bita River during this study. These data are important because they support a general trend of poor recovery or population decline already found by other researchers in Colombian and Venezuelan rivers for this species (Medem 1981; Lugo 1996; Seijas et al. 2010; Espinosa-Blanco and Seijas 2012; Babarro 2014). Our results suggest a possible local extinction or a very low population density of *C. intermedius* in the Bita River, making detection of the species difficult. Other factors affecting detectability of *C. intermedius* include its association with lakes and creeks (Medem 1981; Antelo 2008) and their activity patterns. *Crocodylus intermedius* are active between 0300–0400; 0700–0900; 1500–1600, and 1900–2100 (Moreno-Arias et al. 2016). We surveyed for crocodilians at all of these times except 0300–0400.

If *C. intermedius* persists in the Bita River, it is likely present at very low densities and may only inhabit lakes or creeks associated with the main water course. To confirm the hypothesis, sampling focused on these habitats must be conducted. If *C. intermedius* is already locally extinct in the Bita River, conservation initiatives should consider establishment of new populations at this site. Such action is important to recover the ecological role of *C. intermedius* as a top predator, which would re-establish trophic networks, nutrient cycling, primary productivity, and the maintenance of energy flow in this aquatic ecosystem (Fittkau 1970; Mazzotti et al. 2009; Silva et al. 2010).

***Presence of* C. crocodilus.**—The mean encounter rate of *C. crocodilus*, estimated in this study (3.1 I/km), is lower than that reported for the same river several years ago (8.4 I/km) (Ríos and Trujillo 2004). This difference may be due to a lower sampling effort in Rios and Trujillo (2004): their sampling covered only the lowest rainfall season, and their transects were shorter (2–3 km). When we compare the encounter rate in transects of similar length (13.2 km) to those of the present study, the encounter rate reported in Ríos and

Trujillo (2004) for the Bita River (3.2 I/km) is similar to the average encounter rate found in the present study. The mean encounter rate of *C. crocodilus* we found was lower than that reported in the Meta River, Colombia (7.6 I/km; Ríos and Trujillo 2004), the Unare River in Venezuela (15.12 I/km; Seijas 1996), the Coesewijne River in Suriname (13.93 I/km; Ouboter and Nanhoe 1988), and the Sierpe River in Costa Rica (10.5 I/km; Bolaños et al. 1996).

This greater abundance in *C. crocodilus* recorded in other locations may be the result of differences in the types and quality of habitat or the absence of other crocodilian species in these areas, which may be predators or competitors to *C. crocodilus*. For example, high abundance of *C. crocodilus* has been related to the absence of American Crocodile (*C. acutus*) on the Unaré River in Venezuela (Seijas 1996). In coastal areas of Venezuela (Seijas 1996) and Costa Rica (Bolaños et al. 1996), high relative abundances of *C. acutus* have been found. Likewise, in the Venezuelan Llanos, a low abundance of *C. crocodilus* was found in sites with high abundance of *C. intermedius* (Moreno et al. 2014). In fact, a negative correlation between abundances of sympatric crocodilian species has been reported (Seijas 1996; Llobet and Seijas 2003), meaning that *C. crocodilus* abundances decrease as abundance of other crocodilian species increase. Also, spatial segregation among crocodilian species through resource partitioning has also been observed (Espinosa -Blanco and Seijas 2010; Moreno et al. 2014), facilitating species co-existence.

Conversely, the mean encounter rate of *C. crocodilus* found in this study was higher than that reported in the Negro (0.6 I/km), Claro (0.6 I/km), Canjilones rivers (2.85 I/km; Pacheco-Álvarez 2009), the Yaracuy (0.29 I/km) and Tocuyo rivers (0.80 I/km; Seijas 1996), and the Capanaparo River (2.16 I/km; Moreno et al. 2014), all in Venezuela. Our abundances also were higher than those found in the Venezuelan-Guyana River (2.5 I/km; Gorzula and Paolillo 1986) and the Sarapiquí River (2.55 I/km; Bolaños et al. 1996) in Costa Rica. These lower encounter rates may be related to water reduction in some rivers, where there is a complete loss of the tributary channel during the dry season (Pacheco-Álvarez 2009). In addition to water stress, human activities such as damming, bridge construction, and establishment of human settlements result in significant transformations of rivers (Pacheco-Álvarez 2009), although we do not know if these factors occur in these rivers. These changes can lead to decreases in habitat availability and limit the establishment or stability of crocodilian populations. In Suriname and Costa Rica, high *C. crocodilus* abundance was related to a high availability of breeding, refuge, and feeding habitats (Ouboter and Nanhoe 1988; Bolaños et al. 1996).

***Presence of* P. palpebrosus.—**The mean encounter rate of *P. palpebrosus* (0.5 I/km) in the Bita River during this study was higher than that found in rivers in Colombia (0.05–0.20 I/km; Rodriguez 2000), as well as the Bita River in a previous study (0.06 I/km; Lugo et al. 2013). Also, this species was more abundant in the Bita River (this study) than in rivers in Venezuela (0.10–0.46 I/km; Rebêlo and Lugli 2001; Seijas 2007; Pacheco-Álvarez 2009). These lower abundances of *P. palpebrosus* occur in rivers where this species is sympatric with other crocodilian species such as *C. crocodilus*, Black Caiman (*Melanosuchus niger*), and *P. trigonatus* (Rodríguez 2000; Rebêlo and Lugli 2001). Seasonality also plays an important role in *P. palpebrosus* abundance. For example, Pacheco-Álvarez (2009) found low density of this species during low rainfall seasons in rivers where complete drought occurs.

Conversely, the mean encounter rate of *P. palpebrosus* on the Bita River is lower than that reported on rivers in Colombia (0.5–0.6 I/km; Lugo et al. 2013), rivers in Brazil (1.0–4.5 I/km; Campos et al. 1995; Botero-Arias 2007; Campos et al. 2007), in the Venezuelan-Guyana River (2.0 I/km; Gorzula and Paolillo 1986), and in the Venezuelan Llanos (0.7–2.3 I/km; Pacheco-Álvarez 2009). A higher encounter rate of *P. palpebrosus* was found in some habitat types such as secondary shallow creeks (Campos et al. 1995; Campos et al. 2007), small tributaries with good riparian forest, creeks around *Mauritia* palm areas (Pacheco-Álvarez 2009), or on flooded forest around main rivers (Botero-Arias 2007). Also, a greater abundance of *P. palpebrosus* was found in sites with lower numbers of *C. crocodilus* (Pacheco-Álvarez 2009) and in areas where abundance was estimated by surveys in short transects (2 km; Gorzula and Paolillo 1986). In general, multiple studies have shown that crocodilian abundance is usually high at sites with a marked habitat separation among species (resource partitioning), with good habitat conditions, and with low human pressure. In contrast, other studies have shown low crocodilian abundance in sites where several species are sympatric, as well as those exhibiting water stress and greater human presence.

Population structure.—The population structure of *C. crocodilus* on the Bita River observed in this study does not differ from that documented downstream on the same river (Ríos and Trujillo 2004), on the Unare and Yaracay rivers in Venezuela (Seijas 1996), and the Sierpe and Sarapiquí rivers in Costa Rica (Bolaños et al. 1996). In all these studies, the largest number of individuals were of Classes I and II. Some researchers suggest that a lower proportion of larger individuals (Classes III and IV) are characteristic of populations with low reproductive potential (Bolaños et al. 1996) or unbalanced populations (Rios and Trujillo 2004).

Reproduction in *C. crocodilus*, however, may begin in animals as small as 68 cm TL (Thorbjarnarson 1994), suggesting that a population with a high number of Class II individuals could have a high reproductive potential. In addition, the population structure of *C. crocodilus* we found in the Bita River during the different sampling seasons shows that recruitment occurs in different size classes. The greater abundance of individuals of Classes I and II suggest that Bita River exhibits habitat features that allow animals to survive and grow. Such habitat characteristics include a riverbank forest that provides refuge and feeding, as well as sites for nesting and protection of neonates and juveniles (Moreno-Arias et al. 2013).

The population structure of *P. palpebrosus* in the Bita River observed in this study suggests that adults (> 80 cm TL) comprise the most common size class, a pattern also found in the Venezuelan Llanos (Pacheco-Álvarez 2009) and in Brazil (Rebêlo and Lugli 2001; Botero-Arias 2007). Conversely, this pattern differs from one found in a different population in Brazil (Martins 2004), where the greatest number of individuals belonged were 20–60 cm TL (class II - juveniles). In general, populations of *P. palpebrosus* are mainly represented by adults, a fact that has been attributed to a greater predation of neonates (Pacheco-Álvarez 2009), a phenomenon common in crocodilians. It is important to consider that neonates and juveniles of both *Paleosuchus* species remain close to nesting areas, even multiple years post-hatch (Campos et al. 2012), which makes them difficult to detect during open water (boat) surveys. For find these smaller animals, it is more productive to search by walking along small creeks surrounded by vegetation (i.e., nesting habitat; Magnusson and Lima 1991). Although no neonate or juvenile *P. palpebrosus* were observed in this study, we did find young and old adults, which may be a sign of recruitment.

Temporal and spatial variation of crocodilian abundance.—We observed that the temporal abundance of *C. crocodilus* varied with rainfall. Lowest abundance occurred during the highest rainfall season, whereas a higher abundance was recorded during the dry season, and the highest abundance occurred during the onset of rainy season. This increase in population abundance did not affect our estimation of population structure because the number of individuals observed by size category also increased concomitantly during sampling seasons. An increase in rainfall results in water bodies reaching their maximum levels and overflowing, thus increasing the available habitat for crocodilians (Cabrera et al. 2003). When lower rainfall occurs, crocodilian abundance in surveyed areas (main river) increases because water bodies and associated crocodilian habitats are restricted, causing individuals to be concentrated in the main river course (Staton and Dixon 1975; Cabrera et al. 2003).

The temporal pattern of abundance observed in this study has also been observed in the Caño Negro river in Costa Rica (Cabrera et al. 2003), the Capanaparo River in Venezuela (Moreno et al. 2014), and in the Venezuelan Llanos (Pacheco-Álvarez 2009). In addition, *C. crocodilus* was most often found during March, the month when the Bita River is typically its lowest level. This same pattern was reported for *C. crocodilus* in Venezuela (Staton and Dixon 1975) and Costa Rica (Cabrera et al. 2003). *Caiman crocodilus* abundance also varied spatially in this study, with transects T2 and T7 exhibiting with the lowest number of animals. Spatial variation in abundance of *C. crocodilus* has been generally linked to variation in human presence or with some degree of habitat degradation (Cabrera et al. 2003; Moreno-Arias et al. 2013; Viloria-Lagares et al. 2017). In most cases, highest abundance occurs at sites with low human presence and habitats of good quality.

In the Bita River, human presence is low, and although the establishment of tree plantations (*Pinus, Eucalyptus*, and *Acacia*) is increasing (Peñuela and Rodríguez 2014), human use of the river and surrounding areas is minimal. This suggests that spatial variation in abundance of *C. crocodilus* along the Bita River is due more to variation in habitat quality than to human pressures. As reported in other studies (Cabrera et al. 2003, Moreno-Arias et al. 2013), it would be expected that sites along the Bita River with greater abundances of *C. crocodilus* also exhibit better quality crocodilian habitat (e.g., greater plant cover along riverbanks, more sandbanks, and river shores with low slope).

We recorded the highest abundance of *P. palpebrosus* during the dry season (January), which is consistent with other studies in the Central Brazilian Amazon where this species was most abundant during the dry season (July to October; Botero-Arias 2007). Conversely, in Venezuelan Llanos, there was a slight decrease in encounter rate of *P. palpebrosus* in the dry season compared to the rainy season (Pacheco-Álvarez 2009). Temporal variation in abundance of *P. palpebrosus* seems to be related to the periodic fluctuations of river water levels (Rebêlo and Lugli 2001), and a greater mobility of this species across habitats (Botero-Arias 2007).

Relationships among species.—We did not find a significant correlation between encounter rates of *C. crocodilus* and *P. palpebrosus*, however, because we had a low number of *P. palpebrosus* sightings, the scope of this correlation is limited. What is clear to us is that in Bita River *P.palpebrosus* is indeed at lower abundance than *C. crocodilus*. Negative correlations in abundance have been reported among crocodilian populations on Venezuelan coasts (Seijas 1996) and on Capanaparo River in the same country (Llobet and Seijas

2003). Such negative correlations between or among species could be the result of interspecific competition for habitat resources when species are sympatric (Llobet and Seijas 2003); however, often in cases of sympatry, species adapt through resource partitioning and differential microhabitat use. More detailed investigations are required to adequately examine these and other ecological relationships between and among crocodilian populations in the Bita River.

Conclusions.—Our study constitutes an important contribution to the understanding of crocodilians in Colombia, as it covered almost 90% of the extension of the Bita River and spanned three seasons, allowing us to evaluate the spatial and temporal dynamics of crocodilian populations present in the area. Results suggest *C. intermedius* could be locally extinct or present in very low numbers on the Bita River and highlight the need for conservation strategies to enhance or re-establish *C. intermedius* populations on the river. Mean encounter rates of *C. crocodilus* and *P. palpebrosus* on the Bita River are similar to those reported in other studies. Similarly, population size structure for both species also resembled those previously reported, suggesting recruitment of new individuals and, indirectly, good habitat conditions. Patterns of temporal and spatial (*C. crocodilus*) variation in crocodilian abundance in the Bita River also agree with those recorded in other studies, where highest abundance occurs during the dry season when river water levels are low. We did not find a relationship between the number *C. crocodilus* and the number of *P. palpebrosus* along the Bita River.

Our study provides baseline data that can be used for decision-making and development of conservation and management initiatives focusing on *C. intermedius* recovery on the Bita River. A suggested short-term action is the reintroduction of *C. intermedius* on this river using information on current spatial and temporal distribution of the other crocodilian species along this river. Specifically, we suggest that release processes could be conducted towards the middle part of the Bita River (by T4 to T6), because that was the sector where were we found the best habitat quality and availability for crocodilians (Parra-Torres 2017). Also, size structure of these other crocodilian species could help to define optimum body size of animals for potential reintroduction, to increase survival probability of released animals, and to reduce interspecific competition.

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Literature Cited

Antelo, R. 2008. Biología del Cocodrilo o Caimán del Orinoco (*Crocodylus intermedius*) en la Estación Biológica El Frío, Estado Apure (Venezuela). Tesis Doctoral. Universidad Autónoma de Madrid, España. 332 p.

Ardila-Robayo, M.C., S.L. Barahona, and O.P. Bonilla. 2001. Actualización del status poblacional del Caimán Llanero (*Crocodylus intermedius*) en el Departamento de Arauca (Colombia). Pp. 57–67 *In* Memorias del Taller para la Conservación del Caimán del Orinoco (*Crocodylus intermedius*) en Colombia y Venezuela. Velasco, G., G. Colomine, G. Villarroel, and M., Quero (Ed.). Universidad Central Caracas, Caracas, Venezuela.

Ayarzagüena, J. 1983. Ecología del Caimán de anteojos o baba (*Caiman crocodilus*) en los llanos de Apure (Venezuela). Doñana Acta Vertebrata 10:120–136.

Babarro, R. 2014. Balance de las liberaciones de caimán del Orinoco (*Crocodylus intermedius*) en Venezuela: 25 Años De Esfuerzo. Boletín de la Academia de Ciencias Físicas, Matemáticas y Naturales 74:75–87.

Balaguera-Reina, S.A., A.S. Espinosa-Blanco, M.A. Morales-Betancourt, A.E. Seijas, C.A. Lasso, R. Antelo, and L.D. Densmore. 2017. Conservation status and regional habitat priorities for the Orinoco crocodile: Past, present, and future. PLoS ONE 12:1–20. https://doi.org/10.1371/journal.pone.0172439.

Bolaños, J.R., J. Sánchez, and L. Piedra. 1996. Inventario y estructura poblacional de crocodílidos en tres zonas de Costa Rica. Revista de Biología Tropical 44:283–287.

Botero-Arias R. 2007. Padrões de movimento, uso de microhábitat e dieta do jacaré-paguá, *Paleosuchus palpebrosus* (Crocodilia: Alligatoridae), em uma floresta de Paleovárzea ao sul do Solimões, Amazônia Central, Brasil. Instituto Nacional de Pesquisas da Amazônia, Tesis de postgrado, Manaus, Brasil. 59 p.

Cabrera, J., M. Protti, M. Urriola, and R. Cubero. 2003. Distribución y abundancia de *Caiman crocodilus* en el Refugio Nacional de Vida Silvestre Caño Negro, Costa Rica. Revista de Biología Tropical 51:571–578.

Campos, Z., M. Coutinho, and C. Abercrombie. 1995. Size structure and sex radio of Dwarf Caiman in the Serra Amolar, Pantanal, Brazil. Herpetological Journal 5:321–322.

Campos, Z., T. Sanaiotti, F. Muniz, I. Farias, and W.E. Magnusson. 2012. Parental care in the Dwarf Caiman, *Paleosuchus palpebrosus* Cuvier, 1807 (Reptilia: Crocodilia: Alligatoridae). Journal of Natural History 46:2979–2984.

Campos, Z., C. Zucco, and G. Batista. 2007. Registro de ocurrencia de jacaré-paguá (*Paleosuchus palpebrosus*), na RPPN Engenheiro Eliezer batista, Pantanal, Brazil. Comunicado Técnico 60:1–4.

Castaño-Mora, O.V. (Ed.). 2002. Libro Rojo de Reptiles de Colombia. Serie Libros Rojos de Especies Amenazadas de Colombia. Instituto de Ciencias Naturales-Universidad Nacional de Colombia, Ministerio del Medio Ambiente, Conservación Internacional. Bogotá, D.C., Colombia.

Chabreck, R.H. 1966. Methods of determining the size and composition of Alligator population in Louisiana. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 20:105–112.

Crocodile Specialist Group (CSG). 1996. *Crocodylus intermedius*. The International Union for Conservation of Nature Red List of Threatened Species 1996. http://www.iucnredlist.org.

Espinosa-Blanco, A.S., and A.E. Seijas. 2010. Uso de hábitat entre crocodílidos en el sistema del río Cojedes, Venezuela. Revista Latinoamericana de Conservación 1:112–119.

Espinosa-Blanco, A.S., and A.E. Seijas. 2012. Declinación poblacional del Caimán del Orinoco (*Crocodylus intermedius*) en dos sectores del sistema del río Cojedes, Venezuela. Ecotrópicos 25:22–35.

Fittkau, E. 1970. Role of caimans in the nutrient regime of Mouth-Lakes of Amazon effluents (an hypothesis). Biotropica 2:138–142.

Gorzula S., and A. Paolillo. 1986. La ecología y el estado actual de los aligatoridos de la Guayana venezolana. Pp. 37–54 *In* Special Reprint of the Proceedings of the 7th Working Meeting of the Crocodile Specialist Group. Gorzula, S. (Ed). International Union for Conservation of Nature, Gland, Switzerland.

Instituto Geográfico Agustín Codazzi (IGAC). 1999. Paisajes fisiográficos de Orinoquia - Amazonía. Orinoquia - Amazonía (ORAM), Colombia. IGAC, Bogotá, D.C., Colombia.

King, F.W., M. Espinal, and C.A. Cerrato. 1990. Distribution and status of the crocodilians of Honduras. Pp. 313–354 *In* Proceedings of the 10th Working Meeting of the Crocodile Specialist Group (Volume 1). International Union for Conservation of Nature, Gland, Switzerland.

Llobet, A., and A.E. Seijas. 2003. Estado poblacional y lineamientos de manejo del Caimán del Orinoco (*Crocodylus intermedius*) en el Río Capanaparo, Venezuela. Pp. 117–129 *In* Manejo de Fauna Silvestre en Amazonía y Latinoamérica. Selección de trabajos V Congreso Internacional. Fundación Natura. Polanco-Ochoa, R. (Ed.). Convention on International Trade in Endangered Species of Wild Fauna and Flora, Bogotá, D.C. Colombia.

Lugo, M. 1996. Avance en la investigación del estatus del Caimán del Orinoco. Crocodile Specialist Group Newsletter 15:14–16.

Lugo, M., C.A. Lasso, A. Castro, and M. Morales-Betancourt. 2013. *Paleosuchus palpebrosus* (Curvier 1807). Pp. 187–210 *In* VIII. Biología y Conservación de los Crocodylia de Colombia. Serie Editorial Recursos Hidrobiológicos y Pesqueros Continentales de Colombia. Morales-Betancourt, M., C. Lasso, J. de La Ossa, and A. Fajardo-Patiño (Ed.). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, D.C., Colombia.

Magnusson, W.E., and A.P. Lima. 1991. The ecology a cryptic predator, *Paleosuchus trigonatus*, in a Tropical Rainforest. Journal of Herpetology 25:41–48.

Martins, A. 2004. Uso de habitat por *Caiman crocodilus* e *Paleosuchus palpebrosus* no reservatório da UHE de Lajeado, Tocantins. Teses de Maestria. Universidade de São Paulo, São Paulo, Brasil. 75 p.

Mazzotti, F.J., G.R. Best, L.A. Brandt, M.S. Cherkis, B.M. Jeffery, and K.G. Rice. 2009. Alligators and crocodiles as indicators for restoration of Everglades ecosystems. Ecological Indicators 9:137–149.

Medem, F. 1981. Los Crocodylia de sur America. Volumen I. Los Crocodylia de Colombia. Colciencias, Bogotá, D.C., Colombia.

Morales-Betancourt, M., C. Lasso, J. de La Ossa, and A. Fajardo-Patiño. 2013. VIII. Biología y Conservación de los Crocodylia de Colombia. Serie Editorial Recursos Hidrobiológicos y Pesqueros Continentales de Colombia. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, D.C., Colombia.

Moreno, A., O. Hernández, C. Molina, and J. Amauci. 2014. Uso de hábitat de *Crocodylus intermedius* y *Caiman crocodilus* en el P.N. Santos Luzardo, Estado Apure, Venezuela. Boletín de la Academia de Ciencias Físicas, Matemáticas y Naturales 74:29–38.

Moreno-Arias, R.A., M.C. Ardila-Robayo, W. Martínez-Barreto, and R.M. Suárez-Daza. 2016. Navigating with the Orinoco Crocodile. Crocodile Specialist Group Newsletter 35:14–15.

Moreno-Arias, R.A., M.C. Ardila-Robayo, W. Martínez-Barreto, and R.M. Suárez-Daza. 2013. Ecología poblacional de la babilla (*Caiman crocodilus fuscus*) en el valle del río Magdalena (Cundinamarca, Colombia). Caldasia 35:25–36.

Ouboter, P.E., and L.M. Nanhoe. 1989. Notes on the dynamics of a population of *Caiman crocodilus crocodilus* in northern Suriname and its implications for management. Biological Conservation 48:243–264.

Pacheco-Álvarez, A.D. 2009. Distribución, abundancia y estructura poblacional del Babo Morichalero (*Paleosuchus palpebrosus*) en los Llanos Orientales del estado Anzoátegui. Trabajo especial de Grado, Universidad Central de Venezuela, Caracas, Venezuela. 109 p.

Parra-Torres, F. 2017. Evaluación de la abundancia y el hábitat del *Crocodylus intermedius* y otros cocodrilianos en el río Bita (Vichada, Colombia). Tesis de maestria, Universidad Nacional de Colombia, Bogotá, D.C., Colombia. 87 p.

Peñuela, L., and J.J. Rodríguez. 2014. Capítulo 1. Contexto forestal en la cuenca del río Bita, Vichada. Pp. 27–70 *In* Manejo Forestal Sostenible en Plantaciones en la Cuenca del Río Bita, Vichada, Colombia. No. 4 Serie, Conservación de la Biodiversidad en Predios Productivos. Pacheco, M., L. Peñuela, C. Solano, and S. Galán (Ed.). La imprenta Editores Socidad Anonima., Bogotá, D.C., Colombia.

Rebêlo, G.H., and L. Lugli. 2001. Distribution and abundance of four caiman species (Crocodylia: Alligatoridae) in Jaú National Park, Amazonas, Brazil. Revista de Biología Tropical 49:1095–1109.

Ríos, M., and F. Trujillo. 2004. Censo preliminar de Crocodylia en los ríos Meta y Bita, departamento del Vichada (Colombia). Pp. 229–259 *In* Fauna Acuática en la Orinoquia Colombiana Diazgranados. Trujillo, M.C., and F. Trujillo (Ed.). Instituto de Estudios Ambientales para el Desarrollo - Departamento de Ecología y Territorio, Bogotá, D.C., Colombia.

Rodríguez, M. 2000. Estado y Distribución de los Crocodylia en Colombia. Ministerio del Medio Ambiente, Bogotá, D.C., Colombia.

Seijas, A.E. 1986. Estimaciones de babas (*Caiman crocodilus*) en los Llanos occidentales de Venezuela. Vida Silvestre Neotropical 1:24–30.

Seijas, A.E. 1996. Coexistencia de babas y caimanes en la región costera venezolana. Pp. 217–253 *In* Herpetología Neotropical. Actas del II Congreso Latinoamericano de Herpetología. II Volumen. Péfaur, J.E. (Recopilador). Universidad de los Andes, Consejo de Publicaciones, Consejo de Desarrollo Científico, Humanístico y Tecnológico, Mérida, Venezuela.

Seijas, A.E. 2007. Características distintivas y estado de conocimiento de las especies del género *Paleosuchus* (Crocodylia; Alligatoridae) en Venezuela. Memória de la Fundación La Salle de Ciencias Naturales 166:27–44.

Seijas, A.E. 2010. Efectividad de la liberación de individuos criados en cautiverio como herramienta para restaurar poblaciones de cocodrilos (género *Crocodylus*) en el Neotrópico. Pp. 77–86 *In* Ciencia y Conservación de Especies Amenazadas en Venezuela: Conservación Basada en Evidencias e Intervenciones Estratégicas. De Oliveira-Miranda, R., J. Lessmann, A. Rodríguez-Ferraro, and F. Rojas-Suárez (Ed.). Provita, Caracas, Venezuela.

Silva, A.J., F.M. Nogueira, and J.L. Freitas. 2010. *Caiman crocodilus yacare* em experimento controlado: confirmação estatística de sua contribuição ao balanço de nutrientes em um ecossistema aquático do pantanal Mato-Grossense, Brasil. Engenharia Ambiental 7:59–70.

Staton, M., and J. Dixon. 1975. Studies on the dry season biology of *Caiman crocodilus crocodilus* from the Venezuelan llanos. Memorias de la Fundación La Salle de Ciencias Naturales 35:237–265.

Thorbjarnarson, J.B. 1994. Reproductive ecology of the Spectacled Caiman (*Caiman crocodilus*) in the Venezuelan llanos. Copeia 1994:907–919.

Velasco, A., and J. Ayarzagüena. 1995. Situación actual de las poblaciones de Baba (*Caiman crocodilus*) sometidas a aprovechamiento comercial en los llanos venezolanos. Publicaciones Asociación Amigos de Doñana 5:14–19.

Viloria-Lagares, T.A., R.A. Moreno-Arias, and P. Bloor. 2017. Assessment of American Crocodile, *Crocodylus acutus* (Crocodylidae), and Brown Caiman, *Caiman crocodilus fuscus* (Alligatoridae), populations in the Paramillo National Natural Park, Colombia. Herpetological Conservation and Biology 12:24–32.

Felipe Parra-Torres is a Biologist interested in ecology and conservation of wildlife. He graduated from the Universidad de los Llanos, Villavicencio, Colombia, and obtained his M.Sc. degree at the Universidad Nacional de Colombia, Bogotá, D.C., Colombia. His current research interests are focused on the study of populations and habitats of crocodilians and the development of wildlife management and conservation strategies in the Orinoquia region of Colombia. (Photographed by Felipe Parra-Torres).

Rafael Angel Moreno-Arias is a Biologist interested in evolutionary ecology and conservation of reptiles. He graduated from the Universidad Nacional de Colombia, Bogotá, D.C., Colombia, and obtained his M.Sc. and Ph.D. degrees at the same university. His current research interests are focused on demographic patterns of reptile populations across human-disturbed habitats, human-crocodile conflict, and ecomorphological diversification of mainland *Anolis* lizards. (Photographed by Rafael Moreno-Arias).

Olga L. Montenegro is a Biologist interested in ecology applied to the conservation of biodiversity in general, and mammals in particular. She obtained her Bachelor´s degree from the Universidad Nacional de Colombia, Bogotá, D.C., Colombia, and her Master's and Ph.D. degrees in Ecology and Wildlife Conservation from the University of Florida, Gainesville, USA. Since 2005, Olga has been a Research Professor at the Instituto de Ciencias Naturales de la Universidad Nacional de Colombia, Bogota, D.C. She is a member of the research group on Wildlife Conservation and Management, the Colombian Mastozoology Society, and the Tapir and Peccary Specialist Groups of the International Union for Conservation of Nature. (Photographed by Olga L. Montenegro).