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Amphibians and reptiles of the Calakmul Biosphere Reserve, México, with new records

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Abstract: We provide a list of amphibians and reptiles of the Calakmul Biosphere Reserve in the southern half of the Mexican Yucatan, in the state of Campeche. The study area was sampled through opportunistic, transect and pitfall trap surveys conducted for three successive years. These surveys resulted in a total of 2,359 amphibian and reptile encounters, belonging to 20 amphibian and 69 reptile species from 24 total families. We present herein the records for one snake, one chelonian and two salamander species not previously recorded in the area.

Key words: Herpetofauna, Campeche, Yucatán

INTRODUCTION

Mexico is one of the most biologically rich countries on the planet (Mittermeier and Goettsch-Mittermeier 1997; Gárcia-Frapolli et al. 2009). This is due in no small part to the diversity found in the southern region of the Yucatan Peninsula, which is home to the largest expanse of mature, seasonal tropical forests remaining in Mesoamerica (Carr 1999; Vester et al. 2007). Unlike the majority of forest in the Yucatan Peninsula, the forest in Calakmul Biosphere Reserve, hereafter CBR, of Campeche, Mexico has not been used for large scale timber production nor has it been burned for farming and ranching. As such it is one of the last remaining stands of virgin forest in Mexico, being classified by UNESCO as World Heritage Site of Culture and Nature (UNESCO 2014). In spite of the recognized cultural and ecological value of CBR, few surveys have been conducted on its herpetofauna.

Beginning in 2012, annual biodiversity surveys have been conducted conducted in the CBR by Operation Wallacea, a UK-based non-governmental organization that specializes in biodiversity assessments and monitoring of protected areas through utilizing the expertise of university academics and students. We present herein the results of the herpetological (amphibian and reptile) surveys and discuss their conservation implications for the CBR.

MATERIAL AND METHODS

Our study was conducted in the CBR (18°21.921′ N, 089°53.220′ W; Figure 1), located in the Yucatan Peninsula in Campeche, México. CBR is a large expanse of tropical forest (723,000 ha of reserve and 384,000 ha of buffer zone) that is part of the Selva Maya (Mayan

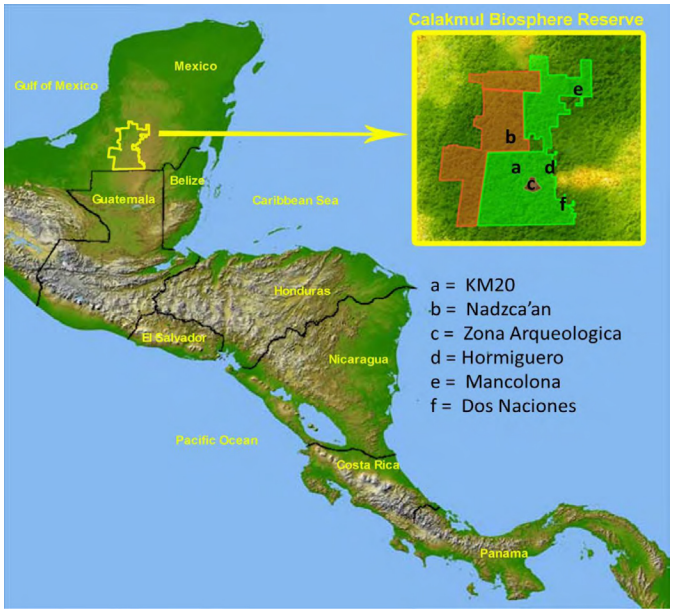

Figure 1. Location of Calakmul Biosphere Reserve within the southern Yucatán Peninsula. Study sites within the reserve are also indicated. KM27 and KM40 are not shown due to their close proximity to KM20 and Zona Arqueologica respectively. Green shading on inset represents the protected reserve (core and buffer zones) and orange shading indicates the connected state reserves of Balam-kim and Balam-ku.

Jungle) which encompasses parts of Mexico, Guatemala and Belize, spans over 10.6 million ha and is the largest continuous section of tropical forest in Mesoamerica (Vester et al. 2007). There is a notable precipitation gradient in the reserve, from 900 mm annually in the north to 1,400 mm annually in the south of the reserve; this has significant effect on forest structure and tree species composition (Vester et al. 2007). The majority of the reserve is composed of tropical semi-deciduous forest with a canopy ranging from 15 to 40 m, whereas the northern parts of the reserve are composed of tropical deciduous forest, with canopy of 8 to 20 m (Chowdhury 2006).

Data collection was carried out between June and August of 2012–2014 and included surveys in seven different sampling localities (Dos Naciones, KM20, KM27, KM40, Mancolona, Nadzca'an, and Hormiguero) within the CBR (Figure 1). Mancolona and Nadzca'an are located in the dry north of the reserve, and are proximal to buffer zones for the reserve. Both of these northern camps have few of the typical large fruiting trees (i.e., ramon (*Brosimium alicastrum*) and zapote (*Manilkara zapota*)) relative the core and southern areas of the reserve. Although situated in the relatively dry north, Nadzca'an was the only site with permanent flowing water in the form of a stream rather than semi-permanent aguadas (temporary pond). KM20 served as the primary base camp and operation headquarters due to the park infrastructure already in place and was located in the transition zone from medium to tall canopy forest. KM27 and KM40 contained the largest and most numerous aguadas among our camps; while Dos Naciones, the southernmost camp, was characterized by the largest and most numerous fruiting trees.

Semi-permanent camps were constructed and utilized at five of the sites (Dos Naciones, KM20, Mancolona, Nadzca'an and Hormiguero). Camp locations were chosen for their accessibility during the wet season and because they cover the full geographical and vegetation range of the reserve. Each camp contained four, two km long transect lines for data collection. Transect surveys were conduct both in the day and at night and all surveys were replicated a minimum of four times. Transect surveys were alternated such that each transect had a minimum of 24 hours rest between surveys. All animals encountered on transect surveys were immediately captured, identified, photographed, when possible marked to avoid repeating counts and identify recaptures, measured and then released at the point of capture. Common, easily identifiable species

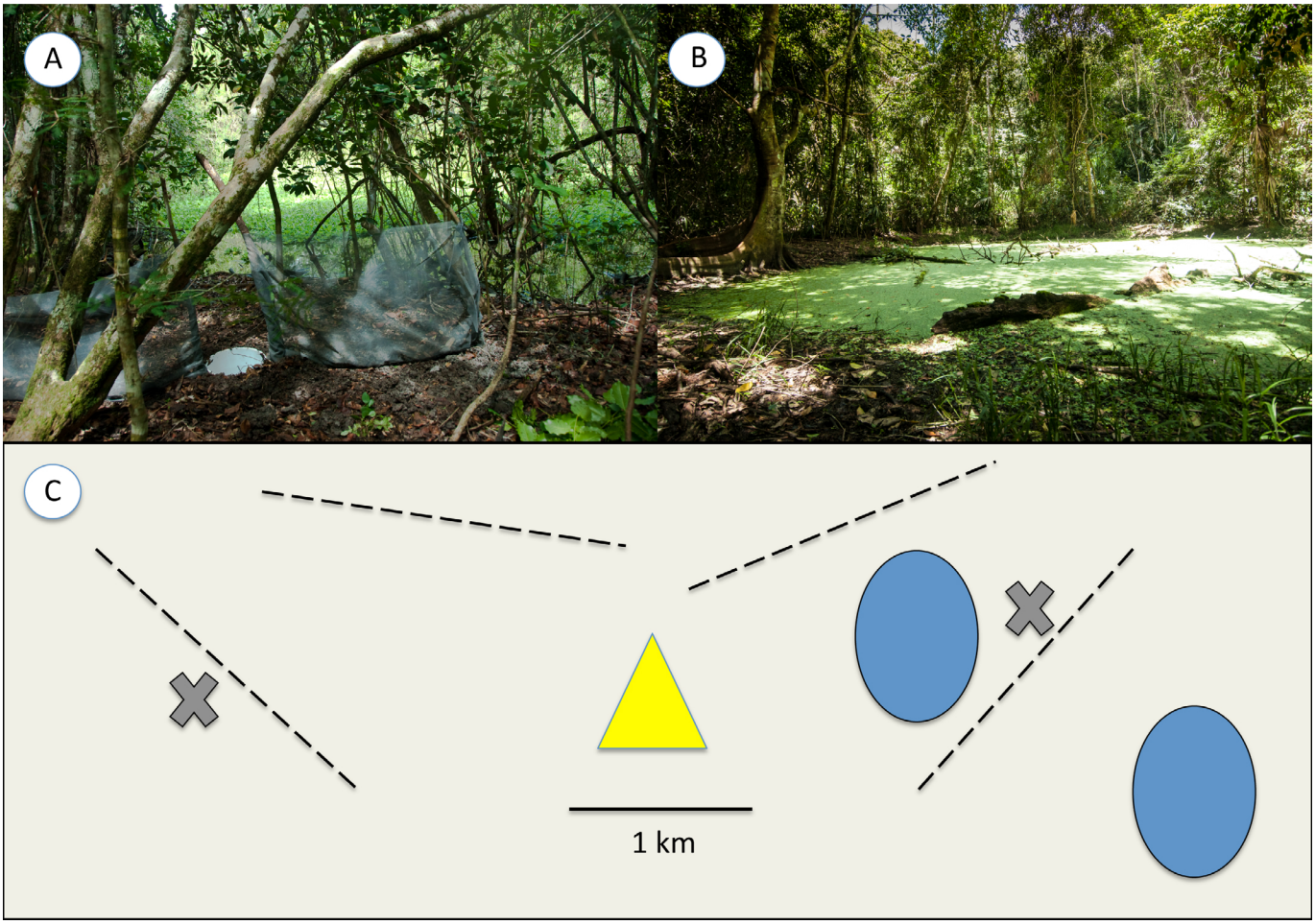

Figure 2. (**A**) Example of pitfall trap and drift fence array. (**B**) Typical semi-permanent aguada. (**C**) Graphical representation of transect and trap design where camp is indicated by yellow triangle, transects by dashed lines, aguadas by blue circles and pitfall and drift fence arrays by Xs.

(e.g., *Ameiva undulata, Incillius valliceps*) were simply counted after a minimum of ten individuals had been measured during a given survey.

At each camp two pitfall trap arrays composed of four buckets each disposed in a Y shape connected by 3 m long by 1 m high drift fences were constructed. In each location, one trap array was placed adjacent to a transect near an aguada, and one adjacent to a transect at least one km from an aguada (Figure 2). Traps were checked each morning and were left open for a minimum of three weeks. All animals captured in traps were immediately removed, identified, photographed, when possible marked to avoid repeating counts and identify recaptures and measured prior to release a safe distance away from the traps while still in the immediate area.

All data were collected by teams of students led by university academics and local indigenous experts. Due to permit restrictions within the Biosphere reserve no specimens were collected but digital photographs were taken and represent digital vouchers for all but two species. These digital vouchers are curated by Operation Wallacea, TJC and Pronatura Peninsula de Yucatan (PPY). Tissue samples in the form of scale, toe or tail clips that resulted from marking individuals were retained and deposited at the tissue collection of the lead author at the University of Mississippi. Additionally, collections of tissues as a by-product of marking individuals followed the University of Mississippi Institute for Animal Use and Care protocols: SOP 13-03 and SOP 13-04.

RESULTS

We recorded a total of 2,359 encounters during our surveys, representing 21 amphibian species included in seven families (Table 1) and 69 reptile species from 17 families (Table 2). All 19 and 65 species of amphibians and reptiles, respectively, previously described for CBR were observed (Lee 2000; Kholer 2008; Mandujuano et al. 2010; Cedeño-Vasquéz et al. 2010). The most species-rich

Table 1. List of amphibians encountered in the CBR. *New records not previously reported for the area. **Digital voucher only.

Family	Species	Field ID	Locality
Bufonidae	*Incilius valliceps*	TJC618	KM20, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Bufonidae	*Rhinella marina*	TJC733	KM20, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Hylidae	*Agalychnis callidryas*	TJC935	KM20, Dos Naciones, Hormiguero, Mancolona
Hylidae	*Dendropsophus ebraccatus*	TJC1042	KM20, Dos Naciones
Hylidae	*Hyla microcephala*	TJC1197	KM20, Hormiguero, Mancolona
Hylidae	*Hyla picta*	TJC1202	KM20
Hylidae	*Scinax staufferi*	TJC605	KM20, Hormiguero, Mancolona
Hylidae	*Smilisca baudinii*	TJC649	KM20, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Hylidae	*Tlalocohyla loquax*	TJC693	KM20, KM40, Dos Naciones, Hormiguero, Mancolona
Hylidae	*Trachycephalus venulosus*	TJC710	KM20, Hormiguero, Mancolona
Leptodactylidae	*Leptodactylus fragilis*	TJC950	KM20, KM40, Mancolona
Leptodactylidae	*Leptodactylus melanonotus*	TJC951	KM20
Microhylidae	*Gastrophryne elegans*	TJC995	KM20
Microhylidae	*Hypopachus variolosus*	TJC626	KM20, KM40, Hormiguero, Mancolona, Nadzca'an
Ranidae	*Lithobates berlandieri*	TJC720	KM20, KM40, Dos Naciones, Hormiguero, Mancolona
Ranidae	*Lithobates vaillanti*	TJC607	KM20, Hormiguero
Rhinophrynidae	*Rhinophrynus dorsalis*	TJC749	KM20, Dos Naciones, Hormiguero
Plethodontidae	*Bolitoglossa mexicana**	TJC1041	KM20, Dos Naciones
Plethodontidae	*Bolitoglossa rufescens*	**	KM20
Plethodontidae	*Bolitoglossa yucatana*	**	KM20, Dos Naciones

Table 2. List of reptiles encountered and localities in the CBR. *New records not previously reported for the area.

Family	Species	Field ID	Locality
Crocodylidae	*Crocodylus moreletii*	**	KM27, Hormiguero, Mancolona
Boidae	*Boa constrictor*	TJC928	KM20, Nadzca'an
Colubridae	*Dryadophis melanolomus*	TJC971	KM27, KM40, Dos Naciones, Mancolona, Nadzca'an
Colubridae	*Drymarchon corais*	TJC843	Hormiguero, Mancolona
Colubridae	*Drymobius margaritiferus*	TJC617	KM20, KM27, KM40, Hormiguero, Mancolona, Nadzca'an
Colubridae	*Elaphe flavirufa*	TJC698	KM20, KM27, KM40, Hormiguero
Colubridae	*Ficimia publia*	TJC780	KM20, Hormiguero
Colubridae	*Lampropeltis triangulum*	TJC786	KM20, Hormiguero
Colubridae	*Leptophis ahaetulla*	**	KM20, KM40, Dos Naciones
Colubridae	*Leptophis mexicanus*	TJC647	KM20, KM27, KM40, Hormiguero, Mancolona
Colubridae	*Mastigodryas melanolomus*	**	KM20
Colubridae	*Oxybelis aeneus*	TJC1032	KM20, Nadzca'an
Colubridae	*Oxybelis fulgidus*	**	Mancolona

Continued

Table 2. *Continued.*

Family	Species	Field ID	Locality
Colubridae	*Pseustes poecilonotus*	TJC766	KM20
Colubridae	*Senticolis triaspis*	**	Mancolona
Colubridae	*Spilotes pullatus*	**	KM27, KM40, Hormiguero
Colubridae	*Symphimus mayae*	**	KM20, Dos Naciones
Colubridae	*Xenodon rabdochephalus*	TJC992	KM20, Mancolona
Corytophanidae	*Basiliscus vittatus*	TJC816	KM20, KM27, KM40, Hormiguero, Mancolona
Corytophanidae	*Corytophanes cristatus*	TJC707	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona
Corytophanidae	*Corytophanes hernandezii*	TJC811	Dos Naciones, Hormiguero
Corytophanidae	*Laemanctus serratus*	TJC659	KM20, Hormiguero, Nadzca'an
Dactyloidae	*Norops biporcatus*	TJC1191	Dos Naciones, Hormiguero
Dactyloidae	*Norops cristellatus*	**	KM20
Dactyloidae	*Norops lemurinus*	TJC1033	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Dactyloidae	*Norops pentaprion*	**	KM20
Dactyloidae	*Norops rodriguezii*	TJC1043	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Dactyloidae	*Norops sagrei*	**	KM20, Dos Naciones, Mancolona
Dactyloidae	*Norops sericeus*	TJC638	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona
Dactyloidae	*Norops tropidonotus*	TJC662	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona
Dipsadidae	*Coniophanes imperialis*	TJC616	KM20, KM27, KM40, Hormiguero, Mancolona, Nadzca'an
Dipsadidae	*Coniophanes schmidti*	TJC725	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Dipsadidae	*Dipsas brevifacies*	TJC674	KM20, KM27, KM40, Hormiguero, Mancolona
Dipsadidae	*Imantodes cenchoa*	TJC954	KM20, Dos Naciones, Hormiguero, Mancolona
Dipsadidae	*Imantodes gemnistratus*	TJC836	KM20, Hormiguero
Dipsadidae	*Imantodes tenuissimus*	TJCA13	KM20, KM27, KM40
Dipsadidae	*Leptodeira frenata*	TJC643	KM20, Hormiguero, Mancolona, Nadzca'an
Dipsadidae	*Leptodeira septentrionalis*	TJC1211	Dos Naciones
Dipsadidae	*Ninia diademata**	TJC1208	KM20, KM40
Dipsadidae	*Ninia sebae*	TJC827	KM20, Hormiguero
Dipsadidae	*Sibon sanniola*	TJCA35	KM20
Dipsadidae	*Tropidodipsas fasciata*	TJC666	Hormiguero
Dipsadidae	*Tropidodipsas nebulata*	**	KM20
Dipsadidae	*Tropidodipsas sartorii*	TJC682	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Elapidae	*Micrurus diastema*	TJC753	KM20, KM27, KM40, Mancolona, Nadzca'an
Gekkonidae	*Coleonyx elegans*	TJC640	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Gekkonidae	*Hemidactylus frenatus*	**	KM20, Dos Naciones, Hormiguero, Mancolona
Gekkonidae	*Thecadactylus rapicauda*	TJC632	KM20, Dos Naciones, Hormiguero, Mancolona
Iguanidae	*Ctenosaura defensor*	**	Hormiguero, Nadzca'an
Phrynosomatidae	*Sceloporus chrysostictus*	TJC642	KM20, Dos Naciones, Hormiguero, Mancolona, Nadzca'na
Phrynosomatidae	*Sceloporus lundelli*	**	Mancolona
Scincidae	*Mesoscincus schwartzei*	TJC987	KM20, Mancolona
Scincidae	*Plestiodon sumichrasti*	**	KM20
Scincidae	*Sphenomorphus cherriei*	TJC1207	KM20
Sphaerodactylidae	*Sphaerodactylus glaucus*	TJC927	KM20, Hormiguero, Mancolona
Teiidae	*Ameiva undulata*	TJC672	KM20, KM27, KM40, Dos Naciones, Hormiguero, Mancolona, Nadzca'an
Teiidae	*Aspidoscelis angusticeps*	TJC609	KM20, KM27, KM40, Hormiguero, Mancolona,
Viperidae	*Agkistrodon bilineatus*	**	KM20, Nadzca'an
Viperidae	*Bothrops asper*	TJC791	KM20, KM27, KM40, Dos Naciones, Nadzca'an
Viperidae	*Crotalus simus*	TJC823	KM20, Dos Naciones, Hormiguero, Nadzca'an
Emydidae	*Terrapene carolina*	TJC754	Hormiguero
Emydidae	*Trachemys scripta*	**	KM20, KM27, Hormiguero
Geoemydidae	*Rhinoclemmys areolata*	TJC840	KM20, Hormiguero
Kinosternidae	*Claudius angustatus*	**	KM20, Hormiguero, Nadzca'an
Kinosternidae	*Kinosternon acutum**	**	Hormiguero
Kinosternidae	*Kinosternon creaseri*	**	KM20, Nadzca'an
Kinosternidae	*Kinosternon leucostomum*	**	KM20, Dos Naciones, Hormiguero, Nadzca'an
Kinosternidae	*Kinosternon scorpioides*	TJC833	KM20, KM27, Hormiguero, Mancolona, Nadzca'an

Figure 3. Snakes encountered in the Calakmul Biosphere Reserve: (**A**) *Ninia diadema*, (**B**) *Ninia sebae*, (**C**) *Coniophanes imperalis*, (**D**) *Ficimia publia*. Photos by TJC.

Figure 4. Turtles encountered in the Calakmul Biosphere Reserve: (A) *Kinosternon leucostomum*; adult and juvenile, (**B**) *Claudius angustatus,* (**C**) *Rhinoclemmys areolata,* (**D**) *Kinosternon acutum* (Photo by JAB). Photos by TJC.

amphibian family was Hylidae (40% of amphibian species richness), while the most species-rich reptile families were Colubridae, Dipsadidae and Dactyloidae (23%, 22% and 13% of reptile species richness, respectively).

The snake *Ninia diademata*; Figure 3, the turtle *Kinosternon acutum*; Figure 4 and two salamanders (*Bolitoglossa mexicana*, *Bolitoglossa rufescens*; Figure 5) were recorded during the study. None of these were previously reported for the CBR although all have been recorded 50 km to the south in Guatemala and to the west in the Mexican state of Chiapas (Lee 2000).

DISCUSSION

In our study, the total number of species found in the CBR represents about 37% of the herpetofaunal species richness observed in the Mayan jungle (188 species; Lee

Figure 5. Amphibians encountered in the Calakmul Biosphere Reserve: (**A**) *Bolitoglossa mexicana*, *Gastrophryne elegans*, (**C**) *Leptodactylus fragilis*. Photos by TJC.

2000). Of this number, nearly 14% of species occur only within the Yucatan Peninsula (e.g., *Bolitoglossa yucatana*; *Coleonyx elegans*). Knowledge of the assemblage and distribution of amphibians and reptiles in the Yucatan Peninsula is, therefore, of great importance when taking measures to preserve the fauna of this region, especially because site conservation may be one of the most effective means of reducing biodiversity loss (Eken et al. 2004).

Our results point out that only about 50% of the recorded species were recorded in three or more camps, suggesting significant differences on species richness and diversity within Calakmul, and therefore highlight the need for specific conservation measures that are adapted to each habitat type. Latitude-correlated rainfall differences among camps may be responsible for differences in local microhabitat differences (Stevens 1989; Lyons and Willig 2002), which may result in species

Figure 6. Lizards encountered in the Calakmul Biosphere Reserve: (**A**) *Basiliscus vittatus*, (**B**) *Laemanctus serratus,* (**C**) *Sphenomorphus cherriei,* (**D**) *Corytophanes hernandezii* , (**E**) *Corytophanes cristatus.* Photos by TJC.

Figure 7. Amphibians encountered in the Calakmul Biosphere Reserve: (**A**) *Triprion petastatus,* (**B**) *Smilisca baudinii,* (**C**) *Rhinophrynus dorsalis,* (**D**) *Dendropsophis ebracatta.* Photos by TJC.

Figure 8. Snakes encountered in the Calakmul Biosphere Reserve: (**A**) *Xenodon rhabdocephalis,* (**B**) *Bothrops asper,* (**C**) *Leptodeira frenata,* (**D**) *Leptodeira septentrionalis.* Photos by TJC.

variation among areas (Vitt et al. 2007; Garda et al. 2012). However, when considering family level variation (e.g., Colubridae, Hylidae) and, to some extent, genus level variation (e.g., *Norops*, *Kinosternon*), richness among our camps was even.

Overall species abundance and diversity appeared to follow the known precipitation gradient in the reserve. Camps in the wetter, central and southern portions of the CBR contained more herpetofaunal species as expected. Interestingly when only considering reptile species diversity the dry northern camp of Nadzca'an had a similar number of reptile species as the southern camps. We suspect this is due to the permanent stream located in the camp which provides suitable habitat to a variety of turtles as well as a water source for other reptiles while not providing suitable breeding habitat for many amphibian species that reproduce in temporary ponds.

Species which favour open or disturbed habitat (e.g., *Sceloporus chrysostictus*) were more abundant at the dry (open canopy) northern camps that are also situated along the edge of the buffer zone of the reserve. Although some frogs were found in or near human-made structures (e.g. *Incillius valliceps*) or small water reservoirs (e.g., *Smilisca baudinii*), the majority of individuals were found near aguadas. On the other hand, some species were recorded away from major water sources (e.g., *Triprion petatsatus*) in seemingly dry habitat. Future studies will specifically test the effect of forest structure, habitat disturbance and distance from aguadas on herpetofaunal community composition.

Guides to species of amphibians (Cedeño-Vasquez et al. 2010) and reptiles (Calderon-Mandujano et al. 2010) of the CBR have already been produced. However, these guides are not indexed and are only available in Spanish. Thereby, our study is the first published indexed species list for the region, and includes four new species that were not previously reported from CBR, and significant range extensions for these species. Future studies should be conducted in other seasons and considerable efforts should be directed toward fossorial amphibians and reptiles, which are hard to detect and may have not been encountered previously.

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Authors' contribution statement: KS and TJC carried out the design of the study, coordinated the data collection and revised and edited the manuscript. JALBN participated in the herpetological surveys and species identification and prepared the first draft of the manuscript. RM, AL, JW, GC, SH, AR, ET, and RJW participated in the herpetological surveys and species identification. All authors read and approved the final manuscript.

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