Revista Mexicana de Biodiversidad

Revista Mexicana de Biodiversidad 93 (2022): e933927

Conservation

Herpetological diversity in Calakmul, Campeche, Mexico: species list with new distribution notes

Diversidad herpetológica en Calakmul, Campeche, México: lista de especies con nuevas notas de distribución

José Antônio L. Barão-Nóbrega [a, b, *], Pedro E. Nahuat-Cervera [a, c], Ignazio Avella [a, d], Griffin Capehart [a], Beau Garcia [a], Joseph Oakley [a], Alexandros Theodorou [a], Kathy Y. Slater [a]

[a] *Operation Wallacea, Wallace House, Old Bolingbroke Lincolnshire PE23 4EX, UK*

[b] *University of Salford, School of Science, Engineering and Environment, Salford M5 4WT, UK*

[c] *Universidad Autónoma de Yucatán, Campus de Ciencias Biológicas y Agropecuarias, Km 15.5 Carretera Mérida-Xmatkuil, 97315 Mérida, Yucatán, Mexico*

[d] *Universidade do Porto, Centro de Investigação em Biodiversidade e Recursos Genéticos da Campus Agrário de Vairão, Rua Padre Armando Quintas, N°7, 4485-661 Vairão, Portugal*

*Corresponding author: jose.antonio@opwall.com (J.A.L. Barão-Nóbrega)

Received: 19 February 2021; accepted: 29 November 2021

Abstract

The herpetofauna occurring in the Selva Maya is one of the richest assemblages in the Americas. We herein provide an updated list of herpetofauna species for the Calakmul region, located in the southern Yucatán Peninsula, Campeche, Mexico. This species list was compiled considering the results of herpetological surveys conducted between 2015-2019 in the Calakmul Biosphere Reserve, information gathered from previous literature, and sighting records from the website iNaturalist. All this information combined resulted in the identification of 109 species, 23 amphibians and 86 reptiles, belonging to 34 families. Furthermore, we hereby present new distribution records for 7 snakes, 2 lizards and 2 frogs not previously observed in the study region. Approximately 38% (n = 41) of the herpetofauna species are listed under a threat category by the environmental Mexican legislation (NOM-059-SEMARNAT-2010). The list presented in this study increases to 109 the number of species known to occur in the Calakmul region, and to 135 in Campeche, which therefore becomes the Mexican state of the Yucatán Peninsula with the highest herpetofauna diversity, followed by Quintana Roo with 133 species.

Keywords: Amphibians; Campeche; Herpetofauna; Selva Maya; Reptiles; Species inventory; Yucatán Peninsula

ISSN versión electrónica: 2007-8706; Universidad Nacional Autónoma de México, Instituto de Biología. https://doi.org/10.22201/ib.20078706e.2022.93.3927

Resumen

La herpetofauna que habita en la selva maya es una de las más diversas en las Americas. Proporcionamos una lista actualizada de especies de la herpetofauna para la región de Calakmul, al sur de la península de Yucatán, Campeche, México. Esta lista de especies fue compilada considerando los resultados de los muestreos herpetológicos realizados entre 2015-2019 en la Reserva de la Biosfera Calakmul, información de literatura previa y registros de avistamientos de iNaturalist.org. Toda esta información combinada resultó en la identificación de 109 especies, 23 anfibios y 86 reptiles, pertenecientes a 34 familias. Además, presentamos nuevos registros de distribución para 7 especies de serpientes, 2 lagartijas y 2 ranas no observadas previamente en esta región. Aproximadamente 38% (n = 41) de las especies de la herpetofauna están incluidas en una categoría de riesgo por la legislación ambiental mexicana (NOM-059-SEMARNAT-2010). La lista presentada en este trabajo aumenta a 109 el número de especies conocidas para la región de Calakmul y a 135 para Campeche, que por lo tanto se convierte en el estado mexicano de la Península de Yucatán con la mayor diversidad de herpetofauna, seguido de Quintana Roo con 133 especies.

Palabras clave: Anfibios; Campeche; Herpetofauna; Selva maya; Reptiles; Inventario de especies; Península de Yucatán

Introduction

Mexico is one of the world's most biologically rich countries (García-Frapolli et al., 2009; Mittermeier & Goettsch-Mittermeier, 1997), largely due to the high biodiversity found in the southern regions of the Yucatán Peninsula, home to the largest expanse of mature seasonal tropical forests remaining in Mesoamerica (Carr III & Stoll, 1999; Vester et al., 2007). The Calakmul Biosphere Reserve (CBR) is located in southern Mexico and together with adjacent state reserves Balam-Kú and Balam-Kin encompasses more than 1.2 million hectares of protected forest under jurisdiction and management of federal and Campeche state authorities, respectively. CBR is a UNESCO World Heritage Site of Culture and Nature due to the multiple ancient Mayan archaeological sites, including the major city of Calakmul and the remnants of the ancient Mayan agroforestry that has given place to a forest of outstanding biodiversity (UNESCO, 2016). This reserve is composed of tropical semi-deciduous forest. In most of the reserve, canopy height ranges between 15 to 40 meters and 20% of trees lose their leaves during the dry season. Canopy in the northern parts of the reserve ranges from 8 to 20 meters in height and 40% of trees are deciduous (Chowdhury, 2006). As with other areas of the Selva Maya (Ross & Rangel, 2011), forest adjacent to ruin sites in Calakmul has notably larger trees, a different tree species composition and higher fruit production than other forested areas (Slater, 2019). Surface water in CBR occurs only in some areas where the terrain allows the accumulation of water, which create semi-temporary natural ponds, locally known as "aguadas" (Barão-Nóbrega, 2019). These "aguadas" are sustained by retaining water provided by the annual precipitation gradient and constitute the only source of water to both the fauna and the human communities of the region (Reyna-Hurtado et al., 2010). These waterbodies are of particular importance to herpetofauna species that require aquatic habitat such as frogs, freshwater turtles, and crocodiles (Cedeño-Vázquez et al., 2010; Colston et al., 2015)

Operation Wallacea is a UK-based non-governmental organization specialized in biodiversity assessments and monitoring of protected areas. Utilizing the expertise of university academics and students, this organization has been performing annual biodiversity surveys in CBR since 2012. In 2015, an indexed species list of amphibians and reptiles of CBR was compiled and published, reporting the presence of 20 amphibian and 69 reptile species from 24 families (Colston et al., 2015). Since then, taxonomic changes affected the nomenclature of many species, with some even subject to taxonomic division (e.g., *Pseudelaphe flavirufa* Cope, 1867 and *Holcosus undulatus* Wiegmann, 1834; González-Sánchez et al., 2017; Meza-Lázaro & Nieto-Montes de Oca, 2015). Operation Wallacea has continued performing annual biodiversity surveys in CBR and found 9 new herpetofauna records not previously reported for the area, with some even representing new records for the state of Campeche and the Mexican Yucatán Peninsula. We herein update and summarize current knowledge on the species of amphibians and reptiles in the region of Calakmul (CBR and surrounding areas) and discuss their conservation implications for the region. We also discuss other herpetofauna species that we believe may also occur in the region but have not been detected yet.

Materials and methods

Calakmul Biosphere Reserve (18°36'20.99" N, 89°56'39.98" W; WGS84; Fig. 1) is an expanse of tropical forest that covers an area of 723,000 hectares,

Figure 1. Location of Calakmul Biosphere Reserve within the southern Yucatán Peninsula in Mexico. Operation Wallacea's annual survey sites are numerated from 1 to 6. All other localities represent opportunistic sightings or survey locations mentioned in previous literature (Calderón-Mandujano et al., 2003, 2010; Colston et al., 2015). Locations 7, 16 and 17 are located within Balam-Ku State Reserve.

and is part of the Selva Maya that encompasses Mexico, Guatemala and Belize, spanning over 10.6 million hectares and making it the largest continuous section of tropical forest in Mesoamerica (Vester et al., 2007). The southern Yucatán Peninsula is characterized by a warm, sub-humid climate with a mean annual temperature of 24.6 ºC. A precipitation ecocline goes from the northwest (ca. 900 mm) to the southeast (ca. 1,400 mm) of the reserve (Vester et al., 2007), over the 120 km from the north of the reserve to the Guatemalan border (Lawrence & Foster, 2002), significantly influencing forest structure and tree species composition (Chowdhury, 2006; Martínez & Galindo-Leal, 2002).

Herpetofauna surveys in CBR were carried out each year between June and August from 2015 to 2019 through transects, timed searches around waterbodies, and opportunistic funnel trapping in 6 different sampling localities (Dos Naciones, KM20, KM27, KM40, Mancolona and Hormiguero; Fig. 1), as part of Operation Wallacea's annual biodiversity monitoring project in the region. For further detailed information on surveyed locations and methods, please see Colston et al. (2015). All data were collected by teams of students led by university academics and local indigenous experts. Due to permit restrictions within CBR, no specimens were collected but digital photographs for all new records were taken and represent digital vouchers (Colston et al., 2015), curated by Operation Wallacea (José António L. Barão-Nóbrega and Pedro E. Nahuat-Cervera) and University of Texas (Eric N. Smith and Gregory Pandelis). Fieldwork was performed in compliance with the protocols described by Beaupre et al. (2004). Research permit was yearly granted to Operation Wallacea's long-term monitoring project, in collaboration with Pronatura Península de Yucatán, A.C., by Secretaría de Medio Ambiente y Recursos Naturales (Semarnat; SGPA/DGVS/005403/18).

We compiled an updated species list for the region of Calakmul by combining our herpetological survey results between 2015-2019 in CBR with *ad libitum* herpetofauna sightings from JALBN's field-work activities in the region, opportunistic amphibian and reptile records from the iNaturalist community (research grade records only; iNaturalist, 2019) and herpetofauna species information from literature review on previous studies conducted within and around the reserve (Calderón-Mandujano et al., 2003, 2008, 2010; Colston et al., 2015; Neri-Castro et al., 2017). We decided to base our taxonomic classification according to González-Sánchez et al. (2017), Lee (2000), Meza-Lázaro and Nieto-Montes de Oca (2015), Wilson, Johnson et al. (2013), and Wilson, Mata-Silva et al. (2013), and we updated the scientific names

of species until October 2021, based on Frost (2021) for amphibians and Uetz and Hošek (2021) for reptiles.

Results

Operation Wallacea's herpetofauna survey records, pooled together with data from pre-existing literature and opportunistic sightings, indicate the occurrence of 109 species of amphibians and reptiles within the region of Calakmul (Table 1). Of this total, 23 are amphibian species belonging to 9 families, while the remaining 86 species are reptiles distributed amongst 25 families. For amphibians, the richest family in terms of species is Hylidae (35% of the total amphibian species richness detected), while for reptiles the richest families are Colubridae (23%), Dipsadidae (20%), and Dactyloidae (8%). Approximately 38% (n = 41) of the herpetofauna species reported to occur in Calakmul (Table 1) are listed under a threat category by the environmental Mexican legislation (NOM-059-SEMARNAT-2010). Of these 41 species, 71% (n = 29) are indicated as in need of Special protection, 24% (n = 10) as Threatened, and 5% (n = 2; *Cachryx defensor* Cope, 1866 and *Claudius angustatus* Cope, 1865) as in Danger of extinction.

During this study, we encountered a total of 11 herpetofauna species (9 in CBR and 2 in the surrounding areas) that had never been previously reported for the region. The frog *Engystomops pustulosus* (Cope, 1864), the lizards *Ctenosaura similis* (Gray, 1831) and *Holcosus gaigeae* (Smith & Laufe, 1946), and the snakes *Coniophanes bipunctatus* (Günther, 1858), *Pseudelaphe phaescens* (Dowling, 1952), and *Stenorrhina freminvillei* (Duméril, Bibron & Duméril, 1854) represent new records for the region of Calakmul (Figs. 2A, C, D, 3A-C). The snakes *Tantilla cuniculator* (Smith, 1939), *Tantilla schistosa* (Bocourt, 1883), and *Scaphiodontophis annulatus* (Duméril, Bibron & Duméril, 1854) represent new records for Campeche (Fig. 4A-C). The frog *Eleutherodactylus leprus* (Cope, 1879) and the snake *Sibon dimidiatus* (Günther, 1872) represent new records for the Mexican Yucatán Peninsula (Figs. 2B, 4D). All new records mentioned above correspond to adult individuals. Number of observed individuals goes as following: 1 individual of *E. pustulosus*, *C. similis*, *C. bipunctatus*, *S. dimidiatus, S. freminvillei*, and *T. cuniculator*; 2 individuals of *S. annulatus*, *T. schistosa*, and *P. phaescens*; more than 5 individuals of *E. leprus* and *H. gaigeae*.

Table 1

List of amphibians and reptiles encountered in the region of Calakmul. Numbers indicate source of species records (1, Colston et al., 2015; 2, This study; 3, Neri-Castro et al., 2017; 4, Calderón et al., 2003; 5, Calderón-Mandujano et al., 2008; 6, Calderón-Mandujano et al., 2010; 7, iNaturalist.org 2019). AO, Álvaro Obregón; BKC, Balam-Kú Conejo; AS, Archaeological site; DN, Dos Naciones; HM, Hormiguero; MC, Mancolona; NDZ, Nadzca'an; NM, Narciso Mendoza; NB, Nuevo Becal; PA, Plan de Ayala. * New records for the region of Calakmul, ** new records for the state of Campeche, *** new records for the Mexican Yucatán Peninsula. NNTV indicates species not native to the Yucatán Peninsula. Information inside parenthesis in localities column indicate either the digital voucher number, or iNaturalist registry ID.

Family	Species	Localities
Bufonidae	*Incilius valliceps* (Wiegmann 1833)	Km20[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Bufonidae	*Rhinella horribilis* (Wiegmann 1833)	Km20[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], NB[2]
Eleutherodactylidae	*Eleutherodactylus leprus* (Cope 1879) ***	DN[2] (UTADC 9452)
Hylidae	*Dendropsophus ebraccatus* (Cope 1874)	Km20[1,2], DN[1,2], NM[4], PA[4]
Hylidae	*Dendropsophus microcephalus* (Cope 1886)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2]
Hylidae	*Scinax staufferi* (Cope 1865)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2]
Hylidae	*Smilisca baudinii* (Duméril & Bibron 1841)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Hylidae	*Tlalocohyla loquax* (Gaige & Stuart 1934)	Km20[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2]
Hylidae	*Tlalocohyla picta* (Günther 1901)	Km20[1]
Hylidae	*Trachycephalus vermiculatus* (Cope 1877)	Km20[1,2], HM[1,2], MC[1,2], Bel-Ha[2]
Hylidae	*Triprion petasatus* (Cope 1865)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2]
Leptodactylidae	*Engystomops pustulosus* (Cope 1864) *	BKC[2] (UTADC 9453)

Table 1. Continued

Family	Species	Localities
Leptodactylidae	*Leptodactylus fragilis* (Brocchi 1877)	Km20[1,2], Km40[1,2], MC[1,2], BKC[2]
Leptodactylidae	*Leptodactylus melanonotus* (Hallowell 1861)	Km20[1,2], DN[1,2], MC[2], BKC[2]
Microhylidae	*Gastrophryne elegans* (Boulenger 1882)	Km20[1,2], DN[1,2], HM[2], MC[2]
Microhylidae	*Hypopachus variolosus* (Cope 1866)	Km20[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Phyllomedusidae	*Agalychnis taylori* Funkhouser 1957)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2]
Ranidae	*Lithobates brownorum* (Sanders 1973)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], BKC[2]
Ranidae	*Lithobates vaillanti* (Brocchi 1877)	Km20[1,2], HM[1,2], MC[2]
Rhinophrynidae	*Rhinophrynus dorsalis* (Duméril & Bibron 1841)	Km20[1,2], DN[1,2], HM[1,2], BKC[2], Bel-Ha[2]
Plethodontidae	*Bolitoglossa mexicana* (Duméril, Bibron & Duméril 1854)	Km20[1], DN[1,2]
Plethodontidae	*Bolitoglossa rufescens* (Cope 1869)	Km20[1]
Plethodontidae	*Bolitoglossa yucatana* (Peters 1882)	Km20[1], DN[1], AO[4]
Family	Species	Locality
Crocodylidae	*Crocodylus moreletii* (Duméril & Bibron 1851)	Km27[1,2], HM[1,2], MC[1,2], BKC[2], AS[2], PA[2], AO[2], NB[2], NM[2]
Corytophanidae	*Basiliscus vittatus* (Wiegmann 1828)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NB[5], BKC[2]
Corytophanidae	*Corytophanes cristatus* (Merrem 1820)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2]
Corytophanidae	*Corytophanes hernandesii* (Wiegmann 1831)	Km40[2], DN[1,2], HM[1,2]
Corytophanidae	*Laemanctus serratus* (Cope 1864)	Km20[1,2], Km48[5], HM[1,2], NDZ[1]
Corytophanidae	*Laemanctus longipes* (Wiegmann 1834)	AS[6]
Dactyloidae	*Norops beckeri* (Boulenger 1881)	Km20[1,2], AO[4], AS[4], Bel-Ha[4]
Dactyloidae	*Norops biporcatus* (Wiegmann 1834)	DN[1,2], HM[1,2]
Dactyloidae	*Norops lemurinus* (Cope 1861)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Dactyloidae	*Norops rodriguezii* (Bocourt 1873)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Dactyloidae	*Norops sagrei* (Duméril & Bibron 1837) NNTV	Km20[1,2], HM[2], DN[1,2], MC[1,2]
Dactyloidae	*Norops tropidonotus* (Peters 1863)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NB[5], BKC[2]
Dactyloidae	*Norops ustus* (Cope 1864)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2]
Eublepharidae	*Coleonyx elegans* (Gray 1845)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], NB[5]
Gekkonidae	*Hemidactylus frenatus* (Duméril & Bibron 1836) NNTV	Km20[1,2], DN[1,2], HM[1,2], MC[1,2], BKC[2]
Iguanidae	*Cachryx alfredschmidti* (Köhler 1995)	Km10[4], Km48[5], AS[4]
Iguanidae	*Cachryx defensor* (Cope 1866)	HM[1,2], NDZ[1]
Iguanidae	*Ctenosaura similis* (Gray 1831) *	Silvituc[2] (UTADC 9451)
Mabuyidae	*Marisora lineola* (Mccranie, Matthews & Hedges, 2020)	HM[2], AO[7], MC[5]

Table 1. Continued

Family	Species	Localities
Phrynosomatidae	*Sceloporus chrysostictus* (Cope 1866)	Km20[1,2], Km27[2], Km50[4], DN[1,2], HM[1,2], MC[1,2], NDZ[1], NB[5], BKC[2]
Phrynosomatidae	*Sceloporus lundelli* (Smith 1939)	Km20[2], MC[1,2], HM[2], AS[4]
Phyllodactylidae	*Thecadactylus rapicauda* (Houttuyn 1782)	Km20[1,2], Km48[5], DN[1,2], HM[1,2], MC[1,2], AS[5]
Scincidae	*Mesoscincus schwartzei* (Fischer 1884)	Km20[1,2], MC[1,2], HM[2], DN[2]
Scincidae	*Plestiodon sumichrasti* (Cope 1867)	Km20[1,2], DN[2], MC[2], AS[4]
Sphaerodactylidae	*Sphaerodactylus glaucus* (Cope 1866)	Km20[1,2], DN[1,2], HM[1,2], MC[1,2]
Sphenomorphidae	*Scincella cherriei* (Cope 1893)	Km20[1,2], HM[2] Km50[4], MC[4], AS[5]
Teiidae	*Aspidoscelis angusticeps* (Cope 1878)	Km20[1,2], Km27[1,2], Km40[1,2], HM[1,2], MC[1,2], BKC[2]
Teiidae	*Aspidoscelis deppii* (Wiegmann 1834)	NM[4]
Teiidae	*Holcosus gaigeae* (Smith & Laufe 1946) *	Km20[2], DN[2] (UTADC 9454)
Teiidae	*Holcosus hartwegi* (Smith 1940)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], NB[5]
Boidae	*Boa imperator* (Daudin 1803)	Km20[1,2], Km27[2], NDZ[1]
Colubridae	*Drymarchon melanurus* (Duméril, Bibron & Duméril 1854)	Km20[2], HM[1,2], DN[2], MC[1,2,] NB[2]
Colubridae	*Drymobius margaritiferus* (Schlegel 1837)	Km20[1,2], Km27[1,2], Km40[1,2], HM[1,2], MC[1,2], NDZ[1], NB[5]
Colubridae	*Ficimia publia* (Cope 1866)	Km20[1,2], HM[1,2], DN[2], AO[5], AS[5]
Colubridae	*Lampropeltis abnorma* (Bocourt 1886)	Km20[1,2], HM[1,2], MC[1,2], Bel-Ha[4]
Colubridae	*Leptophis ahaetulla* (Linnaeus 1758)	Km20[1,2], Km40[1,2], HM[2], DN[1,2]
Colubridae	*Leptophis mexicanus* (Duméril, Bibron & Duméril 1854)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NB[5], BKC[2]
Colubridae	*Mastigodryas melanolomus* (Cope 1868)	Km20[1,2], Km40[1,2], HM[2] DN[1,2], MC[1,2], NDZ[1], NM[4], NB[2]
Colubridae	*Oxybelis potosiensis* (Taylor 1941)	Km20[1,2], NDZ[1], AS[4], PA[4], AO[4]
Colubridae	*Oxybelis fulgidus* (Daudin 1803)	MC[1,2], NB[4], PA[4]
Colubridae	*Phrynonax poecilonotus* (Günther 1858)	Km20[1,2], MC[2], DN[2]
Colubridae	*Pseudelaphe flavirufa* (Cope 1867)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], BKC[2]
Colubridae	*Pseudelaphe phaescens* (Dowling 1952) *	HM[2] (UTADC 9455)
Colubridae	*Senticolis triaspis* (Cope 1866)	MC[1]
Colubridae	*Spilotes pullatus* (Linnaeus 1758)	Km27[1,2], Km40[1,2], HM[1,2], MC[1,2]
Colubridae	*Stenorrhina freminvillei* (Duméril, Bibron & Duméril 1854) *	MC[2] (UTADC 9458)
Colubridae	*Symphimus mayae* (Gaige 1936)	Km20[1,2], Km50[4], DN[1,2], MC[4]
Colubridae	*Tantilla cuniculator* (Smith 1939) **	HM[2] (UTADC 9459)
Colubridae	*Tantilla moesta* (Günther 1863)	DN[2], Km20[2,3]
Colubridae	*Tantilla schistosa* (Bocourt 1883) **	HM[2], MC[2] (UTADC 9460)
Colubridae	*Tantillita lintoni* (Smith 1940)	DN[2], MC[4]
Dipsadidae	*Coniophanes bipunctatus* (Günther 1858) *	Bel-Ha[2] (UTADC 9450)
Dipsadidae	*Coniophanes imperialis* (Baird & Girard 1859)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], MC[1,2], HM[2] NDZ[1], NB[5], BKC[2]

Table 1. Continued

Family	Species	Localities
Dipsadidae	*Coniophanes schmidti* (Bailey 1937)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1], BKC[2]
Dipsadidae	*Dipsas brevifacies* (Cope 1866)	Km20[1,2], Km27[1,2], Km40[1,2], HM[1,2], MC[1,2], DN[2]
Dipsadidae	*Imantodes cenchoa* (Linnaeus 1758)	Km20[1,2], Km48[5], DN[1,2], HM[1,2], MC[1,2]
Dipsadidae	*Imantodes gemmistratus* (Cope 1861)	Km20[1,2], HM[1,2], MC[2], Bel-Ha[4]
Dipsadidae	*Imantodes tenuissimus* (Cope 1867)	Km20[1,2], Km27[1,2], Km40[1,2], MC[2], HM[2]
Dipsadidae	*Leptodeira frenata* (Cope 1886)	Km20[1,2], HM[1,2], MC[1,2], NDZ[1], AS[5], BKC[2]
Dipsadidae	*Leptodeira polysticta* (Günther 1895)	DN[1,2], HM[2], NB[5], AS[5]
Dipsadidae	*Ninia diademata* (Baird & Girard 1853)	Km20[1,2], Km40[1,2]
Dipsadidae	*Ninia sebae* (Duméril, Bibron & Duméril 1854)	Km20[1,2], HM[1,2], DN2, MC4, AS[4]
Dipsadidae	*Pliocercus elapoides* (Cope 1860)	AS[5]
Dipsadidae	*Sibon dimidiatus* (Günther 1872) ***	DN[2] (UTADC 9457)
Dipsadidae	*Sibon nebulatus* (Linnaeus 1758)	Km20[1,2], Km48[5], DN[1,2], AS[4], AO[4], NM[4]
Dipsadidae	*Sibon sanniolus* (Cope 1866)	Km20[1,2], DN[2], AS[4], NM[4]
Dipsadidae	*Tropidodipsas fasciata* (Günther 1858)	Km20[1,2], Km27[1,2], HM[1,2], MC[2], AO[5]
Dipsadidae	*Tropidodipsas sartorii* (Cope 1863)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[1,2], MC[1,2], NDZ[1]
Dipsadidae	*Xenodon rabdocephalus* (Wied-Neuwied 1824)	Km20[1,2], Km48[5], MC[1,2], AS[4], NM[4]
Elapidae	*Micrurus apiatus* (Jan 1852)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], MC[1,2], NDZ[1], NB[5], AS[5]
Natricidae	*Thamnophis marcianus* (Baird & Girard 1853)	AO[4], MC[4]
Natricidae	*Thamnophis proximus* (Say 1823)	Becan[7] (iN 1729318)
Sibynophiidae	*Scaphiodontophis annulatus* (Duméril, Bibron & Duméril 1854) **	DN[2] (UTADC 9456)
Typhlopidae	*Amerotyphlops microstomus* (Cope 1866)	AO[6]
Viperidae	*Agkistrodon russeolus* (Gloyd 1972)	Km20[1,2], NDZ[1], AS[4]
Viperidae	*Bothrops asper* (Garman 1883)	Km20[1,2], Km27[1,2], Km40[1,2], DN[1,2], HM[2], NDZ[1], MC[5], BKC[2]
Viperidae	*Crotalus tzabcan* (Klauber 1952)	Km20[1,2], DN[1,2], HM[1,2], NDZ[1], AS[4], AO[4], NB[4]
Emydidae	*Terrapene yucatana* (Boulenger 1895)	Km20[2], HM[1,2], AO[2], AS[4]
Emydidae	*Trachemys venusta* (Gray 1855)	Km20[1,2], Km27[1,2], HM[1,2], Bel-Ha[2]
Geoemydidae	*Rhinoclemmys areolata* (Duméril, Bibron & Duméril 1851)	Km20[1,2], Km48[5], MC[2], HM[1,2], DN[2], AO[5]
Kinosternidae	*Kinosternon acutum* (Gray 1831)	HM[1,2], DN[2]
Kinosternidae	*Kinosternon creaseri* (Hartweg 1934)	Km20[1,2], NDZ[1], HM[2], DN[2]
Kinosternidae	*Kinosternon leucostomum* (Duméril, Bibron & Duméril 1851)	Km20[1,2], DN[1,2], MC[2], HM[1,2], NDZ[1]
Kinosternidae	*Kinosternon scorpioides* (Linnaeus 1766)	Km20[1,2], Km27[1,2], HM[1,2], MC[1,2], NDZ[1], NB[5]
Staurotypidae	*Claudius angustatus* (Cope 1865)	Km20[1,2], Km27[2], DN[2], HM[1,2], NDZ[1]
Staurotypidae	*Staurotypus triporcatus* (Wiegmann 1828)	NB[4], Arroyo Negro[6,7]

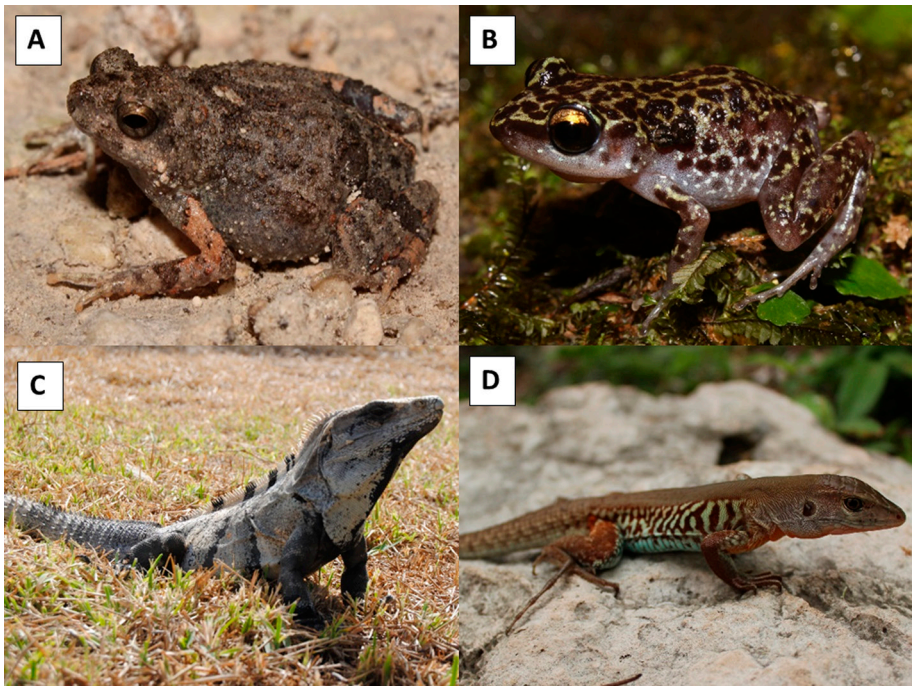

Figure 2. New records encountered in Calakmul: A) *Engystomops pustulosus* (UTADC 9453), B) *Eleutherodactylus leprus* (UTADC 9452), C) *Ctenosaura similis* (UTADC 9451), and D) *Holcosus gaigeae* (UTADC 9454). Photos by PENC.

Figure 3. New records encountered in Calakmul: A) *Coniophanes bipunctatus* (UTADC 9450), B) *Pseudelaphe phaescens* (UTADC 9455), C) *Tantilla cuniculator* (UTADC 9459). Photos A) and B) by PENC, and C) by A Ross.

Figure 4. New records encountered in Calakmul: A) *Stenorrhina freminvillei* (UTADC 9458), B) *Tantilla schistosa* (UTADC 9460), C) *Scaphiodontophis annulatus* (UTADC 9456), D) *Sibon dimidiatus* (UTADC 9457). Photos A) by PENC, B) by AT, C) and (D) by JO.

Discussion

The 109 species of amphibians and reptiles found in CBR and surrounding areas represent, respectively, approximately 84% and 75% of total species richness registered for Campeche and the Mexican Yucatán Peninsula (González-Sánchez et al., 2017), and approximately 60% of the observed herpetofauna richness in the entire Selva Maya (188 species; Lee, 2000). Of the total number of species found in Calakmul, nearly 21% are endemic to the Yucatán Peninsula (e.g., *Bolitoglossa yucatana* Peters, 1882, *Cachryx Defensor*, *Tantilla cuniculator*, *Terrapene yucatana* Boulenger, 1895). Field observations and data from Operation Wallacea's monitoring project between 2014 and 2018 in CBR indicate a decline in overall herpetofauna abundance and diversity, paired with a significant reduction in water availability across the region due to the ongoing prolonged drought the reserve is experiencing (Slater, 2019). As site conservation might be one of the most effective means of reducing biodiversity loss (Eken et al., 2004), our data highlight the importance of increasing our knowledge on the assemblage and distribution of herpetofauna species within the Yucatán Peninsula, when taking measures to preserve the fauna of this region.

Our results from 2015 to 2019 in CBR point out that only about 65% of the species we found were recorded in 3 or more areas. This result is not very different from the percentage previously reported for the reserve (50%; Colston et al., 2015) and further suggests significant differences in species richness and diversity within Calakmul. Topography and latitude-correlated rainfall differences across this region could be accountable for differences in local microhabitat differences (Lyons & Willig, 2002; Stevens, 1989), which might result in species variation among areas (Garda et al., 2013; Vitt et al., 2007).

The significant percentage (38%) of herpetofauna species occurring in Calakmul listed in the risk categories proposed by the Mexican environmental legislation (NOM-059-SEMARNAT-2010) highlights the importance of considering amphibians and reptiles when planning future development projects that would involve habitat loss or alteration in the region (e.g., Mayan train; Pskowski, 2019), as degradation and habitat loss has been indicated as one of the major threats to amphibian and reptile species conservation in Mexico (Flores-Villela & García-Vázquez, 2014; Parra-Olea et al., 2014). Worthy of mention is that unlike CBR, which has federal jurisdiction and management, other areas of the Calakmul region (e.g.,

Balam-Kú and Balam-Kin state reserves) are not under the same legal protection framework, which restricts the conservation efforts of environmental authorities operating in these areas.

Although the frog *E. leprus* and the snake *S. dimidiatus* represent new records for the Mexican part of the Yucatán Peninsula, it was speculated that the distribution of these species could encompass the region of Calakmul, as they have both been reported in Uaxactún (northern Guatemala), which is relatively close (70 km; Lee, 2000) to the southern portion of CBR (González-Sánchez et al., 2017). This situation might also be the case for other amphibians and reptiles, hence we believe that species typically reported in neighbouring regions (e.g., Tabasco) or countries (i.e., Belize and Guatemala), such as the lizards *Celestus rozellae* (Smith, 1942), *Norops capito* (Peters, 1863), *Norops uniformis* (Cope, 1885), *Sceloporus serrifer* (Cope, 1866), *Sphaerodactylus millepunctatus* (Hallowell, 1861), the snakes *Adelphicos quadrivirgatum* (Jan, 1862), *Conophis lineatus* (Duméril, Bibron & Duméril, 1854), *Masticophis mentovarius* (Duméril, Bibron & Duméril, 1854), *Oxyrhopus petolarius* (Linnaeus, 1758), *Tretanorhinus nigroluteus* (Cope, 1861), *Bothriechis schlegelii* (Berthold, 1846), *Porthidium nasutum* (Bocourt, 1868), and the turtle *Dermatemys mawii* (Gray, 1847) might also occur within the region of Calakmul. Some of these species require very specific habitat characteristics to thrive (Lee, 2000), which would likely limit their distribution to very confined areas/habitats within Calakmul. For example, species like *D. mawii* and *T. nigroluteus* inhabit permanent and semi-permanent waterbodies with a relatively slow water flow (Chaves et al., 2016; Lee, 2000; Vogt et al., 2006). Information gathered during author JALBN's PhD activities in the region indicates the presence of areas across Calakmul, away from our regular survey sites, that seem to offer such conditions (Barão-Nóbrega, 2019).

The list presented in this work increases to 109 the number of herpetofauna species known to occur in the region of Calakmul, and to 135 the number of amphibians and reptiles in Campeche, which therefore becomes the Mexican state of the Yucatán Peninsula with the highest herpetofauna diversity, followed by Quintana Roo with 133 species. Furthermore, our study increases to 148 the total number of amphibian and reptile species recorded for the Yucatán Peninsula (González-Sánchez et al., 2017; Ortiz-Medina et al., 2019). Future studies should be performed during different seasons and in other areas within Calakmul, focusing sampling efforts on fossorial amphibians and reptiles (e.g., genera *Tantilla* and *Tantillita*), which are difficult to detect and, therefore, deeply understudied.

Acknowledgements

To villagers from Bel-Ha, Conhuas, Dos Naciones, Hormiguero, Mancolona, Nuevo Becal, and Silvituc (Campeche, Mexico) for granting us the opportunity to work in their ejidal lands and for providing guide services and logistical support. We especially thank O. Platas-Vargas, V. Isoart, V. Corradi, and C. Acton, as field activities for this study would have not been possible without their assistance. We also thank J. R. Cedeño-Vázquez for providing detailed information on the localities of reptile records from Calderón-Mandujano et al. (2010); E. N. Smith and G. Pandelis for providing assistance in obtaining digital vouchers; A. López-Cen and D. Sima-Pantí for their assistance with obtaining yearly research permits; J. M. Hutton, T. Johnson, R. Bhattacharyya-Dickson, N. Weigner, M. Viteri, A. Padilla, A. Romero, A. P. Couto, T. Pinto, R. Smith, R. Piraccini, J. Phangurha, O. Sawościanik, P. Taylor, E. Cambranis, J. Daw and the rest of the Operation Wallacea staff and student volunteers for logistical assistance and data collection. We thank Semarnat and Conanp for providing permits over the period of study (SGPA/DGVS/005403/18), as part of Operation Wallacea's long-term biodiversity monitoring project in collaboration with Pronatura Península de Yucatán. Finally, we thank the two anonymous reviewers which comments improved the manuscript.

References

Barão-Nóbrega, J. A. L. (2019). *Aguadas of Calakmul: an update on location and general structure information of waterbodies in the region of Calakmul, Campeche, Mexico*. Database published on ResearchGate https://www.doi.org/10.13140/RG.2.2.31220.81289/1

Beaupre, S. J., Jacobson, E. R., Lillywhite, H. B., & Zamudio, K. (2004). *Guidelines for the use of live amphibians and reptiles in field and laboratory research*. Miami: American Society of Ichthyologists and Herpetologists.

Calderón-Mandujano, R. R., Cedeño-Vázquez, J. R., & Pozo, C. (2003). New distributional records of amphibians and reptiles from Campeche, México. *Herpetological Review*, *34*, 269–272.

Calderón-Mandujano, R. R., Galindo-Leal, C., & Cedeño-Vázquez, J. R. (2008). Utilización de hábitat por reptiles en estados sucesionales de selvas tropicales de Campeche, México. *Acta Zoológica Mexicana*, *24*, 95–114. https://doi.org/10.21829/azm.2008.241626

Calderón-Mandujano, R. R., Pozo, C., & Cedeño-Vázquez, J. R. (2010). *Guía rústica de los reptiles de la región de Calakmul, Campeche, México*. Chetumal: Conabio/ ECOSUR.

Carr III, A., & Stoll, A. C. D. (1999). *Biological monitoring in the Selva Maya*. Gainsville, USA: US Man and the Biosphere/ Wildlife Conservation Society.

Cedeño-Vázquez, J. R., Calderón-Mandujano, R. R., & Pozo, C. (2010). *Anfibios de la Región de Calakmul, Campeche, México*. Chetumal: Conabio/ ECOSUR.

Chaves, G., Lamar, W., Porras, L. W., Sasa, M., Solórzano, A., & Sunyer, J. (2016). *Tretanorhinus nigroluteus*. The IUCN Red List of Threatened Species 2016. http://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T198526A2530050.en

Chowdhury, R. R. (2006). Landscape change in the Calakmul Biosphere Reserve, Mexico: Modeling the driving forces of smallholder deforestation in land parcels. *Applied Geography*, *26*, 129–152. https://doi.org/10.1016/j.apgeog.2005.11.004

Colston, T. J., Barão-Nóbrega, J. A. L., Manders, R., Lett, A., Willmott, J., Cameron, G. et al. (2015). Amphibians and reptiles of the Calakmul Biosphere Reserve, México, with new records. *Check List*, *11*, 1759. https://doi.org/10.15560/11.5.1759

Eken, G., Bennun, L., Brooks, T. M., Darwall, W., Fishpool, L. D. C., Foster, M. et al. (2004). Key biodiversity areas as site conservation targets. *Bioscience*, *54*, 1110–1118. https://doi.org/10.1641/0006-3568(2004)054[1110:KBAASC]2.0.CO;2

Flores-Villela, O., & García-Vázquez, U. O. (2014). Biodiversidad de reptiles en México. *Revista Mexicana de Biodiversidad*, *85*, 467–475. https://doi.org/10.7550/rmb.43236

Frost, D. R. (2021). Amphibian species of the World: an online reference. Versions 6.0. Retrieved on January 20th, 2021 from: http://www.research.amnh.org/herpetology/amphibia/index.html

García-Frapolli, E., Ramos-Fernández, G., Galicia, E., & Serrano, A. (2009). The complex reality of biodiversity conservation through Natural Protected Area policy: three cases from the Yucatán Peninsula, Mexico. *Land Use Policy*, *26*, 715–722. https://doi.org/10.1016/j.landusepol.2008.09.008

Garda, A. A., Wiederhecker, H. C., Gainsbury, A. M., Costa, G. C., Pyron, R. A., Calazans-Vieira, G. H. et al. (2013). Microhabitat variation explains local-scale distribution of terrestrial Amazonian lizards in Rondônia, Western Brazil. *Biotropica*, *45*, 245–252. https://doi.org/10.1111/j.1744-7429.2012.00906.x

González-Sánchez, V. H., Johnson, J. D., García-Padilla, E., Mata-Silva, V., DeSantis, D. L., & Wilson, L. D. (2017). The herpetofauna of the Mexican Yucatán Peninsula: composition, distribution, and conservation. *Mesoamerican Herpetology*, *4*, 264–380.

iNaturalist. (2019). Research-grade observations. Occurrence dataset iNaturalist. Retrieved on October 1st, 2019 from: https://www.inaturalist.org/

Lawrence, D., & Foster, D. (2002). Changes in forest biomass, litter dynamics and soils following shifting cultivation in southern Mexico: an overview. *Interciencia*, *27*, 400–408.

Lee, J. C. (2000). *A field guide to amphibians and reptiles of the Maya World: the lowlands of México, Northern Guatemalan and Belize*. New York: Cornell University Press.

Lyons, S. K., & Willig, M. R. (2002). Species richness, latitude, and scale-sensitivity. *Ecology*, *83*, 47–58. https://doi.org/10.1890/0012-9658(2002)083[0047:SRLASS]2.0.CO;2

Martínez, E., & Galindo-Leal, C. (2002). La vegetación de Calakmul, Campeche, México: clasificación, descripción y distribución. *Boletín de la Sociedad Botánica de México*, *71*, 7–32. https://doi.org/10.17129/botsci.1660

Meza-Lázaro, R. N., & Nieto-Montes de Oca, A. (2015). Long forsaken species diversity in the Middle American lizard *Holcosus undulatus* (Teiidae). *Zoological Journal of the Linnean Society*, *175*, 189–210. https://doi.org/10.1111/zoj.12264

Mittermeier, R., & Goettsch-Mittermeier, C. (1997). *Megadiversity: the biological richest countries of the world*. México City: Conservation International/CEMEX.

Neri-Castro, E. E., Montalbán-Huidobro, C., & Ortiz-Medina, J. A. (2017). First record of *Tantilla moesta* (Squamata: Colubridae) from the state of Campeche, Mexico. *Mesoamerican Herpetology - Distribution Notes*, *4*, 673–674.

Ortiz-Medina, J. A., Cabrera-Cen, D. I., Chan-Noh, M. M., & Cedeño-Vazquéz, J. R. (2019). First record of the Moorish gecko, *Tarentola mauritanica* (Linnaeus, 1758) (Squamata: Phyllodactylidae), in Mexico. *Herpetology Notes*, *12*, 971–974.

Parra-Olea, G., Flores-Villela, O., & Mendoza-Almeralla, C. (2014). Biodiversidad de anfibios en México. *Revista Mexicana de Biodiversidad*, *85*, 460–466. https://doi.org/10.7550/rmb.32027

Pskowski, M. (2019). Mexico's "Mayan Train" is bound for controversy. CityLab Daily (February 2019). Retrieved on October 1st, 2019 from: https://www.citylab.com/environment/2019/02/mexico-travel-mayan-train-yucatan-tourism-economic-development/583405/

Reyna-Hurtado, R., O'Farril, G., Sima, D., Andrade, M., Padilla, A., & Sosa, L. (2010). Las aguadas de Calakmul, reservatorios de fauna silvestre y de la riqueza natural de México. *Biodiversitas*, *93*, 1–6.

Ross, N. J., & Rangel, T. F. (2011). Ancient Maya agroforestry echoing through spatial relationships in the extant forest of NW Belize. *Biotropica*, *43*, 141–148. https://doi.org/10.1111/j.1744-7429.2010.00666.x

Slater, K. (2019). Informe del proyecto de monitoreo de flora y fauna de Operation Wallacea y Pronatura Península de Yucatán en la Reserva de la Biosfera de Calakmul, 2014-2018. Spilsby, UK: Operation Wallacea.

Stevens, G. C. (1989). The latitudinal gradient in geographical range: how so many species coexist in the tropics. *The American Naturalist*, *133*, 240–256.

Uetz, P., & Hošek, J. (2021). The Reptile Database. Retrieved on January 20th, 2021 from: http://www.reptile-database.org

UNESCO (United Nations Educational, Scientific and Cultural Organization). (2016). Decisions adopted during the 40th session of the World Heritage Committee (Istanbul/UNESCO, 2016). United Nations Educational, Scientific and Cultural Organization. Retrieved on October 1st, 2019 from: http://whc.unesco.org/archive/2016/whc16-40com-19-en.pdf

Vester, H. F. M., Lawrence, D., Eastman, J. R., Turner, B. L., Calmé, S., Dickson, R. et al. (2007). Land change in the southern Yucatán and Calakmul Biosphere Reserve: effects

on habitat and biodiversity. *Ecological Applications*, *17*, 989–1003. https://doi.org/10.1890/05-1106

Vitt, L. J., Colli, G. R., Caldwell, J. P., Mesquita, D. O., Garda, A. A., & França, F. G. R. (2007). Detecting variation in microhabitat use in low-diversity lizard assemblages across small-scale habitat gradients. *Journal of Herpetology*, *41*, 654–663. https://doi.org/10.1670/06-279.1

Vogt, R. C., Gonzalez-Porter, G. P., & Van Dijk, P. P. (2006). *Dermatemys mawii* (errata version published in 2016). The IUCN Red List of Threatened Species 2006. Retrieved on October 1st, 2019 from: http://doi.org/10.2305/IUCN.UK.2006.RLTS.T6493A12783921.en

Wilson, L. D., Johnson, J. D., & Mata-Silva, V. (2013). A conservation reassessment of the amphibians of Mexico based on the EVS measure. *Amphibian & Reptile Conservation*, *7*, 97–124.

Wilson, L. D., Mata-Silva, V., & Johnson, J. D. (2013). A conservation reassessment of the reptiles of Mexico based on the EVS measure. *Amphibian & Reptile Conservation*, *7*, 1–47.