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Two caves in western Honduras are important for bat conservation: first checklist of bats in Santa Bárbara

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Abstract

Caves are important reservoirs for species, including bats, but in Honduras there is little known information about these biodiverse ecosystems. We describe the importance of two caves in Ceguaca in western Honduras, based on the species richness of each cave. From December 2015 to May 2016, we used three mist-nets in seven journeys (74.27 mist-net/hours). We captured 139 bats belonging to 23 species of four families. We recorded 10 species in the crop of Quita Sueño, 10 in the cave of El Peñón, and 12 in the cave of Monte Grueso. In overall, 17% of the bats were captured in the crops of Quita Sueño, 62% in the cave of Monte Grueso, and 21% in the cave of El Peñón. About 9% of bat species of the total account for Honduras could be found in the cave of El Peñón, and 10% in the cave of Monte Grueso. If we consider the number of the species that have been recorded since 1979, between 20.9 and 49.2% of the expected species are still unrecorded, this suggests that despite low sampling effort there is a high diversity. However, the diversity of bats species using these caves embraced on the Tropical Dry Forest of Ceguaca is threatened by the fragmentation of the ecosystem due to the following reasons: intentional fires in the caves, extensive cattle raising, replacement of native plants with extensions of crops, and human-vampire conflicts (*Desmodus rotundus*).

Keywords
Ceguaca, Chiroptera, Mammalia, subterranean ecosystems, Tropical Dry Forest

Introduction

Caves are reservoirs for exceptional levels of endemic and threatened species, very high levels of genetic uniqueness, and they harbor unconventional taxa such as blind fishes, crustaceans, worms, and many other groups, including bats (Medellín et al. 2017). These ecosystems enclosed unique features for housing bats such as the complete or partial absence of light, constant temperature, and high air humidity (Deleva and Chaverri 2018).

Caves are also considered as a complex system with a variety of microclimates and roosting conditions for bats (Rodríguez-Durán 2009; Furey and Racey 2016). In other cases, bats are so abundant that they can significantly modify the caves by altering their microclimate conditions and providing important amounts of guano, which is an essential food source for trophic chainsin most caves (Deleva and Chaverri 2018). In return, caves provide to bats a refuge from predators, inconstant weather, and a critical venue for social interactions, reproduction, hibernation, roosting and even alimentation (Furey and Racey 2016).

On the tropical regions of America, bat caves have been studied in Puerto Rico (Rodríguez-Durán 1998), West Indies (Rodríguez-Durán 2009), Mexico (Medellín et al. 2017), Brazil (Bichuette et al. 2018), and Costa Rica (Deleva and Chaverri 2018). Recently, in Honduras, there are records by Divoll and Buck (2013) of some bat species captured in caves: *Phyllostomus hastatus* and *Balantiopteryx io* captured in Río Masca, Piedra Cocha in Cortés (northern Honduras); and *Sturnira hondurensis* (referred as *S. ludovici*) in San Juancito, Parque Nacional La Tigra in Francisco Morazán (central Honduras). After those records, nothing is known about cave-dwelling bats in Honduras recently.

Chiroptera is the order with more mammalian species in Honduras, which is represented by approximately 114 species (Mora et al. 2018). Even though there is a high diversity of bats in Honduras, information of roosting sites, ecology, natural history, and systematic studies of each species is scarce (Turcios-Casco and Medina-Fitoria 2019). Herein, we describe the importance of two caves in Ceguaca, Santa Bárbara in western Honduras based on the number of species recorded and the historical records of Santa Bárbara. Finally, we provide the first checklist of bat species of Santa Bárbara with a discussion regarding the importance of this Tropical Dry Forest that embrace two caves for bat conservation.

Methods

Study area

Three sites were studied in Ceguaca, Santa Bárbara in western Honduras (Figure 1). Site 1 in the locality of Quita Sueño (14°46'32"N, 88°12'00"W; 299 m), a crop of *Zea mays* (Poaceae) in the middle of a Tropical Dry Forest. One cave was studied in the locality of Monte Grueso (Figures 3A, 3B; 14°47'51"N, 88°12'19"W; 534 m) which

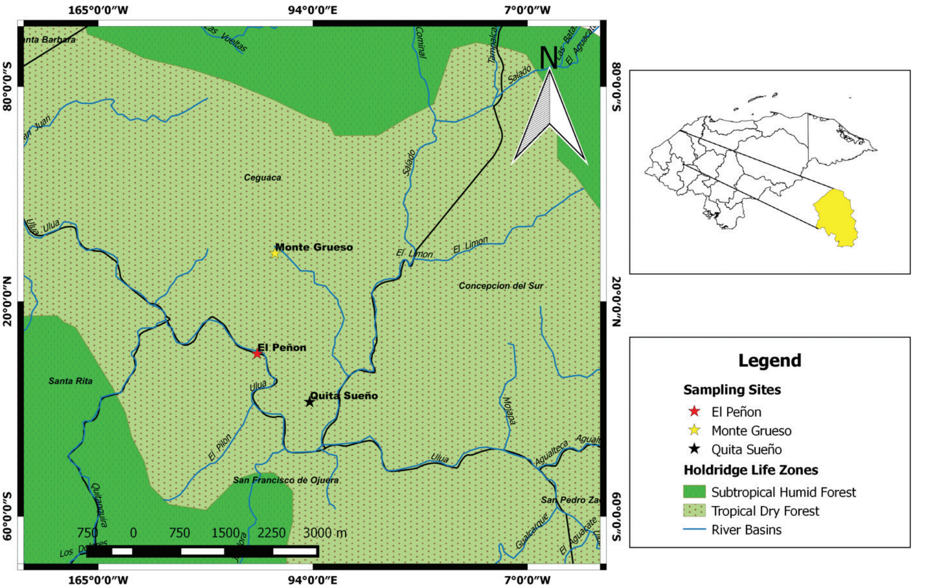

Figure 1. Study sites at Ceguaca, Santa Bárbara in western Honduras. Note that near the Tropical Dry Forest of Ceguaca there are Humid Subtropical Forest. Also, the cave of El Peñon is located near Río Ulúa, one of the longest rivers in Honduras The life zones are based on Holdridge (1987). Map organized in QGIS software, version 2.18, Author: Diego Ordoñez.

has an entrance of approximately 5 m beneath the ground and a width of 10 m; the interior of the cave is divided into several branches, but the main branch is often used by bats for going in or out of the cave. The other cave was studied in the locality of El Peñón (Figure 4; 14°46'57"N, 88°12'29"W; 249 m), which is an agglomeration of 7 caves that are located riverside of the Río Ulúa; the entrance of the main cave has a height of approximately 3 m, and five meters of width, while the others have a height between 1 to 2 m, and a width of 2 to 3 m.

In general, 54.65% of the vegetation coverage of Ceguaca are crops and grasslands, and the other percentage include vegetation of Tropical Dry Forest and Secondary Deciduous Vegetation (ICF 2015). Ceguaca have a mid-annual precipitation of 1,900 mm, mid temperatures from 20–26 °C, and a mid-annual relative humidity from 78–79.4% (IHCIT 2012; Suazo Oliva 2014). Based on Holdridge (1987), the sites studied in Ceguaca are embraced on a Tropical Dry Forest. Plants species include: *Aristolochia* (Aristolochiaceae), *Clusia* (Clusiaceae), *Crescentia* (Bignoniaceae), *Desmodium* and *Enterolobium*, (Fabaceae), *Ficus* (Moraceae), *Guazuma* (Malvaceae) *Ipomoea* (Convolvulaceae), *Mangifera* (Anacardiaceae), *Solanum* (Solanaceae); as well as crops of *Z. mays* (Poaceae) and cattle.

Sampling and bat identification

From December 2015 to May 2016 we made seven surveys, using three mist-nets (9 × 2.5 m and 14 × 2.5 m; mesh of 35 mm) that remained opened from 16:30 until

4:30 h and were checked every 20 minutes. In some occasions they remain opened for monitoring birds until 9:00, but the sampling effort was not taken in account. The positions of the mist-nets were selected according to Kunz and Kurta (1988), based on the vegetation, topography, and bodies of water.

We determined the sex of the bats according to Kunz et al. (1996), and the biological age according to Brunet-Rossinni and Wilkinson (2009). We took measurements with a vernier with spire Mitutoyo (505–675) to the closest 0.01 mm. Body mass was measured with a scale of 10 or 100 g. We followed Timm et al. (1999), Medellín et al. (2008), and Aguirre et al. (2009) for the taxonomical identification of the bats. Finally, we followed the taxonomical proposals of Velazco and Patterson (2013), Simmons (2005), and Baker et al. (2016).

The following specimens were sacrificed according to the guidelines of the use of mammals in wildlife research (Rabinowitz et al. 2000; Kingston 2016; Sikes et al. 2016), and deposited in the Zoological Collection in the Escuela Agrícola Panamericana (EAP): *Diphylla ecaudata* (CZB–2019–1; CZB–2019–7), *Glossophaga soricina* (CZB–2019–2), *Desmodus rotundus* (CZB–2019–8), *Sturnira parvidens* (CZB–2019–13), *Micronycteris schmidtorum* (CZB–2019–14), *Carollia subrufa* (CZB–2019–15), and *Dermanura phaeotis* (CZB–2019–15).

Species richness and sampling effort

We estimated species richness based on our sampling effort and the abundance of each species using the software EstimateSMac 910 with 100 randomizations to eliminate the specific order of the data (Colwell and Coddington 1994; Colwell 2013). We made accumulation curves using Chao 1, Chao 2, and ICE as species richness estimators, and the sampling effort was calculated by the time each mist-net remained open during each survey (Moreno 2001; Rex et al. 2008).

Results

Species richness and sampling effort

We accumulated 74.27 mist-net/hours in seven journeys and captured 139 bats (1.87 individuals per mist-net/hour) belonging to 23 species (0.31 species per mist-net/hour) of four families (0.05 families per mist-net/hour). The sampling effort was distributed as the following: 39% in the crops of Quita Sueño, 39% in the cave of Monte Grueso, and 22% in the cave of El Peñón. Based on Chao 1, Chao 2 and ICE (Table 2), we recorded between 41.71–64.95% of the expected species in Ceguaca, Santa Bárbara (Figure 2), 10 species in the crops of Quita Sueño, 10 in the cave of El Peñón, and 12 in the cave of Monte Grueso. We captured 17% of the individuals in the crop of Quita Sueño, 62% in the cave of Monte Grueso, and 21% in the cave of El Peñón.

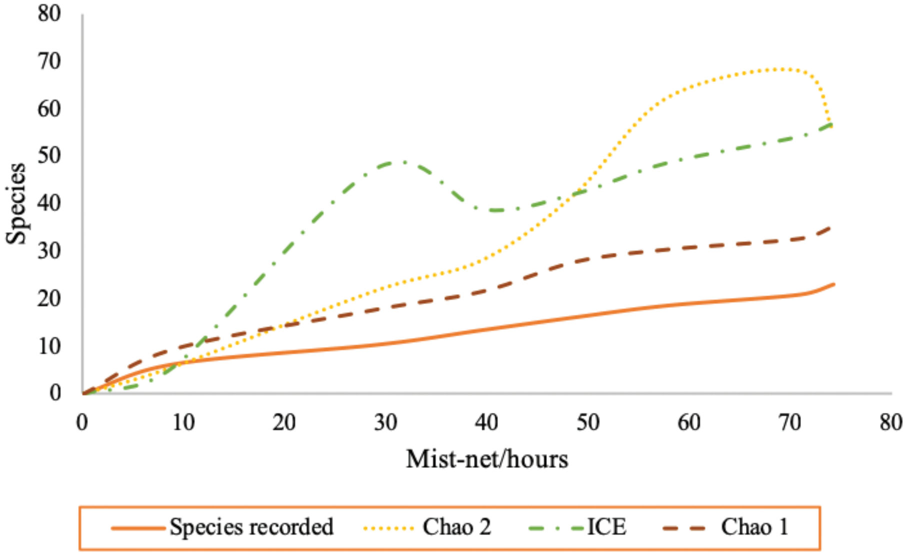

Figure 2. Species richness of bats in Ceguaca, Santa Bárbara based on the abundance of individuals captured during 2015 and 2016. Based on the estimator indexes, between 35.05 and 58.29% of bat species are still unrecorded. None of these accumulation curves reached an asymptote, which reflects that more sampling effort is needed in the area.

In general, the most common family was Phyllostomidae with 83.5% of the captures, followed by Emballonuridae (13.7%), Vespertilionidae (1.4%), and Mormoopidae (1.4%). The most common species was *Glossophaga soricina* with 28.8% of the captures, followed by *Artibeus jamaicensis* and *D. rotundus* with 27.3% of the captures and *Peropteryx macrotis* (12.2% of the captures). The most uncommon species with one capture each were: *Carollia subrufa*, *Chiroderma villosum*, *C. salvini*, *Dermanura phaeotis*, *D. tolteca*, *D. watsoni*, *Micronycteris microtis*, *M. schmidtorum*, *Myotis albescens*, *M. nigricans*, and *Sturnira parvidens* (Table 1).

Discussion

Caves in Honduras

Hernández (2015) mentioned that only two caves have approval for tourism in Honduras: Taulabé, Comayagua (central Honduras) and Talgua, Olancho (eastern Honduras), but unfortunately are altered by footpaths and lightings. In Honduras, there is a cave declared as a SICOM (abbreviation in Spanish for Site with Importance for the Conservation of Bats) by the RELCOM (abbreviation in Spanish for Latin American Network for the Conservation of Bats), and PCMH (abbreviation in Spanish for Program for the Conservation of Bats in Honduras) known as Hato Viejo, a cave in which

Figure 3. A the main entrance of the cave of Monte Grueso is a climb of approximately 5 meters drop. The inside of the cave is divided into tree branches. The photo was taken by Hefer Ávila **B** main branch of the cave, which is often used by the bats whenever they entered or exited the cave. Notice the guano in the floor of the cave of hematophagous bats (*D. ecaudata* and *D. rotundus*). The photo was taken by Manfredo Turcios Padgett.

Figure 4. Caves of El Peñon are located riverside of Río Ulúa. This agglomeration of 7 caves is located riverside of the Río Ulúa. During the surveys we found an owl (Strigidae) coming out of the cave when the activity of the bats (18:00) started, and also, we found remains of the food belonging to a presumably *Chironectes minimus* (Didelphidae), that use rocks of these caves to eat fishes. The photos were taken by Hefer Ávila.

is estimated that 35,000 bats inhabit on it, and still is the biggest aggregation of bats in a natural refuge for Honduras.

Conservation of bat caves

Most of the species recorded on this study are typically recorded on intervened habitats, with the exception of species of Phyllostominae which are considered bioindicators of

Table 1. Checklist of bat species in Santa Bárbara including historical records. Abbreviations are defined as: 1 = Davis (1970); 2 = Dolan and Carter (1979); 3 = Davis (1984); 4 = McCarthy et al. (1993); 5 = Mora et al. (2018); EP = Cave of El Peñón; MG = Cave in Monte Grueso; QS = crops in Quita Sueño. The abundance presented on this table is based on the individuals captured during this study.

No.	Family	Subfamily	Species, author and year	Site in which was captured and/or historical records	Abundance
1	Emballonuridae		*Balantiopteryx plicata* Peters, 1867	4	0
2			*Peropteryx macrotis* (Wagner, 1843)	EP	17
3			*Rhynchonycteris naso* (Wied-Neuwied, 1820)	EP (captured in the upstream of Río Ulúa)	2
4	Mormoopidae		*Pteronotus personatus* (Wagner, 1843)	EP	2
5	Phyllostomidae	Micronycterinae	*Micronycteris microtis* Miller, 1898	MG	1
6			*Micronycteris schmidtorum* Sanborn, 1935	QS, 4	1
7		Lonchorhininae	*Lonchorhina aurita* Tomes, 1863	4, 5	0
8		Phyllostominae	*Phyllostomus hastatus* (Pallas, 1767)	4	0
9		Desmodontinae	*Desmodus rotundus* (É. Geoffroy, 1810)	EP, MG, QS	19
10			*Diphylla ecaudata* Spix, 1823	MG	5
11		Glossophaginae	*Glossophaga leachii* Gray, 1844	MG	2
12			*Glossophaga soricina* (Pallas, 1766)	MG, QS	40
13		Carollinae	*Carollia castanea* H. Allen, 1890)	MG	3
14			*Carollia perspicillata* (Linnaeus, 1758)	MG	4
15			*Carollia sowelli* Baker, Solari & Hoffmann, 2002	EP, MG, QS	6
16			*Carollia subrufa* (Hahn, 1905)	EP	1
17		Stenodermatinae	*Artibeus jamaicensis* Leach, 1821	MG, QS, 1	19
18			*Artibeus lituratus* (Olfers, 1818)	MG, QS, 3	8
19			*Chiroderma salvini* Dobson, 1878	MG	1
20			*Chiroderma villosum* Peters, 1860	QS	1
21			*Dermanura phaeotis* (Miller, 1902)	QS	1
22			*Dermanura tolteca* Saussure, 1860	QS	1
23			*Dermanura watsoni* (Thomas, 1901)	MG	2
24			*Sturnira parvidens* (Goldman 1917)	QS	1
25	Natalidae		*Natalus stramineus* Gray, 1838	4	0
26	Vespertilionidae	Myotinae	*Myotis albescens* (É. Geoffroy, 1806)	EP	1
27			*Myotis nigricans* (Schinz, 1821)	EP	1
28	Molossidae		*Molossus sinaloae* J.A. Allen, 1906	2	0
	Total				**139**

well-conserved areas in the sites in which they forage and live, maintaining themselves fragile to the changes of their habitats (Emmons and Feer 1997). In accordance with Vela-Vargas and Pérez-Torres (2012), we identified that the Tropical Dry Forest in Ceguaca is undergoing deforestation, as well as in Dry Forests of Colombia, due to two main reasons: (1) fragmentation of the forest for crops of *Zea mays*, and (2) extensive livestock around remnants of Tropical Dry Forests.

If we considered the number of species reported by Mora et al. (2018), 9% of bat species of the total account for Honduras could be found in the cave of El Peñón, and 11% in the cave of Monte Grueso. We must consider that some of the species re-

Table 2. Accumulation of individuals, mist-net hours, species recorded and expected based on statistical estimators (Chao 2, ICE and Chao 1). Sample sites 1, 2 and 5 were in Quita Sueño; 3 and 4 were in Monte Grueso; 6 and 7 were in El Peñón.

Samples sites	Individuals	Mist-net/hours	Species recorded	Chao 2	ICE	Chao 1
1	19.86	9.03	6.29	5.81	5.81	9.52
2	39.71	29.03	10.33	21.82	47.62	17.85
3	59.57	39.54	13.43	28.22	38.89	21.67
4	79.43	48.715	16.11	42.16	42.22	27.92
5	99.29	57.89	18.57	62.48	48.77	30.53
6	119.14	70.97	20.86	68.02	54.33	32.81
7	139	74.27	23	55.14	57.13	35.41

corded only in the crops of Quita Sueño, could be also living in the caves of El Peñón and Monte Grueso (e.g. *Micronycteris schmidtorum*). Interestingly, if we considered the number of the species that have been recorded since 1979, between the 20.9 and 49.2% of the species expected are still unrecorded. Besides the diversity of bats that can be encountered in those caves and based on the comments of people of the community in Ceguaca, another importance of the cave of Monte Grueso is its use by pregnant females of White-tailed deer (*Odocoileus virginianus*, national mammal of Honduras) as a refuge. Remarkably, we recorded individuals of *C. perspicillata* and *G. soricina* returning at 4:00 h to the caves of Monte Grueso, as well as a record of *C. perspicillata* captured at 9:00 h returning from the crops of *Z. mays* to the Tropical Dry Forests in Quita Sueño (these records could reveal different activity patterns from the usual). Also, people from the community have encountered crystalized teeth of mammals, fragments of bones, obsidian, and artifacts such as vessels of clay with printings on them. These caves could not only represent an importance for the conservation of bats but also for knowing more about an unstudied culture of the area.

Based on Mora et al. (2018), *D. ecaudata* (Figure 7) is a species that is considered threatened in Honduras, specifically due to the human-vampire conflicts, and these caves could represent one of their principal refuges for conservation. Moreover, after the additional records of *M. schmidtorum* by McCarthy et al. (1993), there is one more record of this species in northwestern Honduras, in Cusuco National Park in Cortés by Estrada-Villegas et al. (2007). The record of this species might represent the first one after eight years. Additionally, we encountered pregnant females of *Pteronotus personatus* (May; Figure 5), *Peropteryx macrotis* (May), *Artibeus jamaicensis* (December), *Desmodus rotundus* (December), *Carollia subrufa* (May), and females in lactation period of *Myotis albescens* (May) and *Sturnira parvidens* (December). Reproductive males of *Artibeus lituratus* (December), *Desmodus rotundus* (January), *Glossophaga leachii* (January), and *G. soricina* (January), were also recorded. Importantly, these caves could represent their primary roosting site and nursery when they have newborns. Destroying and not protecting those caves could determine the decrease of the populations of bats specialized in seed dispersal, pollination (Figure 6) as well as controlling pest species (e.g. insects of crops) in Ceguaca.

Figure 5. Pregnant female of *Pteronotus personatus* in the Cave of El Peñón during the survey of May 8, 2016. The photo was taken by Hefer Ávila.

Figure 6. An adult female of *Glossophaga soricina* returning to the cave of Monte Grueso after the pollination of certain species of plants. During these surveys, we found trees with opened flowers of *Crescentia alata* (Bignoniaceae). The photo was taken by Hefer Ávila.

Figure 7. Adult female of *Diphylla ecaudata* captured in the cave of Monte Grueso when leaving the cave for searching food. The shelters of this unstudied species in Honduras in Monte Grueso could represent an important site for their conservation. The photo was taken by Hefer Ávila.

Importance of bat caves in Ceguaca

We encountered 0.30 species per mist-nets/hours on those located in the Tropical Dry Forest in Ceguaca. This result is comparably higher to other studies in different Dry Forests of America, for example: Chávez and Ceballos (2001) reported 15 species in a Dry Forest in Jalisco, México with a sampling effort of 410 mist-net/hours (0.04 species per mist-net/hours); Medina et al. (2004) reported 24 species in a Dry Forest in Rivas, Nicaragua, with a sampling effort of 5376 mist-net/hours (0.005 species per mist-net/hours); Vela-Vargas and Pérez-Torres (2012) reported 20 species in a Tropical Dry Forest in El Refugio, Colombia, with a sampling effort of 4673 mist-net/hours (0.004 species per mist-net/hours); and Ramírez Fráncel et al. (2015) recorded 10 species with a sampling effort of 7776 mist-net/hours (0.001 species per mist-net/hours) in Tolima, Colombia. Although, there is a low sampling effort in our study, the richness represented is higher in comparison to other studies with a higher sampling effort. However, the asymptote of the accumulation curves was not reached, and more effort is needed to support the high diversity estimated.

The Dry Forests of Honduras are one of the most threatened ecosystems due to the continuous fragmentation processes of habitats that are related to the use of soil in crops, cattle, and other agricultural systems. We conclude that the fragmentation of ecosystems in Ceguaca, is due to the following reasons: extensive cattle raising, replacement of native plants with extensions of grasslands for crops, and human-vampire conflicts (*D. rotundus*) which lead to intentional fires in the caves caused by the demonized concept of bats in the area, for example, the caves of El Peñón have been set on fire at least three times in the last five years. This study represents the first preliminary inventory of those caves on that Tropical Dry Forest. Thus, we strongly recommend the continuity of this study for a longer period of time, including wet and dry seasons, with a greater sampling effort. Furthermore, other methodologies to study bats must be included: harp nets, pulley nets, and vocalization recording. Finally, with this baseline, we hope to encourage the PCMH to declare these diverse caves as AICOMS (abbreviation in Spanish for Areas with Importance for the Conservation of Bats) for their conservation.

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