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Source: Tropical Conservation Science, 9(4)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/194008291667003

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Research Article

Tropical Conservation Science
October-December 2016: 1–16
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DOI: 10.1177/1940082916670003
trc.sagepub.com

Species Diversity, Distribution, and Conservation Status in a Mesoamerican Region: Amphibians of the Uxpanapa-Chimalapas Region, Mexico

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Abstract

The Uxpanapa-Chimalapas region, with one of the most extensive and best preserved tropical forest areas in Mexico, is undergoing major anthropogenic changes, and only some portions of the territory are under the protection of local communities. Although the biodiversity of the region is known to be high, no study has yet analyzed the diversity of amphibian species in the region or contributed to valuing the region in a context of amphibian conservation. Based on a review of databases and the existing scientific literature, as well as our own fieldwork, in this study, we analyze the amphibian species richness, species composition, their spatial distribution, and their conservation status in the Uxpanapa-Chimalapas region. Additionally, we compare this information with the available data for seven other tropical regions in central-northern Mesoamerica. The amphibian fauna recorded at the study region comprises 51 species, which makes it the richest tropical region in amphibian species in central-northern Mesoamerica and Mexico. Among the regions compared, this one stands out as the one with the most distinctive composition of amphibian species, sharing on average only 35% of its species with the other regions. However, it is also the region with the highest number of threatened species since one third of its species are in higher extinction risk categories. These characteristics turn the Uxpanapa-Chimalapas into a high-priority region for both Mexico and Mesoamerica, and a regional conservation plan is necessary for the immediate protection of areas where the forest is being replaced and to promote or to support community protected areas.

Keywords

amphibian fauna, species richness, species composition, conservation value

Introduction

Of all terrestrial environments, tropical forests have the greatest share of the planet's biodiversity (Gentry, 1992). However, the tropical region is facing a great loss of forests, and the current trend in forest loss is increasing. It is estimated that from 2000 to 2012, forest loss increased 2,101 km^2/year (Hansen et al., 2013). A sizable part of Mesoamerica is still forested (~200,000 km^2; FAO, 2011), but the extent of their humid forests continues to decline. In Mexico and Guatemala combined, the loss of humid forest during the first decade of this century was over 15,000 km^2 (Aide et al., 2013). The area of tropical forests in Mesoamerica is currently only 20% of what it once was (Harvey et al., 2008). Given the loss of forests in the region and the high number of species that inhabit them—a high number of which are endemic—Mesoamerica is considered a biodiversity hotspot and a conservation priority (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000).

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Received 25 May 2016; Revised 19 August 2016; Accepted 29 August 2016

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Located in the Isthmus of Tehuantepec, Mexico, in central-northern Mesoamerica, the Uxpanapa-Chimalapas region (UC) features a sizeable area of several vegetation types defined as tropical forests, according to the classification proposed by Olson et al. (2001). Along with the Lacandona and Calakmul, the UC is one of the best preserved and largest regions of tropical forest in Mexico (Peterson et al., 2003). It is part of the Priority Conservation Area, known as La Selva Zoque-La Sepultura characterized by a high diversity of ecosystems and a large number of species, many of which are endemic or threatened (Arriaga, Espinoza, Aguilar, Martínez, Gómez, & Loa, 2000). Among the several threats to its biodiversity, this area faces the following: reduction of forest area owing to human activity, pressure on key species, and unsuitable land management practices (Arriaga et al., 2000; Arriaga-Cabrera, Aguilar, & Espinoza, 2009), and only the eastern part of the La Selva Zoque-La Sepultura is protected by the federal government because it happens to lie within the La Sepultura and El Ocote Biosphere Reserves in the state of Chiapas. The remaining area of forest in Oaxaca and southern Veracruz (i.e., the UC region) is devoid of municipal, state, or federal protection (Ochoa-Ochoa, Urbina-Cardona, Vázquez, Flores-Villela, & Bezaury-Creel, 2009). However, community-protected areas do exist in the Chimalapas of Oaxaca, where the local inhabitants have taken to themselves to preserve the forest, and it is thanks to their initiatives that a large area of forest still stands in the region (Anaya & Álvarez, 1994; Martínez-Pacheco, 2012). Some of these community-protected areas have obtained certification by the federal government (Anaya & Álvarez, 1994; INECC, 2011; Martínez-Pacheco, 2012; Ochoa-Ochoa et al., 2009). In contrast, in the Uxpanapa portion (in Veracruz), there are no protected areas whatsoever, and the forest as a result has been severely fragmented and forest cover reduced to about 20% of the total area (Arriaga et al., 2000). Thus, despite being part of the same region, the Uxpanapa and Chimalapas portions have experienced different land-use change trends. The UC region was originally covered by approximately 600,000 ha of different forest types, including evergreen tropical forest, deciduous tropical forest, tropical montane cloud forest, and pine-oak forest (De Teresa, 2000). Today, forests are reduced to one third of their size due to land-use changes associated to agriculture, livestock production, agroforestry, and urban expansion (Asbjornsen, Velázquez-Rosas, García-Soriano, & Gallardo-Hernández, 2005; Ewell & Polleman, 1980; Navarro-Sigüenza et al., 2014).

The UC region is renowned for its high diversity of vertebrate species. It is home to at least 464 species of birds (Peterson et al., 2003) of the 1,107 species recorded in Mexico (Navarro-Sigüenza et al., 2014) and 149 species of mammals (Lira-Torres, Galindo-Leal, & Briones-Salas, 2012) of the 564 recorded in the country (Sánchez-Cordero et al., 2014). However, the total number of species of amphibians in the region has not been recorded, and their species composition remains unknown.

Worldwide, amphibians are the most threatened group of terrestrial vertebrates, with an estimated one in three species facing a high risk of extinction (Stuart et al., 2008). In Mexico, a little more than half of the amphibian species are in some risk of extinction category, according to the International Union for the Conservation of Nature (IUCN, 2015) and the Mexican Ministry of the Environment (SEMARNAT, 2010). Therefore, it is urgent to identify all the areas that still have natural vegetation and those inhabited by a high number of amphibian species, endangered species, or species assemblages with a distinctive species composition, in order to construct a well-founded case for their conservation.

Since the middle of the last century, there have been herpetological expeditions to specific places of the UC region (Aguilar-López, 2010; Carmona-Torres, 2013; Duellman, 1960; Lynch & Wake, 1989; Navarro-Sigüenza & Meave del Castillo, 1998; Taylor, 1951). However, extensive areas still remain unchartered or there is very little information about them. Given the variety of tropical forests that cover them, as well as their geographic location and environmental heterogeneity, it is possible to think that amphibian diversity in these areas may be quite high, and a significant portion of amphibian species may be under a high risk of extinction. Its characteristics suggest that this region may have notable conservation value at the local, national, and regional levels.

The aim of this study was to evaluate amphibian diversity in the UC region. Through database searches, a revision of the specialized literature and fieldwork, here, we provide a comprehensive amphibian survey of the UC region, assessing species richness, species composition and distribution, and the conservation status of the amphibian species. Additionally, we compared this information with other tropical regions on the northern end of Mesoamerica. We expect that the results of this study will contribute to establish the relevance of the UC for amphibian conservation, a region with high biological diversity, which still preserves large areas of tropical forest but now is facing a continuous reduction of its forests.

Methods

Study Area

Mountains and hills dominate the UC region (Ortiz-Pérez, Hernández-Santana, & Figueroa, 2004; Wendt, 1987) creating a broad mountain range with an elevation between 100 and 2,300 m a.s.l. The region includes several original vegetation types (following the classification

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systems proposed by Beard, 1955; Leopold, 1950) like evergreen tropical forest (100–1,000 m a.s.l.), semievergreen tropical forest (600–1,200 m a.s.l.), deciduous tropical forest (100–600 m a.s.l.), cloud forest (1,100–1,800 m a.s.l.), and pine-oak forest (1,800–2,300 m a.s.l.). Mean annual temperature ranges from 12°C to 23°C and mean annual rainfall values are within 800 to 4,400 mm (Beard, 1955; Leopold, 1950; Ortiz-Pérez et al., 2004; Vidal-Zepeda, 1990; Wendt, 1987).

Areal delimitation was carried out using the polygon set by Arriaga et al. (2000) for the Selva Zoque-La Sepultura Priority Conservation Area, but in this study, it was limited to the UC region lying within the states of Oaxaca and Veracruz. This was done for two reasons: First, the UC has a well-defined vegetation continuum that remains separate from the part corresponding to the state of Chiapas (Figure 1); second, unlike the latter, which comprises the Protected Natural Areas of La Sepultura and El Ocote, this region has no state- or federal-protected areas, though some protection exists by local communities (Ochoa-Ochoa et al., 2009).

Data Collection

The consultation of databases and the specialized literature was complemented with firsthand data obtained through fieldwork. The databases consulted were the National Information System on Biodiversity by the National Commission for the Knowledge and Use of Biodiversity (Conabio), the Global Biodiversity Information Facility (GBIF; www.gbif.org), and the VertNet project database (www.vertnet.org). Consultation of these databases took place between January and June 2015. The scientific literature reviewed included published studies containing information on amphibians at the study region (Aguilar-López, 2010; Aguilar-López, Pineda, & García-Vázquez, 2010; Canseco-Márquez & Ramírez-González, 2015; Carmona-Torres, 2013; Luría-Manzano, Aguilar-López, Canseco-Márquez, & Gutiérrez-Mayén, 2014; Navarro-Sigüenza & Meave del Castillo, 1998).

Fieldwork was carried out in 2013 and 2014 in Arroyo Zarco, Uxpanapa (17° 11′N, 94° 28′W); San Francisco La Paz, Oaxaca (17° 5′N, 94° 8′W); and La Esmeralda, Oaxaca (17° 9′N, 94° 46′W). Samplings were conducted in areas with evergreen tropical forest and semievergreen tropical forest using the visual and auditory encounter survey techniques (Crump & Scott, 1994), during crepuscular hours and at night. The cumulative sampling effort involved 3,250 person-hours.

Records obtained from these three sources of information were crosschecked to avoid duplication, given that the databases consulted might have information about the same specimens. Only those records with precise geographic coordinates or detailed information about the collection and observation site were included. Once all the

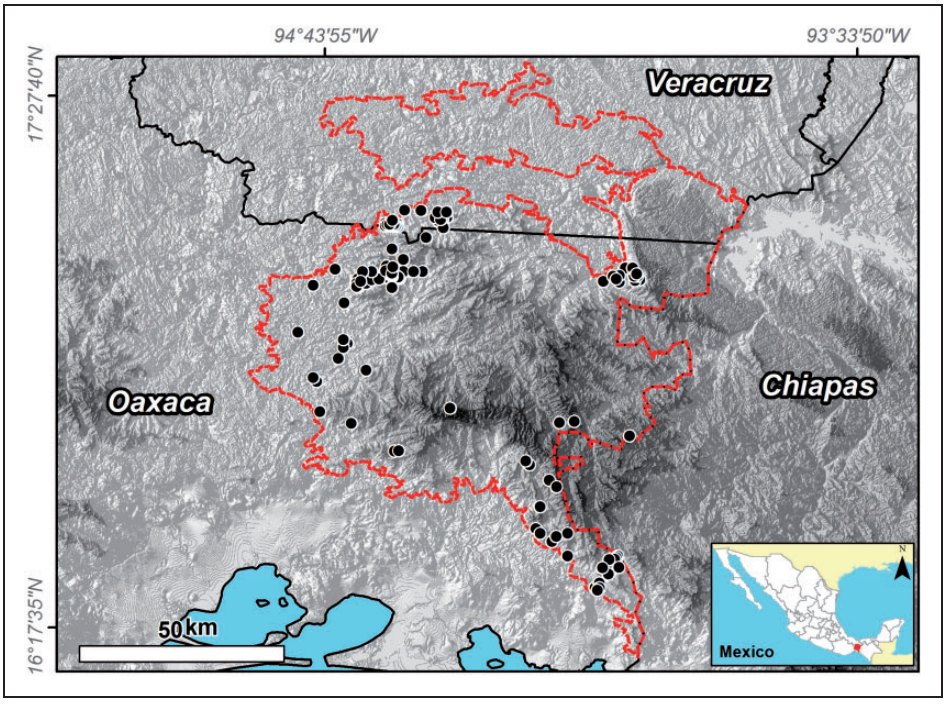

Figure 1. Location of the Uxpanapa-Chimalapas region. Red dotted line denotes the limits of the study area, black line denotes the states limits, and black circles denote the spatial distribution of amphibian records in the region.

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records had been checked, a general database was compiled.

Information about amphibian richness and composition was obtained from the following seven tropical regions to compare with our data for the study region: (a) Los Tuxtlas in Veracruz (Pérez-Higareda, Vogt, & Flores-Villela, 1987; López-Luna, in press), (b), Las Choapas municipality in Veracruz (Aguilar-López & Canseco-Márquez, 2006), (c) El Ocote Biosphere Reserve in Chiapas (Espinoza et al., 1999; Martínez & Muñoz, 1998; Muñoz-Alonso, 2010; Muñoz, Martínez-Castellanos, & Hernández-Martínez, 1996; Reynoso, Paredes-León, & González-Hernández, 2011), (d) La Lacandona in Chiapas (Hernández-Ordóñez et al., 2014; Hernández-Ordoñez et al., 2015; Muñoz-Alonso, 2010; Ochoa-Ochoa & Whittaker, 2014; Reynoso et al., 2011), (e) the Calakmul Biosphere Reserve in Campeche (Calderón-Mandujano, Cedeño-Vázquez, & Pozo, 2003; Cedeño-Vázquez, Calderón-Mandujano, & Pozo, 2006; Lee, 1996), (f) the Sian Ka'an Biosphere Reserve in Quintana Roo (Calderón-Mandujano & Moratembre, 2004; Calderón-Mandujano, Bahena-Basave, & Calmé, 2008; Lee, 1996), and (g) the Mayan Forest in Guatemala (Campbell, 1998; Lee, 1996). The data set was taxonomically standardized and updated following the online reference at the Amphibian Species of the World 6.0 website (Frost, 2015), and the identity of some species reported in the above-mentioned studies were updated based on Campbell and Savage (2000), Zaldivar-Riverón, León-Regagnon, and Nieto-Montes de Oca (2004), Streicher et al. (2014), and Duellman, Marion, and Hedges (2016).

Data Processing and Analysis

To identify the spatial distribution of amphibians in the study region, their georeferenced records were projected onto the polygon proposed by Arriaga et al. (2000) using ArcGIS software, version 10.0 (ESRI, 2010). To determine the distribution of the species that inhabit the UC region, we initially consulted the Amphibian Species of the World 6.0 website (Frost, 2015), which offers the spatial distribution of the amphibian species worldwide. Then, using the compiled data, we defined four distribution categories: Widely distributed species (WD), species restricted to Mesoamerica (MA), species restricted to northern Mesoamerica (MAMx), and species restricted to the Uxpanapa-Chimalapas region (UC). Our delimitation for Mesoamerica follows the one used by Campbell (1999), and to determine our "Under Risk of Extinction" species category, we consulted the list of Species at Risk published by the Mexican Ministry of the Environment, updated in 2015 (SEMARNAT, 2010) and the Red List of the IUCN (2015). The categories considered in the former source were "Subject to Special Protection" (Pr; *Sujetas a Protección Especial*), "Threatened" (A; *Amenazada*), and "Endangered" (P; *En Peligro de Extinción*). As for the latter source, the categories were "Vulnerable," "Endangered," and "Critically Endangered." As for the Mayan Forest in Guatemala, we could avail of only the latter source, since the area is not covered by the Semarnat survey.

Regional comparison of the composition of the amphibian fauna was carried out using Jaccard's Similarity Index (Magurran, 2004), which works with presence–absence data and is expressed as

$$C_j = \frac{a}{a+b+c}$$

where a is the number of species shared between the two sites under comparison, b is the number of species exclusive to the first site, and c is the number of species exclusive to the second site. The index ranges from zero to one, where zero means no species are shared between the sites being compared and one means that all species are found in both of the sites. We plotted a dendrogram using PAST software version 2.17 c (Hammer, Harper, & Ryan, 2001) to represent the relationship between sites in terms of the similarity of their species composition, according to the Jaccard Index.

Results

Species Richness, Distribution, and Conservation Status

A total of 51 amphibian species belonging to 25 genera and 11 families has been recorded at the UC region. Of these, 44 are anurans, 6 are salamanders, and 1 is a caecilian (Appendix A). The Hylidae family is the best represented, with 19 species, followed by the Craugastoridae, with 8 species, and the Bufonidae and Plethodontidae, with 6 species each. The families with the fewest species in the region are Centrolenidae, Eleutherodactylidae, Rinophrynidae, and Dermophidae, each with one species.

Of the 51 species of amphibians present in the UC, 49 had been recorded in the databases or in the specialized literature. During our fieldwork (2013–2014), we recorded 29 species, of which two were new records for the region for the first time and reported in this study: *Exerodonta bivocata* and *Agalychnis moreletii*.

Amphibians have been recorded mostly at the periphery of the study region, notably its northeastern portion. In the northwest, northeast, and west, collection sites were located below 1,000 m a.s.l., while in the southeast, most of them were between 1,000 and 2,000 m a.s.l. In the northwestern, central, and northern portions of the region, amphibians have not been recorded (Figure 1).

The distribution of the 51 species recorded in the UC region was as follows: 4 species (8%) were exclusive to the

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Table 1. Taxonomic Composition of Amphibian Fauna Recorded in the Uxpanapa-Chimalapas Region and Seven Other Regions in Northern Mesoamerica.

Tropical region	Orders	Families	Genera	Anurans	Salamanders	Caecilians	Species
Uxpanapa-Chimalapas	3	11	25	44	6	1	51
Mayan Forest	3	12	24	37	7	2	46
Lacandona	3	12	26	36	4	2	42
Los Tuxtlas	3	11	25	34	6	1	41
El Ocote	3	8	17	24	5	1	30
Las Choapas	3	8	14	20	2	1	23
Calakmul	2	7	15	18	2	0	20
Sian Ka'an	2	8	16	18	2	0	20

UC region, 9 species (18%) were found in the northern part of Mesoamerica that corresponds to Mexico, 25 species (49%) were restricted to Mesoamerica, and 13 species (25%) had a wide distribution, extending beyond Mesoamerica (Appendix A).

As for the species at risk of extinction, one third of the amphibian species recorded in the UC study region fell into a high-risk category. According to the Mexican Ministry of the Environment, 18 species are threatened: 15 of them are in the Subject to Special Protection category (Pr) and 3 are in the Threatened category (A). According to the IUCN's Red List, 17 species are threatened: seven are Vulnerable, 6 are Endangered, and 4 are Critically Endangered (Appendix A).

Comparing the Richness, Composition, and Conservation Status of the Amphibian Species of the UC With That of Other Tropical Regions

In terms of species richness, the UC, with 51 species of amphibians, occupies the first place among the tropical regions considered in this study (Table 1). The Mayan Forest, in Guatemala, is in second place, with 46 species; La Lacandona, in Mexico, in third place, with 42 species, followed by Los Tuxtlas (41 species), El Ocote (30 species), and Las Choapas (23 species). The Calakmul and Sian Ka'an Biosphere Reserves occupy the last place, with 20 species each.

The similarity analysis reveals that the UC region was least similar to the other seven regions (Figure 2). La Lacandona is the region that is most similar to the UC in species composition, sharing 45% of its species (Jaccard Index = 0.45), and Los Tuxtlas is the second most similar region in species composition (43% shared). With regard to the regions closest to the UC, Las Choapas, and El Ocote, the similarity in species composition is 37% in both cases. The least similar to the UC is Sian Ka'an, with only 22% of their species in common. The regions that are most similar in species composition are Calakmul and Sian Ka'an, which share 82% of their species, followed by La Lacandona and the Mayan Forest in Guatemala, with 66% of their species in common (Appendix B).

Among the regions compared, the UC has the highest number of threatened species, followed by Los Tuxtlas (with 15 and 14 spp. at risk of extinction, according to NOM-059 and the IUCN, respectively). The only regions that do not have any threatened species according to the IUCN's Red List are Sian Ka'an and Calakmul (Figures 3 and 4).

Discussion

The results of our study show that the UC region is the tropical region with the largest number of recorded species of amphibians in central-northern Mesoamerica, and the one with the most distinct species composition. Furthermore, our list of UC species reveals that one in every three species in the region is threatened, three of every four species are endemic to Mesoamerica, and almost 10% of all the species are exclusive of the UC region and neighboring areas. This, along with its high species diversity, the number of species with a limited distribution and the number of threatened species that inhabit it, makes the UC a highly relevant region for the amphibians of Mexico and Mesoamerica in general.

With 51 species of amphibians, the UC region stands out as the richest tropical forest region in Mexico in terms of amphibians, even richer than La Lacandona (42 species) and Los Tuxtlas (41 species; Hernández-Ordóñez et al., 2014). The richness of the UC is equivalent to 13% of the 376 amphibian species recorded in Mexico (Parra-Olea, Flores-Villela, & Mendoza-Arellana, 2014), 42.5% of the 120 amphibian species recorded for southeastern Mexico (Johnson, Mata-Silva, & Ramírez-Bautista, 2010), and 6.4% of the 796 species recorded in Mesoamerica (Mesoamerican Herpetology, 2016). In addition to its high species richness, the UC region is noteworthy for its species composition. The fact that Lacandona and Los Tuxtlas regions were most similar

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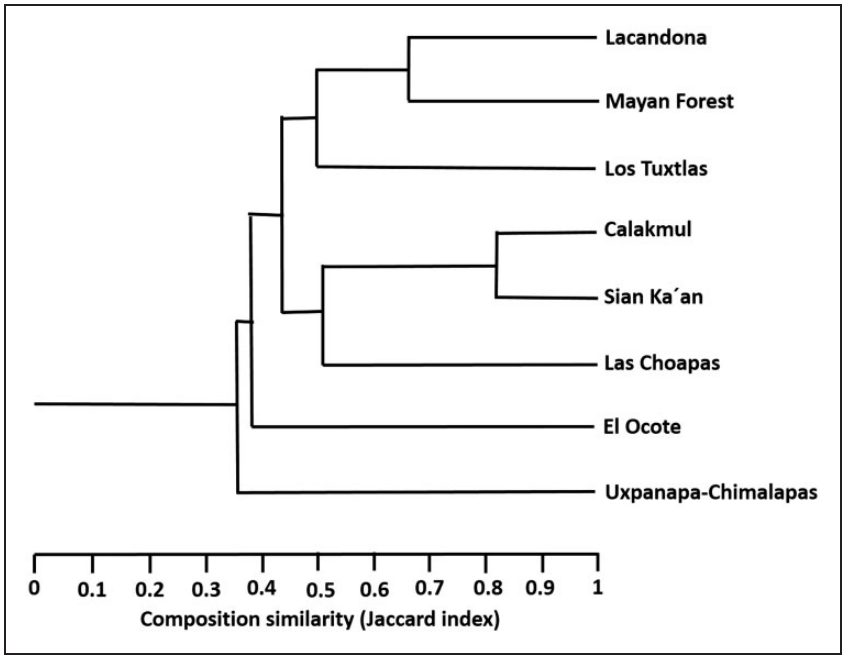

Figure 2. Similarity in amphibian species composition for different tropical areas in northern Mesoamerica.

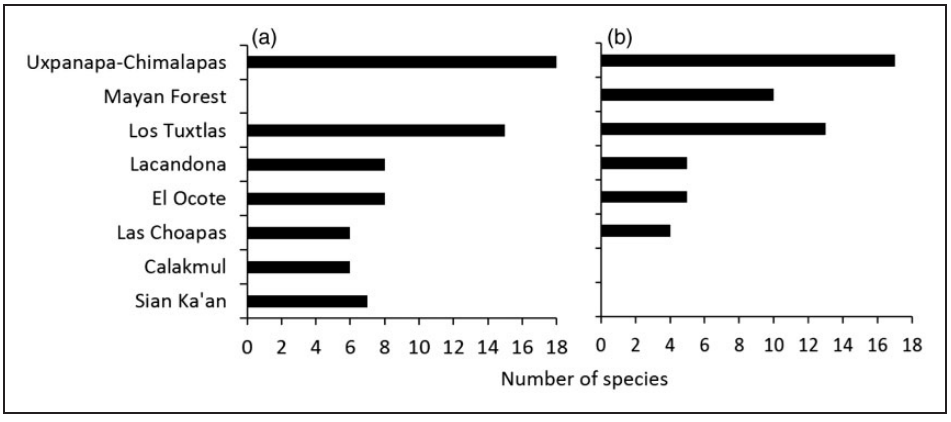

Figure 3. Number of amphibian species in threatened categories according to (a) NOM-059-SEMARNAT-2010 and (b) the IUCN's Red List for eight tropical regions in northern Mesoamerica.

in species composition to the UC region indicates that the UC shares the highest number of amphibian species with these two regions (29 and 28 species, respectively), in which species richness is also high. Even though El Ocote and Las Choapas are the closest regions to UC, species composition was less similar because in both of these regions, the number of species is lower (30 and 23 species, respectively) and the number of shared species is also lower (22 and 20 species, respectively).

At the mesoscale, species diversity is determined by ecological and historical factors, (Ricklefs & Schluter, 1993) and in the case of the UC, the role of these factors seems to be determinant in its high species richness and composition of the amphibian fauna. The orography of the region is notably complex, with lowlands toward the Gulf of Mexico and Pacific slopes, and a series of mountain ranges of intermediate elevation such as the Sierra Atravesada, the Espinazo del Diablo, and the Sierra de Tres Picos (Ortiz-Pérez et al., 2004; Wendt, 1987), with altitudes from 100 to 2,300 m a.s.l. There is a 15°C variation in temperature between the two ends of the altitude gradient and a 3,200 mm variation in annual rainfall among different sites (Beard, 1955). Additionally, there are at least seven vegetation types in the region (Arriaga et al., 2000) that, along with the complex orography and variations in elevation, temperature, and rainfall, creates a variety of habitats for a large variety of amphibians with different ecophysiological requirements.

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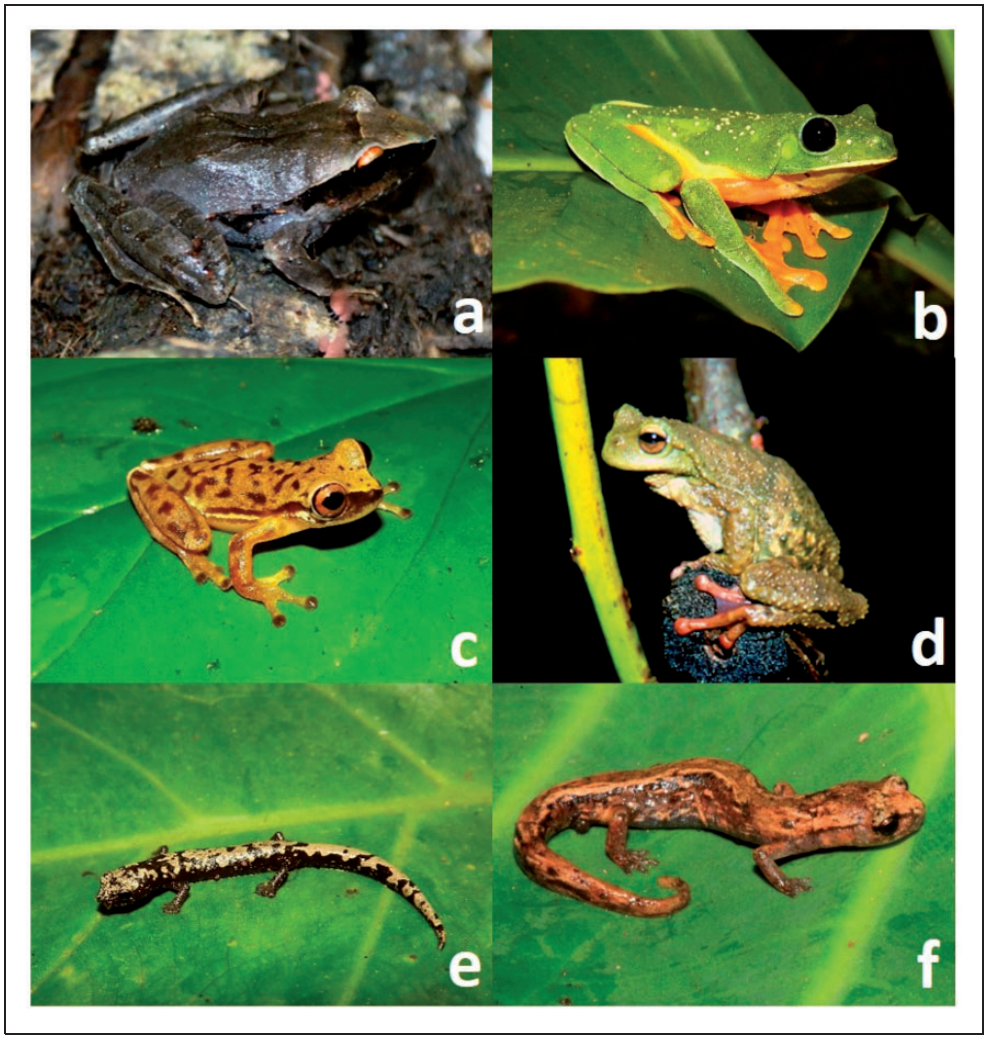

Figure 4. Amphibian species that are critically endangered or whose distribution is restricted to the Uxpanapa-Chimalapas region (see text). a= *Craugastor lineatus*, b= *Agalychnis moreletii*, c= *Exerodonta bivocata*, d=*Plectrohyla hartwegi*, e= *Bolitoglossa veracrucis*, and f = *Ixalotriton parvus*.

Of the regions compared, the UC varies the most in elevation and is among those with a great diversity of vegetation types; a diversity that results from the orography and the biogeographic location, in which different floral provinces converge.

In a historical context, the spatial location of the UC region suggests that at least three biogeographical provinces have influenced its species composition (Morrone, 2005). This appears to be the case with *Incilius marmoreus*, *Exerodonta sumichrasti* (Mexican Pacific Coast), *Eleutherodactylus leprus*, *Lithobates brownorum* (Gulf of Mexico), *Duellmanohyla chamulae*, and *Exerodonta bivocata* (Mountains of Chiapas). The Isthmus of Tehuantepec has acted as a biogeographic barrier affecting the phylogeographic patterns of different biological groups, including amphibians (Mulcahy, Morrill, & Mendelson, 2006; Rovito & Parra-Olea, 2016; Rovito, Parra-Olea, Vázquez-Almazán, Luna-Reyes, & Wake, 2012). Also, during the Pleistocene climate, conditions may have caused species diversification in different biological groups (Lira-Torres et al., 2012; Rodríguez-Gómez, Gutiérrez-Rodríguez, & Ornelas, 2013), as happened with amphibian species such as *Craugastor silvicola*, *Ixalotriton parvus, Bolitoglossa veracrucis*, and *Ptychohyla* sp. nov., whose distribution is limited to the region, and *Bolitoglossa veracrucis*, whose distribution is limited to the region and neighboring areas.

The large number of species and the outstanding number of threatened species that inhabit the UC region attest to its conservation value along with the other regions studied. It is worth mentioning that seven of the threatened species in the region (including those with a dubious risk category due to insufficient data) have not been reported at any protected natural

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area: *Craugastor berkenbuschii* (see Santos-Barrera & Flores-Villela, 2004), *Craugastor silvicola* (see Santos-Barrera & Canseco-Márquez, 2004), *Duellmanohyla chamulae* (see Santos-Barrera & Muñoz-Alonso, 2004), *Exerodonta bivocata* (see Santos-Barrera, 2004), *Exerodonta chimalapa* (see Muñoz-Alonso & Canseco-Márquez, 2004), *Bolitoglossa veracrucis* (see Parra-Olea, Wake, & Papenfuss, 2008), and *Ixalotriton parvus* (see Parra-Olea, Wake, & Papenfuss, 2008). This means that if the UC region were to be declared a protected area and conservation measures were to be implemented, these species would be protected, in addition to other threatened species of amphibians in other protected areas, as well as other highly diverse biological groups in the region, such as birds and mammals (Lira-Torres et al., 2012; Navarro-Singuenza, Márquez, & Monrroy, 2008; Peterson et al., 2003).

The distribution within the UC region of the sampling sites where amphibians have been recorded indicates that extensive areas, such as the mountainous central portion of the region, remain unchartered or are poorly studied. This suggests that the number of species could be even larger than reported here. The fact that during our fieldwork we recorded two so far unrecorded species (*Exerodonta bivocata* and *Agalychnis moreletii*) in three locations and their surroundings may attest to this view. In any case, this study is the first to report *Exerodonta bivocata* in the state of Veracruz, a species whose known distribution was limited to the highlands of central Chiapas (Duellman, 2001). In the case of *Agalychnis moreletii*, our findings fill a gap in the knowledge about its spatial distribution, since the closest locations where it had been collected are in central Oaxaca and central Chiapas (Duellman, 2001). Finally, according to the databases we consulted, five amphibian species have been recording at the surroundings of the region (*Incilius marmoreus*, *Dendropsophus ebraccatus*, *Dendropsophus robertmertensi*, *Tlalocohyla loquax*, *and Trachycephalus typhonius*), and if the presence of these species is confirmed later within the region, the number of species in the UC region would reach 56.

Further study of amphibians in the UC region is necessary to document their distribution patterns, abundance, and species diversity, not only in the areas with tropical forest but also in the landscapes modified by human action, now covering a significant part of the region. It is important to identify those areas with potential to preserve (albeit partially) the species diversity of the region, such as rubber tree plantations and secondary forests (Aguilar-López, 2010).

Implications for Conservation

We would like to end by emphasizing the urgency of protecting the UC region and put an end to an omission in the conservation of the biological diversity of Mesoamerica; an omission that occurs in other parts of the world (Rodrigues et al., 2001). A regional conservation plan is in order for the immediate protection of areas where the forest is being replaced (mainly in the Uxpanapa portion) and the promotion of social initiatives for forest preservation in rural protected areas (in the Chimalapas portion). Such plan could also include agricultural landscapes (in both protected and modified habitats; Harvey et al., 2008; Melo, Arroyo-Rodríguez, Fahrig, Martínez-Ramos, & Tabarelli, 2013) in an effort to maintain amphibian diversity and other biological groups in the region. A good part of the study region includes the Mesoamerican Biological Corridor, an international initiative that seeks to maintain biological diversity, decrease habitat fragmentation, and improve the connectivity of the landscape and of the ecosystems in Mesoamerica, in addition to promoting sustainable social and economic development (Miller, Chang, & Johnson, 2001). In this context, the protection of UC fits in perfectly with the approach and purposes of the Mesoamerican Biological Corridor.

Appendix A. List of Amphibians Species Recorded in the Uxpanapa-Chimalapas Region, Their Distribution Range, and Conservation Status.

Species recorded in the Uxpanapa-Chimalapas region	Common name	Altitudinal range (m a.s.l.)	Forest type	Breadth of distribution	Conservation status	
					NOM	IUCN
CLASS AMPHIBIA						
Order Gymnophiona						
Family Dermophiidae						
Dermophis mexicanus[a]	Mexican caecilian	80–170	ETF	MA	Pr	VU
Order Caudata						
Family Plethodontidae						
Bolitoglossa alberchi[a]	Alberch's Salamander	80–730	ETF	MAMx		LC

(continued)

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Appendix A. Continued

Species recorded in the Uxpanapa-Chimalapas region	Common name	Altitudinal range (m a.s.l.)	Forest type	Breadth of distribution	Conservation status	
					NOM	IUCN
Bolitoglossa mexicana[a]	Mexican Mushroom-tonged Salamander	112	ETF	MA	Pr	LC
Bolitoglossa occidentalis	Southern Banana Salamander	580–1600	POF	MA	Pr	LC
Bolitoglossa rufescens[a]	Northern Banana Salamander	90–579	ETF	MA	Pr	LC
Bolitoglossa veracrucis[a]	Veracruz Salamander	121–730	ETF	UC	Pr	EN
Ixalotriton parvus	Dawrf False Brook Salamander	1550	POF, CF	UC	A	CR
Order Anura						
Family Bufonidae						
Incilius canaliferus	Dwarf Toad	191	DTF	MA		LC
Incilius macrocristatus[a]	Huge-crested Toad	95–800	ETF	MA		VU
Incilius marmoreus	Marbled Toad	200	ETF	MAMx		LC
Incilius tutelarius	Chimalapas Toad	1370	POF	MA		EN
Incilius valliceps[a]	Southern Gulf Coast Toad	70–457	ETF	MA		LC
Rhinella marina[a]	Marine Toad	180–914	ETF	WD		LC
Family Centrolenidae						
Hyalinobatrachium fleischmanni[a]	Fleischmann's Glass Frog	198–800	ETF	WD		LC
Family Craugastoridae						
Craugastor alfredi[a]	Alfred's Rainfrog	106–214	ETF	MA		VU
Craugastor berkenbuschii[a]	Berkenbusch's Stream Frog	198–335	ETF	MAMx	A	NT
Craugastor laticeps	Broad-headed Rainfrog	600–950	ETF	MA	Pr	NT
Craugastor lineatus	Montane Robber Frog	770	ETF	MA	Pr	CR
Craugastor loki[a]	Common Leaf-litter Frog	60–1550	ETF, CF	MA		LC
Craugastor pygmaeus[a]	Pigmy Robber Frog	150–472	ETF	MA		VU
Craugastor rugulosus	Rugulose Rainfrog	300	ETF	MAMx		LC
Craugastor silvicola	Forest Robber Frog	1493	CF	UC	Pr	EN
Family Eleutherodactylidae						
Eleutherodactylus leprus[a]	Leprus Chirping Frog	228–396	ETF	MA		VU
Family Hylidae						
Agalychnis callidryas[a]	Red-eye Treefrog	112	ETF	WD		LC
Agalychnis moreletii[a1]	Morelet's Leaf Frog	391	ETF	MA		CR
Anotheca spinosa	Coronated Treefrog	298	ETF	MA		LC
Charadrahyla chaneque	Fairy Treefrog	335–396	ETF, CF	MAMx	Pr	EN
Dendropsophus microcephalus[a]	Yellow Treefrog	71	ETF	WD		LC
Duellmanohyla chamulae[a]	Chamula Mountain Brook Frog	198–391	ETF	MAMx	Pr	EN
Duellmanohyla schmidtorum	Schmidt's Mountain Brook Frog	255	POF	MA	Pr	VU
Exerodonta bivocata[a2]	Chiapan Highlands Treefrog	302–391	ETF	MAMx		DD
Exerodonta chimalapa	Chimalapa Treefrog	1325–1370	POF	MAMx		EN
Exerodonta sumichrasti	Sumichrast's Treefrog	280–1050	DTF	MAMx		LC
Plectrohyla hartwegi	Hartweg's Spikethumb Frog	2250	CF	MA	Pr	CR

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Appendix A. Continued

Species recorded in the Uxpanapa-Chimalapas region	Common name	Altitudinal range (m a.s.l.)	Forest type	Breadth of distribution	Conservation status	
					NOM	IUCN
Plectrohyla matudai	Matuda's Spikethumb Frog	1171	ETF, CF	MA		VU
Ptychohyla euthysanota	Cloud Forest Stream Frog	1171	CF	MA		NT
Ptychohyla sp. nov. [a]		237–273	ETF	UC		
Scinax staufferi[a]	Stauffer's Long-nosed Treefrog	212	ETF	WD		LC
Smilisca baudinii[a]	Mexican Treefrog	150–600	ETF	WD		LC
Smilisca cyanosticta[a]	Blue-spotted Mexican Treefrog	182–609	ETF	MA		NT
Tlalocohyla picta[a]	Painted Treefrog	270	ETF	MA		LC
Tlalochohyla smithii	Dwarf Mexican Treefrog	251	DTF	WD		LC
Family Leptodactylidae						
Engystomops pustulosus	Túngara Frog	100–200	DTF	WD		LC
Leptodactylus fragilis[a]	White-lipped Frog	189–235	ETF	WD		LC
Leptodactylus melanonotus[a]	Sabinal Frog	106–396	ETF	WD		LC
Family Microhylidae						
Hypopachus ustus[a]	Two spade Narrowmouth Toad	90–114	ETF	MA	Pr	LC
Hypopachus variolosus	Sheep Frog	88–90	ETF	WD		LC
Family Ranidae						
Lithobates brownorum[a]	Brown's Leopard Frog	212–480	ETF	MA	Pr	LC
Lithobates maculatus	Masked Mountain Frog	1171	ETF	MA		LC
Lithobates vaillanti[a]	Vaillant's Frog	115–300	ETF	WD		LC
Family Rinophrynidae						
Rhinophrynus dorsalis	Burrowing Toad	111	DTF	WD	Pr	LC

Note. The forest types are ETF = evergreen tropical forest; DTF = deciduous tropical forest; CF = cloud forest; POF = pine-oak forest. The categories of species distribution are WD = widely distributed; MA = restricted to Mesoamerica; MAMx = restricted to northern Mesoamerica; UC = restricted to the Uxpanapa-Chimalapas region. The risk categories from the IUCN Red List are CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; Data Deficient = DD. The risk extinction categories from the Mexican NOM-059 are Pr = Subject to Special Protection (Sujetas a Protección Especial); A = Threatened (Amenazada). The superscript numbers 1 and 2 indicate the species recorded for the first time in the region through this study.

aThe species was recorded during our fieldwork.

Appendix B. Matrix of Presence-Absence of the Amphibian Species Recorded in Uxpanapa-Chimalapas (UC) and Other Seven Tropical Regions of Mesoamerica: La Lacandona (Laca), Mayan Forest (Maya), Calakmul (Cala), Sian-Ka'an (SiKa), Los Tuxtlas (LTux), El Ocote (Ocot), and Las Choapas (Choa).

	Region							
Species	UC	Laca	Maya	Cala	SiKa	LTux	Ocot	Choa
Dermophis mexicanus	1	1	1			1	1	1
Gymnopis syntrema		1	1					
Bolitoglossa alberchi	1					1	1	
Bolitoglossa dofleini			1					
Bolitoglossa mexicana	1	1	1	1			1	1

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Appendix B. Continued

	Region							
Species	UC	Laca	Maya	Cala	SiKa	LTux	Ocot	Choa
Bolitoglossa mulleri		I	I					
Bolitoglossa occidentalis	I						I	
Bolitoglossa odonnelli			I					
Bolitoglossa platydactyla						I	I	
Bolitoglossa rufescens	I	I	I		I	I	I	I
Bolitoglossa veracrucis	I							
Bolitoglossa yucatana			I	I	I			
Ixalotriton parvus	I							
Oedipina elongata		I	I					
Pseudoeurycea orchimelas						I		
Pseudoeurycea werleri						I		
Thorius narismagnus						I		
Incilius canaliferus	I							
Incilius campbelli		I	I					
Incilius cavifrons						I		
Incilius macrocristatus	I	I						
Incilius marmoreus	I						I	
Incilius tutelarius	I							
Incilius valliceps	I	I	I	I	I	I	I	I
Rhinella marina	I	I	I	I	I	I	I	I
Hyalinobatrachium fleischmanni	I	I	I			I		
Craugastor alfredi	I	I	I			I	I	I
Craugastor amniscola							I	
Craugastor berkenbuschii	I							I
Craugastor chac			I					
Craugastor laticeps	I	I	I			I		I
Craugastor lineatus	I	I					I	
Craugastor loki	I	I	I			I	I	I
Craugastor megalotympanum						I		
Craugastor nefrens			I					
Craugastor palenque		I						
Craugastor pozo							I	
Craugastor psephosypharus			I					
Craugastor pygmaeus	I	I				I		I
Craugastor rivulus			I					
Craugastor rugulosus	I							
Craugastor sabrinus			I					
Craugastor sandersoni			I					
Craugastor silvicola	I							
Craugastor vulcani						I		
Craugastor yucatanensis					I			
Eleutherodactylus leprus	I	I	I			I		I
Agalychnis callidryas	I	I	I	I	I	I	I	I
Agalychnis moreletii	I	I	I			I	I	
Anotheca spinosa	I					I	I	

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Appendix B. Continued

	Region							
Species	UC	Laca	Maya	Cala	SiKa	LTux	Ocot	Choa
Bromeliohyla bromeliacia		I	I					
Charadrahyla chaneque	I					I		
Dendropsophus ebraccatus		I	I	I	I	I	I	I
Dendropsophus microcephalus	I	I	I	I	I	I		I
Dendropsophus robertmertensi							I	
Duellmanohyla chamulae	I							
Duellmanohyla schmidtorum	I							
Ecnomiohyla minera			I					
Ecnomiohyla valancifer						I		
Exerodonta bivocata	I							
Exerodonta chimalapa	I							
Exerodonta sumichrasti	I						I	
Plectrohyla hartwegi	I							
Plectrohyla matudai	I	I						
Ptychohyla euthysanota	I							
Ptychohyla macrotympanum		I						
Ptychohyla sp. nov.	I							
Rheohyla miotympanum		I				I	I	
Scinax staufferi	I	I	I	I	I	I	I	I
Smilisca baudinii	I	I	I	I	I	I	I	I
Smilisca cyanosticta	I	I	I			I	I	
Tlalocohyla loquax		I	I	I	I	I	I	I
Tlalocohyla picta	I	I	I	I	I	I		I
Tlalochohyla smithii	I							
Trachycephalus typhonius		I	I	I	I	I		I
Triprion petasatus		I	I	I	I			
Engystomops pustulosus	I	I	I			I		
Leptodactylus fragilis	I	I	I	I	I	I		I
Leptodactylus melanonotus	I	I	I	I	I	I	I	I
Gastrophryne elegans		I	I	I	I	I	I	
Hypopachus ustus	I					I		
Hypopachus variolosus	I	I	I	I	I	I	I	
Lithobates brownorum	I	I	I	I	I	I	I	I
Lithobates juliani			I					
Lithobates maculatus	I	I	I					
Lithobates vaillanti	I	I	I	I		I	I	I
Rhinophrynus dorsalis	I	I	I	I	I	I		

Acknowledgments

The authors thank Arístides G. Vinalay, Conrado Nochebuena, Daniel Aportela, Luis F. Vázquez, Luis Alcaide, Jennifer López, Marco Oropeza, Roberto Flores, Jaime Pelayo, Itzue Caviedes, Flor Vázquez, Carlos Hernández, and Uri García for helping with the fieldwork. Policarpo Ronzón, Luis Feria, and Antonio Vázquez provided logistical support for the trips to the field. The authors are grateful to Ruth Percino for providing photographs of *Plectrohyla hartwegi*, Roberto Luna providing photographs of *Craugastor lineatus*, and Israel Solano for providing photographs of *Ixalotriton parvus*. Israel Estrada helped with a first version of the map and Adriana Sandoval-Comte performed the final version of the map. Two anonymous reviewers provided helpful suggestions that improved this manuscript. The Toala and Chacha families provided accommodation and were our field guides during our work in Uxpanapa. JLAL was awarded graduate studies

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scholarship No. 344651 by CONACYT. This article was written in partial fulfilment of the requirements of Graduate Studies Program of the Instituto de Ecología, A. C. for JLAL's doctoral degree. Permits for this study were issued by the Mexican Wildlife Agency, Dirección General de Vida Silvestre of the Secretaría de Medio Ambiente y Recursos Naturales (collecting permit numbers: SGPA/DGVS/03665/06 and SGPA/DGVS/03444/15).

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was funded by project JF-212-Conabio.

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