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Reptile community structure in two fragments of cloud forest of the Sierra Madre Oriental, Mexico

Aurelio RAMÍREZ-BAUTISTA* and Raciel CRUZ-ELIZALDE

Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Mexico,
A.P. 1-69 Plaza Juárez, C. P. 42001, Pachuca, Hidalgo, Mexico.
*Corresponding autor, A. Ramírez-Bautista, E-mail: ramibautistaa@gmail.com

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Abstract. Cloud forests located in the Sierra Madre Oriental of Mexico have high species richness and endemism of reptiles, although habitat fragmentation has led to small remnant patches of the original vegetation. In this study, we evaluated the compositions, differences, and conservation status of members of reptile communities in two fragments of cloud forest in the Sierra Madre Oriental of eastern Hidalgo, Mexico. Both fragments exhibited similar compositions of snakes and lizards, with high species turnover; lizards were most abundant. Likewise, this study reports a high percentage of reptiles under some category of risk. The results also show that regionally, cloud forest fragments contain comparable reptile assemblages, which highlights the importance of conserving these areas because these pools can help promote reestablishment of mature ecosystems if preservation efforts of disturbed areas succeed.

Key words: cloud forest, fragmentation, Mexico, reptiles, Sierra Madre Oriental.

Introduction

Studies on patterns of species richness in reptiles commonly have been focused on tropical and arid environments, which contain high species richness (Pianka 1986, Duellman 1987). This focus has generated a notable increase in the study of biological assemblages of reptiles in those environments, by incorporating aspects of ecology and life history strategies (Mesquita et al. 2006, Vitt et al. 2007).

Reptiles are closely linked to their environments due to specific regulatory features, such as poor dispersal ability (low vagility) and abiotic (temperature, humidity) and biotic factors (competition, predation) (Patterson & Brown 1991). These factors limit geographic ranges (Wiens 2011) and represent good models to explain structural patterns of ecological communities (Mesquita et al. 2006).

Most studies on ecological communities at local levels (assemblages, regions) mention factors such as competition and predation as major influences affecting species richness (Wiens & Donoghue 2004). However, at broader spatial scales (provinces, continents), biogeographic processes can better explain species richness and abundance (Wiens 2011).

A pattern of species richness similar to that found in tropical and arid areas is reported for mountainous regions of Mexico (Flores-Villela et al. 2010), particularly in cloud forests (CF), an environment that is well represented in the highlands of northern Oaxaca, Chiapas, and the Sierra Madre Oriental (SMO), as delimited by Ponce-Reyes et al. (2012). Montane cloud forests also have been characterized as having high richness of endemic species of amphibians and reptiles (Wake 1987, Wilson et al. 2010). From a biogeographic point of view, this richness has been attributed to climatic changes during the Pleistocene (Flores-Villela 1998), suggesting relatively recent isolation and vicariance speciation (Wiens 2011); the narrow geographic ranges of many endemic species is due to poor dispersal ability of reptiles (Porter 1972).

In Hidalgo, Mexico, CF is distributed as a belt on the upper Gulf slope of the SMO (Martínez-Morales 2007, Ponce-Reyes et al. 2012), although most has been altered and fragmented by farming activities and climate change (Raxworthy & Attuquayefio 2000, Ponce-Reyes et al. 2012). These changes have impacted species richness, abundance, and geographic distribution of species of different taxonomic groups, including reptiles (Macip-Ríos & Muñoz-Alonso 2008). Also, the edge effect and the composition of the surrounding matrix can influence the composition and structure of communities of reptiles in patches of vegetation formed by the effect of fragmentation and land use change (Urbina-Cardona et al. 2006).

Cloud forest has been considered important for reptile conservation because it contains high species richness (Wilson et al. 2010). Additionally, since reptiles have distributional limitations because of the influence of ecological factors (Vitt &

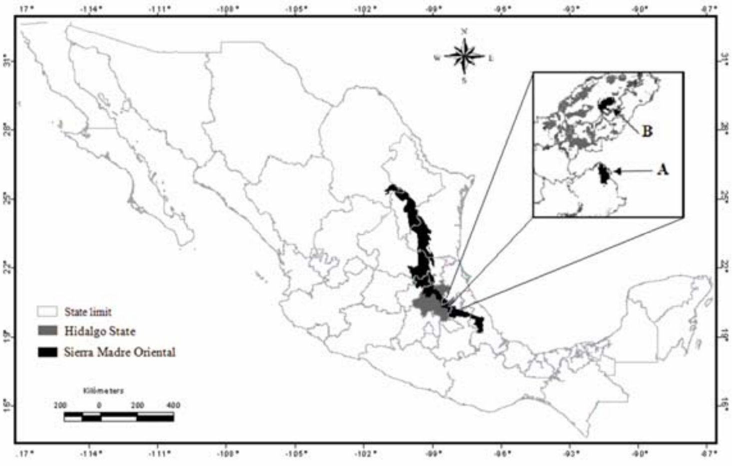

Figure 1. Location of the two cloud forest fragments analyzed in the Sierra Madre Oriental in Hidalgo, Mexico (lines and letters indicate each fragment: A = Acaxochitlán; B = San Bartolo Tutotepec).

Caldwell 2009), the mountainous environment is subject to high species turnover over short geographic distances (Lomolino 2001, Ponce-Reyes et al. 2012).

This paper addresses the following objectives: (*i*) to describe reptile species richness in two fragments of CF in the SMO in Hidalgo, Mexico; (*ii*) to assess species abundance in each fragment; (*iii*) to describe the change in species compositions between fragments of CF; and (*iv*) to present the conservation status of each species in both fragments. We expected to find similar reptile species richness and abundance in the two CF fragments because they were part of a former continuous belt of original vegetation; we also presumed high species turnover between the areas.

Material and Methods

<u>Study area</u>

The study area included two CF fragments located in eastern Hidalgo, Mexico (Fig.1 A, B). Fragment A (partial data from Cruz-Elizalde & Ramírez-Bautista 2012) is located in the northern portion of the municipality of Acaxochitlán (20° 08´N, 98° 08′W; datum: WGS84), which covers about 9.5 ha, and fragment B is in the municipality of San Bartolo Tutotepec (20° 25´N, 98° 10´W; datum: WGS84), which covers ca. 10.7 ha. These fragments are separated from each other by a distance of about 32 air-line km. The surrounding matrix of both fragments is composed of agricultural and urban areas, as well as continuous vegetation remnants called "living fences". Fragment A is located in an area ranging in elevation from 1400 to 2400 m a.s.l. and fragment B from 700 to 2200 m a.s.l. (Rzedowski 1978, INEGI 2005). Both fragments have climates characteristic of CF, with a mean annual temperature of 15°C and a maximum of 23°C (INEGI 2005, Pavón & Meza Sánchez 2009). The vegetation is dominated by tree species of the genera *Liquidambar*, *Quercus*, *Pinus*, and *Fagus* (Luna-Vega et al. 2000).

<u>Fieldwork</u>

Fieldwork was based on systematic sampling (observations) in each CF fragment during one-day monthly surveys. Sampling in fragment A lasted from August 2008 to September 2009, covering the rainy (August-September 2008 and June-September 2009) and dry seasons (March-May 2009). Sampling in fragment B was conducted from June 2009 to August 2010, also during rainy (June-September 2009 and July-August 2010) and dry seasons (March-May 2010).

Sampling methods were standardized for both sites. There were two episodes of observations from 10:00 to 14:00 hrs (diurnal) and from 19:00 to 23:00 hrs (nocturnal). Walks were conducted in a straight line (transect) in each of the patches of vegetation types to cover a high proportion of the area, and to avoid the edge effect on the richness of each fragment. We conducted the walks only in the interior of the vegetation patches where vegetation was abundant and not on the edge or in the surrounding area. Most reptiles were observed and registered (visual observations, most not captured, see below) by foot patrols in each fragment and also by searching specific types of microhabitats (e.g., under rocks, under logs, on vegetation, in crevices). Sampling involved three people and was normalized by determining hours/person (e.g., 4 hours for 3 persons = 12 person hours). The total sampling effort for each fragment was 288 person hours. Because we determined the abundance of each species in each fragment for each season, we avoided repeatedly sampling in the same site (pseudoreplicas) to avoid bias

Table 1. Species list and individual abundance of analyzed reptiles (A = Acaxochitlán; B = San Bartolo Tutotepec). Letters (Code) representing each species in Figure 2. Risk category by SEMARNAT-NOM-ECOL-059-2010 ([a] Pr = Special protection, A = Threatened, Nc = Not considered), IUCN ([b] LC = Least concern, V = Vulnerable, Nc = Not considered) and endemic to Mexico ([c] E = Endemic, Ne = Not endemic).

Taxa	Species	Code	Fragment		[a] NOM-ECOL-059-2010 Category	[b] IUCN Red List Category	[c] Endemic to Mexico
Squamata			A	B			
Sauria							
Anguidae	*Abronia taeniata*	A	0	1	Pr	V	E
	Barisia imbricata	B	0	3	Pr	LC	E
Phrynosomatidae	*Sceloporus aeneus*	C	1	0	Nc	LC	E
	Sceloporus grammicus	D	4	4	Pr	LC	Ne
	Sceloporus variabilis	E	5	32	Nc	Nc	Ne
Dactyloidae	*Anolis naufragus*	F	5	1	Pr	V	E
Scincidae	*Plestiodon lynxe*	G	5	4	Pr	LC	E
Sphenomorphidae	*Scincella gemmingeri*	H	6	8	Pr	LC	E
Teiidae	*Holcosus undulatus*	I	0	2	Nc	Nc	Ne
Xantusiidae	*Lepidophyma sylvaticum*	J	1	1	Pr	LC	E
Serpentes							
Colubridae	*Conopsis lineata*	K	0	3	Nc	LC	E
Dipsadidae	*Coniophanes fissidens*	L	1	0	Nc	Nc	Ne
	Geophis mutitorques	M	1	3	Pr	LC	E
	Geophis sp	N	0	2	Nc	Nc	Nc
	Leptodeira septentrionalis	Ñ	0	2	Nc	Nc	Ne
	Ninia diademata	O	0	1	Nc	LC	Ne
Natricidae	*Storeria dekayi*	P	2	7	Nc	LC	Ne
	Thamnophis eques	Q	1	0	A	LC	Ne
	Thamnophis proximus	R	1	1	A	Nc	Ne
	Thamnophis scalaris	S	1	0	A	LC	E
	Thamnophis sumichrasti	T	2	3	A	LC	E
Viperidae	*Ophryacus undulatus*	U	1	0	Pr	V	E

toward abundant species that might overly influence results (Manzilla & Péfaur 2000).

The sampling and handling of specimens, when necessary, were based on techniques described by Casas-Andreu et al. (1991) and modified according to the behavior of each species inhabiting the study areas (arboreal or terrestrial). Only a few unrecognized individuals were collected and later identified to species. These samples were sacrificed humanely by freezing and fixed in 10% formalin in the laboratory. When necessary, specimens were identified to species with relevant dichotomous keys found in Smith & Taylor (1966), Campbell & Lamar (2004), Wilson & Townsend (2007), and Ramírez-Bautista et al. (2009). The classification of species used in this study was based on the reptile taxonomy in Ramírez-Bautista et al. (2010) and Wilson et al. (2013). Specimens were deposited in the Colección Herpetológica, Laboratorio de Ecología de Poblaciones, Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo.

Data analysis

In order to evaluate completeness of the inventory in each fragment, we constructed species accumulation curves with data obtained during fieldwork (Moreno 2001). We used the nonparametric estimators ACE and Chao 1, which are based on abundance estimates (Jiménez-Valverde & Hortal 2003). We also used logarithms that evaluate species represented by only one ("singletons") and two ("doubletons") individuals in the samples (Colwell & Coddington 1994). A species accumulation curve was prepared with the computer program EstimateS V.750 (Colwell 2005). We evaluated abundance of reptiles (lizards and snakes) in both fragments by counting number of individuals per species in each (Magurran 1998). In addition, we estimated the frequency of lizards and snakes between seasons and between fragments. To estimate beta diversity (β) between fragments, we used the equation $\beta_J = 1\text{-}J$, where J is Jaccard´s similarity index defined as $a/(a + b + c)$, a is the number of species shared between two localities, and b and c are the numbers of species unique to each locality (Koleff et al. 2003). Finally, we established the conservation status of each species, based on the determination in SEMARNAT (2010) and IUCN (2013).

Results

We registered 115 individuals belonging to 22 species of reptiles (10 lizards, 12 snakes) in CF fragments A and B (Table 1). Fragment B, with 17 species, had a slightly higher species richness than fragment A, which contained 15 species.

Table 2. Reptile richness, species number predicted by the estimators (ACE and Chao 1) and completeness of the inventory of reptiles in both fragments (A = Acaxochitlán; B = San Bartolo Tutotepec).

Fragment	Species richness	ACE	Completeness (%)	Chao 1	Completeness (%)
A	15	24	61	24	62
B	17	21	82	20	87

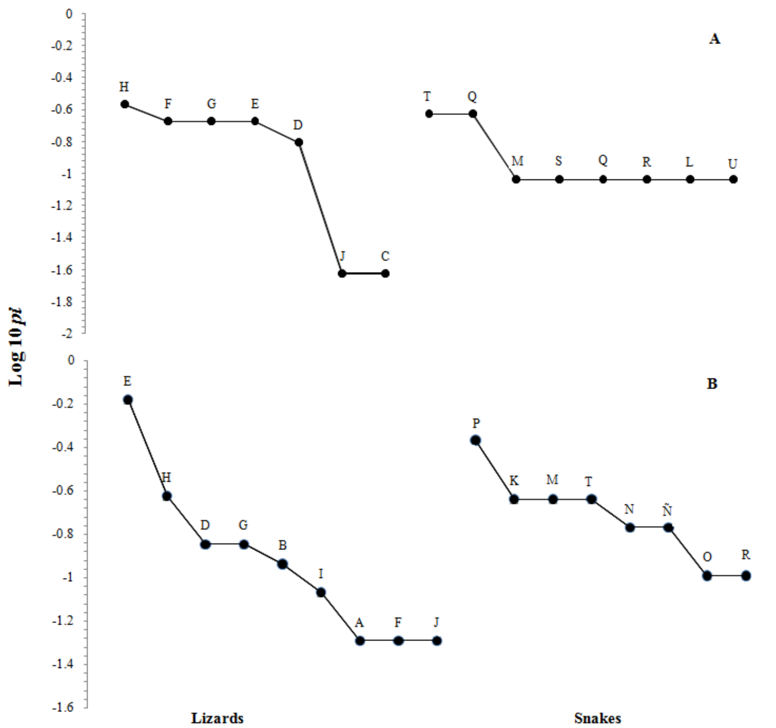

Figure 2. Rank-abundance curves of lizards and snakes in each fragment (A: Acaxochitlán; B = San Bartolo Tutotepec). The X axis represents the group of lizards and snakes for each fragment, and the Y axis the $\log_{10}$ of the proportion of each species. Capital letters represent each species listed in Table 1.

<u>Accumulation curves and inventory completeness</u>

The accumulated species richness was 22 reptiles distributed in the two CF fragments surveyed. The nonparametric estimators, ACE and Chao 1, predicted there should be higher numbers of species within both sites, although the percentage of completeness was higher in fragment B for both estimators (Table 2). Still, according to Moreno & Halffter (2001) and Pineda & Halffter (2004), our survey indicated an appropriate sampling effort for reptiles, especially in fragment B.

<u>Reptile abundance</u>

The abundance of the reptile species was similar between the two fragments, revealing few lizards and snakes with high abundance; most were rare species (Table 1; Fig. 2). Lizards generally had higher abundance in both fragments, with the skink *Scincella gemmingeri* (6 individuals) representing the most abundant species in fragment A, and *Sceloporus variabilis* (32 individuals) in fragment B. Snakes at both sites had not only much less species richness but also less abundance of individuals per species (Table 1). *Thamnophis sumichrasti* (2 individuals) and *Storeria dekayi* (2 individuals) were the most abundant snakes in Fragment A, but as the numbers show, both were uncommon. In Fragment B, the highest abundance was for *T. sumichrasti* (7 individuals).

Abundance of lizards and snakes was similar during the two seasons in each fragment (Fig. 3); however, in fragment A, lizards had a higher

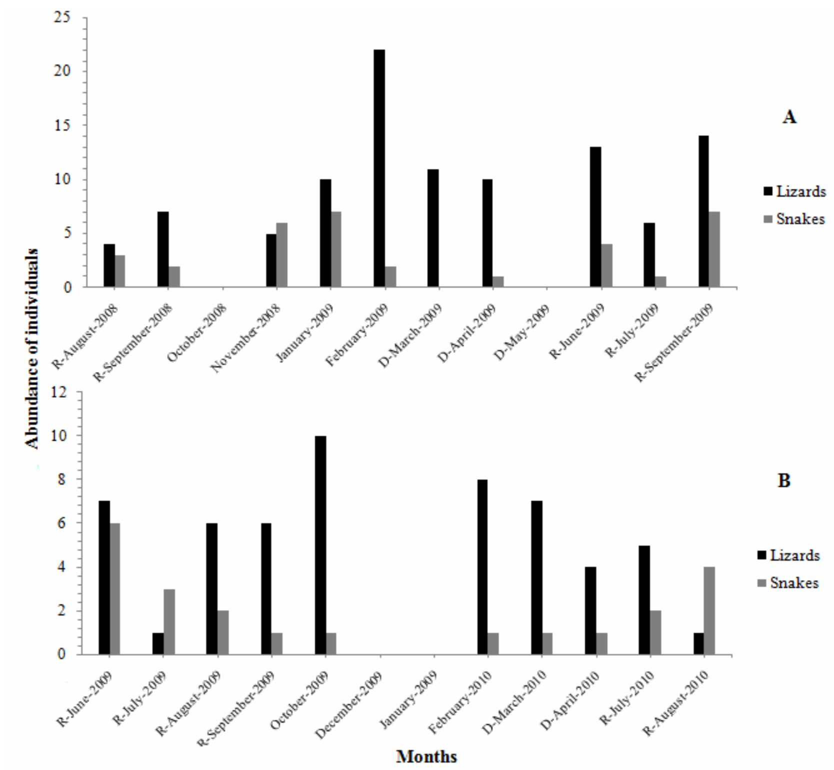

Figure 3. Abundance of individuals of reptiles (lizards and snakes) collected during 12 sampling (months) and rainfall (R) and dry (D) periods in both fragments (A = Acaxochitlán; B = San Bartolo Tutotepec).

number of individuals in February, March, and April, and in the case of snakes, in January and September (Fig. 3). Lizards in fragment B showed highest abundances in October, February and March, and in the case of snakes, peak abundance was in June and then decreased throughout the rainy season; abundance increased again during the following dry season.

Beta diversity (β)

The value of the β diversity index (β_J) shows a medium value in species composition between sites $\beta_J = 0.54$. However, there was less sharing for snakes ($\beta_{J\text{-Snakes}} = 0.67$) and greater sharing for lizards ($\beta_{J\text{-Lizards}} = 0.40$) between fragments.

Conservation status

The two reptile communities in the study areas included a combined figure of 13 species under some category of conservation concern as listed in the official Mexican list (SEMARNAT 2010). This represents 59.09 % of the all reptile species (22) that are either under special protection (Pr) (*Abronia taeniata*, *Barisia imbricata*, *Sceloporus grammicus*, *Anolis naufragus*, *Plestiodon lynxe, Scincella gemmingeri*, *Lepidophyma sylvaticum*, *Geophis mutitorques,* and *Ophryacus undulatus*) or threatened (A) (*Thamnophis eques*, *T. proximus*, *T. scalaris*, and *T. sumichrasti*) (Table 1). IUCN (2013) placed 16 of the 22 species (72.7%) in either the category of Least Concern (LC; 13 species - 59.09 %) or Vulnerable (V; 3 species - 13.63 %); six species have not been evaluated (NC; 6 species - 27.27 %) (Table 1). Twelve of the 22 species (54.5 %) recorded in this study are endemic to Mexico, and another one is an undescribed species of *Geophis* (Table 1).

Discussion

The structure and composition of reptile communities at local scales are influenced by biotic and abiotic factors (Chen et al. 2011). The species richness found in the two fragments during our survey was nearly identical (15 and 17 species), suggesting homogeneity in species composition for CF in the SMO in Hidalgo. We recorded 21 of the 143 species (14.68 %) listed for the SMO as defined by Canseco-Márquez et al. (2004); another is an undescribed species. This fact indicates that the SMO exhibits, throughout its geographic area, regional patches of homogeneous CF reptile communities, which, according to Patterson & Brown (1991), can be explained by causality factors, such as (*i*) a common biogeographic history, (*ii*) similar contemporary environments, and (*iii*) hierarchical sets of ecological relationships among species. Therefore, the species richness pattern recorded herein probably is due to regional ecological and biogeographical factors in the discontinuous CF habitats of the SMO (Wiens & Donoghue 2004). Reptiles occurring in remnants of CF in temperate climatic environments of the SMO in east central Mexico (Flores-Villela et al. 2010) will tend to contain species with similar ecological requirements and tolerances (Patterson & Brown 1991, Chen et al. 2011).

Our recording of the species reported in this study represents an important contribution to the knowledge of SMO diversity, including the finding of an undescribed species of snake (*Geophis* sp.), and documents the richness and abundance of lizards and snakes contained in two local fragments of cloud forest. More lizard species are shared between the two fragments (7), including *Sceloporus variabilis*, which exhibited the highest abundance, especially in fragment B (32 individuals). Snakes shared the fewest species (3 species), and generally had lower abundances (Table 1, Fig. 2). A partial explanation for these patterns is that lizards have better dispersal ability and usually higher abundance (Barbault et al. 1985) than do snakes, which are more specialized and have lower population densities (Vitt & Caldwell 2009).

Lizards were abundant most of the year, whereas snakes were most active during the rainy season. Abundance during the rainy season, at least for lizards, might be related to resource availability, because the increase in number of individuals is most likely related to an increase in insects and other small invertebrates (Vitt & Carvalho 1995); however, it is important to consider how habitat fragmentation and the resulting edge effect affects species composition in biological communities in terms of species loss or gain (Urbina-Cardona et al. 2006). The biological group analyzed in this study and the sampling design that included only the interior of the patches provides an outcome that evaluates the species richness using the available microhabitats within patches (Sartorius et al. 1999, Santos-Filho et al. 2012). For example, Urbina-Cardona et al. (2006) recorded in the ecotone pasture-edges-interior of the forest of the Los Tuxtlas Region (Mexico), a high abundance of lizard species such as *Ameiva* (*Holcosus*) *undulata* (*us*) and *Sceloporus variabilis*, of which the latter was abundant in both fragments analyzed in this study.

In the same way, the size and vegetational structure of the fragments is a determinant of reptile species richness (Santos-Filho 2012), since the fragment that had the highest species number (fragment B) is larger (10.7 ha) than fragment A (9.5 ha). These data suggest that species richness increases with increase in patch size, as has been shown in other groups of organisms, such as birds (Sándor & Domsa 2012), insects (Balog et al. 2012), and plants (Trifunov et al. 2013), however, is important to consider the sampling methods and the areas that affect the exchange of species (matrix-edge-interior), which highlights the importance of developing studies that consider the edges areas and the surrounding matrix in the fragments to evaluate the effects that these show, both in richness and in the composition of the reptile communities in these areas, as well as the exchange there between (Ries et al. 2004).

Reptiles, as with other small-bodied vertebrates, have restricted distributional limits (Hardly & Maurer 2001), a common pattern among diminutive sympatric species utilizing similar environmental resources (Brown 1984). Comparable patterns have been observed in tropical (Vitt et al. 2007), desert (Pianka 1986), temperate (Cruz-Elizalde & Ramírez-Bautista 2012, Akman et al. 2013, Göçmen et al. 2013), and in fragmented environments (Macip-Rios & Muñoz-Alonso 2008).

The reptile communities in the two CF patches include a relatively high number of species of conservation concern, as determined on the official Mexican (SEMARNAT 2010) and IUCN (2013) lists. This fact points out the importance of protecting the two CF fragments to help preserve these threatened species. In this study, we recorded 22 species, 12 of which (54.54 %) are endemic to Mexico (SEMARNAT 2010). Overall, the preservation of CF fragments containing indigenous species of reptiles in most areas of the SMO, including the ones discussed here, is being affected seriously by habitat destruction, agricultural development, the killing of species perceived to be dangerous, and human uses such as the pet trade and folk medicine (Fitzgerald et al. 2004). All of these factors adversely can distress species with low natural abundance (Raxworthy & Attuquayefio 2000), such as *Ophryacus undulatus* and *Abronia taeniata* (Canseco-Márquez et al. 2004, Cruz-Elizalde & Ramírez-Bautista 2012). It is imperative that SEMARNAT (2010) and IUCN (2013) continue assessment of the conservation status of many of the species in these CF patches, with the understanding that CF in the SMO are being destroyed along with their reptile residents (Canseco-Márquez et al. 2004).

This study demonstrates regional diversity and abundance characteristic of CF reptile communities within temperate mountainous environments containing pine-oak forest, which in conjunction with other areas of SMO historically have produced the physiographic region containing the most species of amphibians and reptiles and highest endemism in Mexico (Wake 1987, Flores-Villela et al. 2010, Wilson & Johnson 2010). Mountain forest fragments normally maintain high species richness (and, to some extent, endemism) of reptiles, as well as of birds and insects (Vergara & Simonette 2004, Martínez-Morales 2007). All these data highlight the importance of protecting these regional habitats (Lomolino 2001), especially from high rates of vegetation loss (Ponce-Reyes et al. 2012) due to human impacts. Also important is to protect the more restricted microhabitats within habitat patches that are essential resources for specialized species (Porter 1972, Vitt et al. 2007).

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