
AMPHIBIAN AND REPTILE COMMUNITY STRUCTURE IN PRISTINE CONIFEROUS FORESTS: BASELINE DATA FOR CONSERVATION STUDIES

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Abstract.—Pristine ecosystems are scarce worldwide. Understanding the community structure of amphibians and reptiles in pristine forests allows us to quantify the essential habitat features necessary for the species of animals and plants to survive. Data on the herpetofaunal community in pristine ecosystems also provides a baseline to evaluate the impacts of disturbance. We surveyed five vegetation types within a coniferous forest protected by indigenous people in a high mountain forest in southern Mexico. We found high endemism of the herpetofauna associated with temperature and humidity along an elevation gradient. Salamander richness and abundance was greater at higher elevations (2,760–3,260 m) in broadleaf and coniferous forests, and lizard and snake richness was greater at lower elevations (1,940–2,400 m) in riparian vegetation, oak-pine, and pine-oak forests. Some salamander and snake species were restricted to particular vegetation types suggesting that the alteration of these vegetation types may negatively impact unique species. The community structure of amphibians and reptiles, based on composition, richness, and abundance, can be used as an indicator to evaluate environmental changes in conservation and restoration projects.

Key Words.—broadleaf forest; conservation; oak-pine forest; pine-oak forest; riparian vegetation

INTRODUCTION

There are few ecosystems that remain without perturbation from human influences (Gardner et al. 2010). Lack of baseline studies in pristine sites impedes both the establishment of criteria for their conservation and an impact evaluation when degradation occurs in native biotic communities (Drumbrell et al. 2008; Trisurat et al. 2010). However, very few studies have provided information on the composition and structure of species from areas that have not been disturbed because they are often places that are difficult to access (Morissette et al. 2009). Although forests are distributed throughout the world, forests that have never been subjected to logging are extremely rare (Josefsson et al. 2010) and are valuable references to guide conservation actions (Lindenmayer 2010).

Biodiversity of vertebrates in coniferous forests in neotropical areas has been relatively understudied compared to coniferous forests in temperate areas (Newton et al. 2009; Hernández-Salinas and Ramírez-Bautista 2012). These forests include a unique combination of northern (Nearctic) and southern (Neotropical) elements at high elevation within the Neotropics (Greller 1990). Coniferous forests harbor large numbers of species, many of which are rare and threatened according to the IUCN Red-List

(Quintana-Ascencio et al. 2004). The continuous loss of coniferous forests has threatened many animal and plant species that inhabit them (Bengtsson et al. 2000). Despite the high diversity and vulnerability of coniferous forests, detailed surveys of vertebrate diversity in tropical coniferous forests, especially of species that may be restricted to certain microclimates, are lacking (Peterson et al. 1993; Chávez-León et al. 2004). In pristine sites, some organisms act as indicators of the patterns of biodiversity and habitat quality (Gardner et al. 2008). For example, assemblages of amphibians and reptiles can provide information about habitat quality (Hernández-Salinas and Ramírez-Bautista 2012).

Amphibians and reptiles are often ideal indicators of habitat quality because they are among the first vertebrate species to disappear after perturbation (Wake 1991, Urbina-Cardona et al. 2006; Cabrera-Guzmán and Reynoso 2012). The sensitivity of amphibians and reptiles to environmental changes is well known (Gardner et al. 2007). For example, salamander populations can decline drastically in pine forests when fragmentation occurs owing to their narrow niche requirements and isolated populations distributions (Gibbs 1998). Both *Thorius* and *Pseudoeurycea* have shown declines in the past decades in Mexican forests (Parra-

Olea et al. 1999). The vulnerability of amphibians and reptiles underscores the requirements of habitat quality (Gibbons et al. 2000), and the need to understand the attributes important to herpetofauna. Habitat quality can be evaluated by herpetofaunal communities attributes, such as richness, composition, and abundance (Flores-Villela et al. 2010; Nuñez et al. 2010).

Herpetofaunal communities in pristine forests are at risk of being affected in composition and structure because of habitat loss (Russell et al. 2002). Insight into the structure of amphibian and reptile communities allows understanding the microclimate preference of this species, and thus to better understand their reaction if disturbance occurs (Goldingay et al. 1996). Detailed baseline surveys are needed to allow us to differentiate vulnerable species from disturbance-resistant species during future studies (Cromer et al. 2002). In addition, such data can provide information regarding the expected structure of community climax for environmental restoration programs, and evaluation for conservation priorities (deMaynadier and Hunter 1995).

In this study, we analyzed the community structure of amphibians and reptiles along an elevational gradient in five vegetation types located in pristine sites within the Santa María Yavesía forest in the Sierra de Juárez, southern Mexico. These forests are under protection of the Zapotec indigenous people, but may be threatened because of pressure to illegally log timber and as a result of nearby population growth. Conservation efforts to avoid potential destruction on these habitats should consider the preferences of amphibians and reptiles occurring along these gradients. This work provides important baseline information on herpetofaunal communities of pristine coniferous forests in the Neotropics of Mexico and will assist in future conservation decisions in unmanaged forests and restoration programs of degraded habitats.

METHODS

Study area.—We conducted our study within the communal indigenous Zapotec territories of Santa María Yavesía, in the northern region of the state of Oaxaca, southern Mexico (17°08'30"–17°15'45" N and 96°21'15"–96°27'45" W; elevation 1,900–3,280 m). This area comprises 6,455 ha covered by well-

preserved coniferous forests with pine, oaks, and fir trees. Approximately 6,000 ha are protected in a community reserve, designated by its inhabitants. Three main valleys and several other minor ones cross the area and converge on the Yavesía River. The highest point is the watershed of the Papaloapan River basin that drains into the Gulf of Mexico and the Oaxacan Valley that drains into the Pacific Ocean.

In this area we selected five pristine vegetation types at two elevations and conducted six surveys during August, September, November 2008, and February, April, and June 2009 to cover rainy and dry seasons. During each survey we included vegetation types at different elevations. In lower elevations, we sampled riparian vegetation (elev. 1,940–1,960 m; *Alnus jorullensis*, *Salix bonplandiana*), oak-pine forest (elev. 2,040–2,180 m; *Quercus acutifolia*, *Pinus pseudostrobus* var. *apulcensis*), and pine-oak forest (elev. 2,280–2,400 m; *Pinus lawsonii*, *Quercus laeta*; Figs. 1, 2). The climate is temperate sub-humid with 1,029 mm annual mid precipitation, 16.8° C annual mid temperature, and summer rainfall. In higher elevations, we sampled broadleaf forest (elev. 2,760–2,880 m; *Pinus ayacahuite*, *Quercus ocoteaefolia*) and coniferous forest with two dominant species (*Abies hickelii* and *Pinus hartwegii*; elev. 3,020–3,260 m; Fig. 1, 2). The climate is semi-cold and semi-humid with 1,122 mm total annual precipitation, 9.9° C annual average temperature, and with rainfall primarily during the summer.

Amphibian and reptile sampling.—In each survey, we visited every site once (12 h of searching by 3 people: 8 h day and 4 h night) noting species richness and abundance (Jones 1986). Each vegetation type was surveyed for the same number of hours and always by 3 people. We conducted surveys using the visual encounter survey method (Heyer et al. 1994) in different vegetation strata where organisms could potentially be found: ground, trunks, branches, dead leaves, trees, bushes, rocks, epiphytes, and stream edges (Heyer et al. 1994; Scrocchi and Kretzschmar 1996). We focused the search on amphibians and reptiles found from ground level to two meters.

We captured at most two specimens of each species and sex to represent morphological variation, and some were sacrificed for identification, and deposited at the Museo de Zoología “Alfonso L. Herrera,” Facultad de

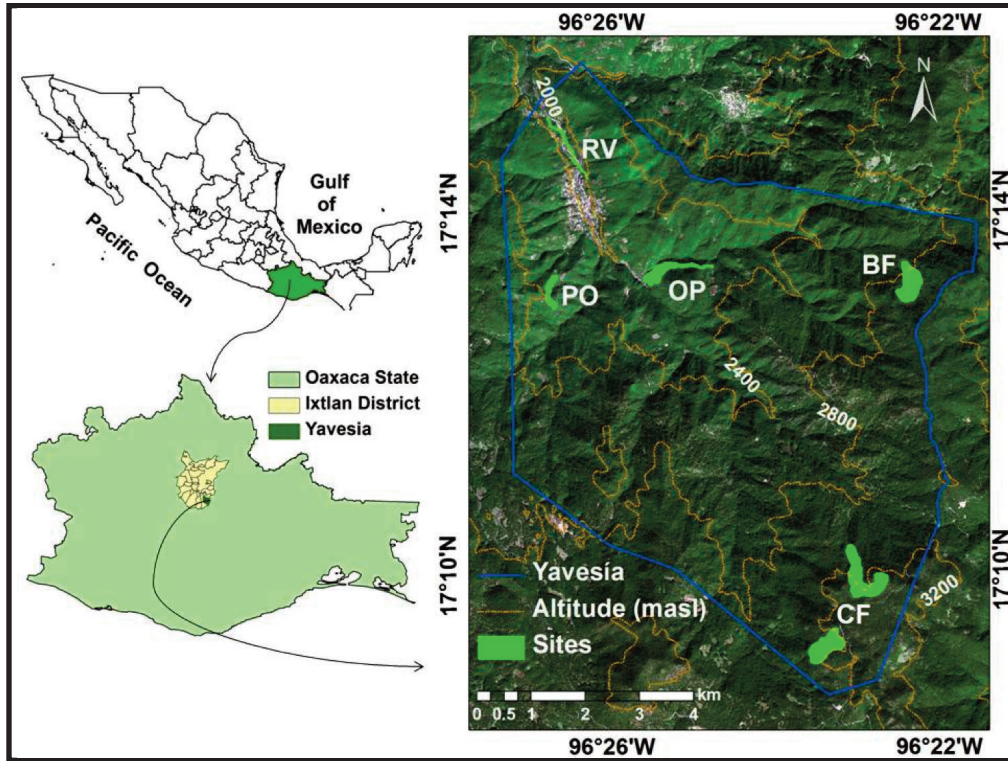


FIGURE 1. Study site in Santa María Yavesía, Oaxaca, Mexico. Image Spot 5 December 2010. Abbreviations: RV = riparian vegetation, OP = oak-pine forest, PO = pine-oak forest, BF = broadleaf forest, and CF = coniferous forest.

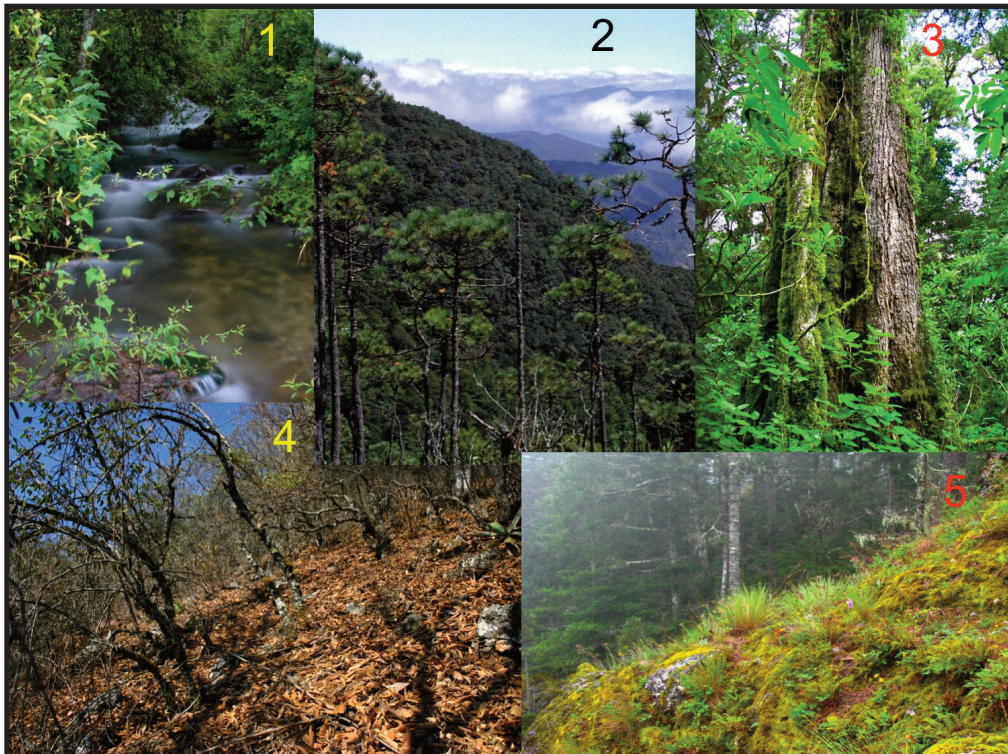


FIGURE 2. Vegetation types at the study site. 1. Riparian vegetation, 2. Pine-oak forest, 3. Broadleaf forest, 4. Oak-pine forest, 5. Coniferous forest. All photographs by Irma Trejo.

Ciencias, Universidad Nacional Autónoma de México (MZFC) in Mexico City as voucher specimens. Individuals that were observed and not used as voucher specimens were only identified in the field and released at the place where they were first sighted. Methods used for sacrificing amphibians and reptiles followed humane techniques for each species and were preserved according to accepted herpetological techniques (Scrocchi and Kretzschmar 1996). Because salamander morphological identification is difficult, we Bar Coded them using 16S ribosomal mtDNA fragments using standard techniques (Parra-Olea 2002).

Environmental conditions during survey.—

Data on precipitation, relative humidity, and temperature were obtained during the sampling period to evaluate differences between elevation gradients. During the surveys, it rained 747.15 mm in the lower elevations and 1,466.4 mm in higher elevations. Relative humidity registered in the year during the survey ranged from 50% in the lower elevation sites to 95% in the higher elevation sites throughout the year. The low temperatures in conifer and broadleaf forest were -2 and 0° C, respectively. During the day average temperature was 10° C at higher elevation sites, while at lower elevation sites it ranged from 15 to 20° C.

Data analysis.—We generated species accumulation curves for amphibians and reptiles using the subsampling without replacement option to represent the increase rate of species for each vegetation type. These curves plot the cumulative number of species as a function of sampling effort, which is represented by the number of individuals of herpetofauna registered in each sample (Colwell and Coddington 1994). We used the count of each species found at each site per sample occasion. We evaluated the effectiveness of the sampling in the community through the non-parametric estimators Chao 2 and ACE (Abundance-base Coverage Estimator) following the criteria by Magurran (2004) using the program Estimates Win 7.52 (Colwell 2005). Chao 2 estimation is suitable for low abundance species communities and small samples, and is based in the number of uncommon species in the sample using incidence data. ACE estimation of coverage considers abundance and infers total richness from uncommon species (species ≤ 10 individuals; Chao et al. 2000).

To achieve enough statistical power we analyzed the differences among vegetation types using amphibians and reptiles together and not as two different groups. We evaluated differences in species incidence (as an indicator of composition) among vegetation types using the non-parametric Cochran test (Siegel 1988; Zar 2010) that evaluates the distribution of incidences in the sample, and we evaluated species abundance with Friedman independent multiple tests in STATISTICA Version 9. We used data on incidence across sampling occasions for the Cochran test and counts across sampling occasions for the Friedman test. We evaluated the similarity between vegetation types with the Sorensen quantitative index (C_N) as modified by Chao et al. (2006). In ecological studies, this index is preferred over other similarity indexes (e.g. Jaccard, Simpson, etc.) because it gives more weight to abundance rather than incidence per species data. We used the count of abundance across sampling occasions for this analysis. To visualize differences among groups, we generated a matrix with C_N index data and plotted it as a phenogram using UPGMA (unweighted pair group method with arithmetic mean) in NTSYS-2.02 (Rohlf 1998).

We constructed rank abundance curves to evaluate changes in relative abundance of species among vegetation types (Magurran 2004). For each vegetation type, we plotted the relative abundance for amphibians and reptiles on a logarithmic scale against the rank order of the species from most to least abundant.

To identify differences between amphibian and reptile community compositions between two main elevation zones in the area (by determining whether both independent groups come from the same population), we used a Mann-Whitney U test (Siegel 1988) in STATISTICA program Version 9. We used the sum of ranks of species.

RESULTS

In Santa María Yavesía we documented 35 species (12 amphibian species comprised of six genera within five families, and 23 reptile species comprised of 18 genera and seven families). Twenty-nine of the 35 species (83%) are endemic to Mexico, and 14 are listed in the Mexican Red List of Threatened Species NOM-059 SEMARNAT-2010 (Appendix 1).

Sampling effectiveness.—Accumulation

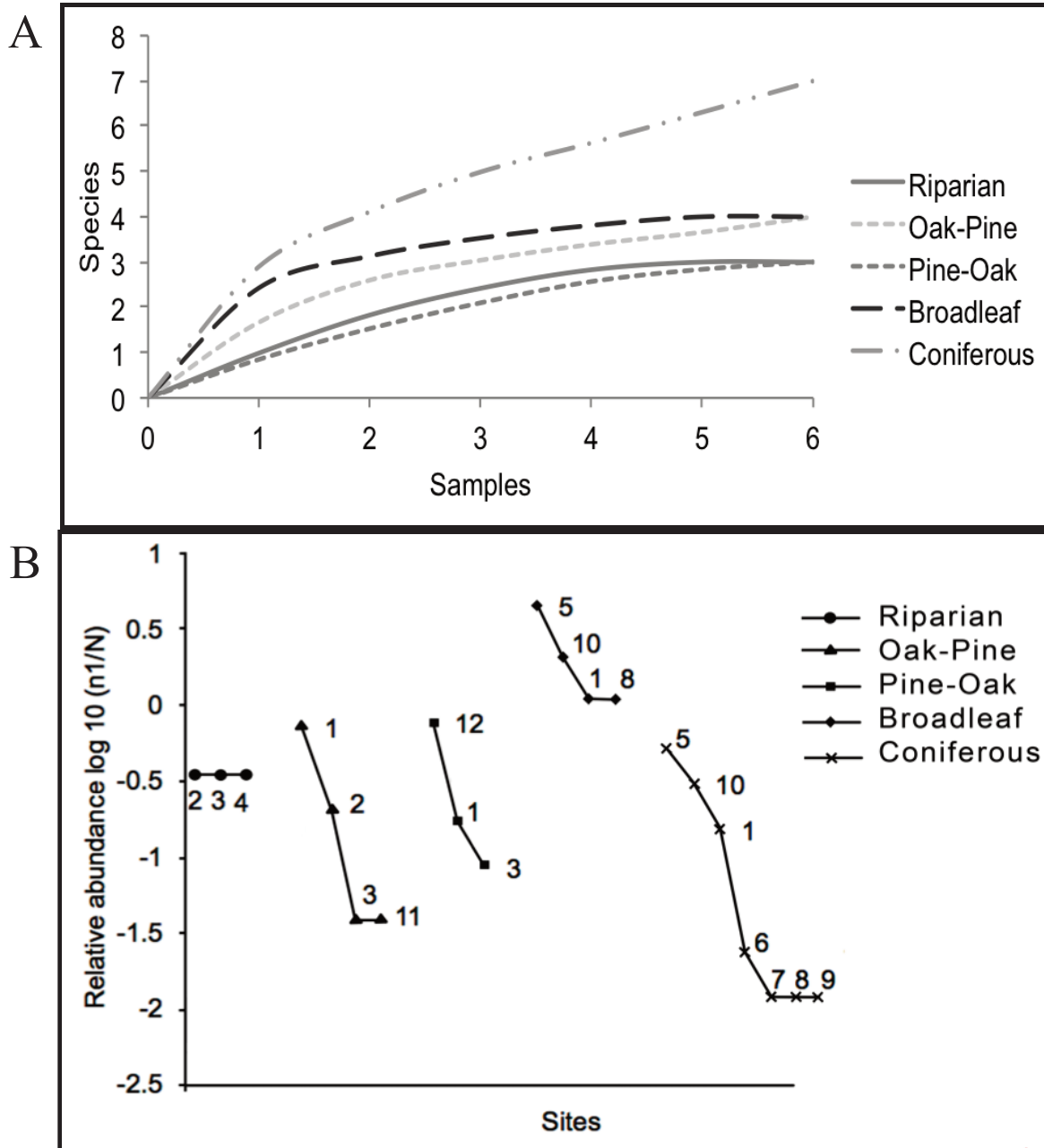


FIGURE 3. a) Species accumulation curves for each vegetation type for amphibians. b) Rank-abundance curves for amphibians at each vegetation type. Species codes are given in Appendix 1. For each habitat the relative abundance of each species (n_i/N) was plotted on a logarithmic scale against the species rank ordered from most to least abundant.

curves for amphibians in the different vegetation types (Fig. 3a) illustrate that the riparian vegetation, pine-oak forest, and broadleaf forest were well sampled, since their curves reached the asymptote. In reptiles, the accumulation curves reached an asymptote in broadleaf forest and coniferous forest (Fig. 4a). Chao 2 index for

all sites (Table 1) showed an overall sampling effectiveness of 56% for amphibians and over 54% for reptiles. These values appear to be low, however, we found 100% of the expected records in riparian vegetation, pine-oak forest, and broadleaf forest for amphibians, and 100% in broadleaf forest and coniferous forest for

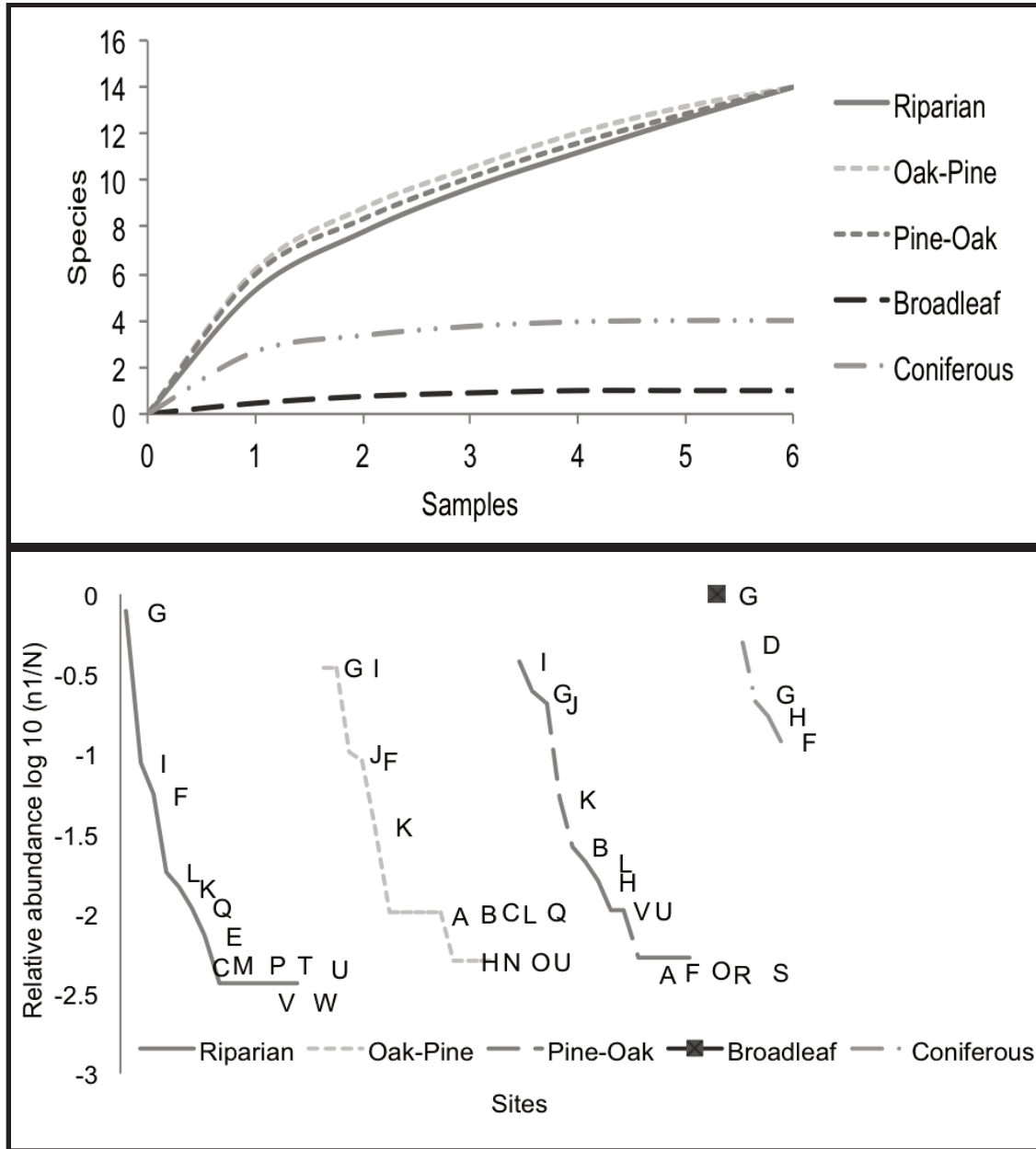


FIGURE 4. a) Species accumulation curves for each vegetation type for reptiles. b) Rank-abundance curves for reptiles at each vegetation type. Species codes are given in Appendix 1. For each habitat the relative abundance of each species (n_i/N) was plotted on a logarithmic scale against the species rank ordered from most to least abundant.

reptiles. A slightly lower effectiveness index of 82% was found in oak-pine forest for amphibians (Table 1), and of 61% and 89% for pine-oak forest and oak-pine forest for reptiles (Table 1).

Richness and composition of habitats.—We recorded 18 species of amphibians and reptiles in oak-pine forest. Species that were only found

in this forest were the salamander *Thorius* sp. nov. 1 and the snake *Pituophis lineaticollis*. We observed 17 species in riparian vegetation and pine-oak forest. However, the composition of both communities was different. In riparian vegetation alone we found the frogs *Eleutherodactylus nitidus* and *Hyla euphorbiacea*, the lizards *Gerrhonotus liocephalus* and *Phrynosoma braconnieri*, the

TABLE 1. Sampling effectiveness for amphibians and reptiles per site. We present the number of species observed, the species expected by Chao 2 index, and the percentage found on this study.

Site	Species observed	Chao 2	Percentage
Amphibians			
Riparian Vegetation	3	3	100.00
Oak-Pine Forest	4	4.83	82.82
Pine-Oak Forest	3	3	100.00
Broadleaf Forest	4	4	100.00
Coniferous Forest	7	12	58.33
Reptiles			
Riparian Vegetation	14	25.67	54.54
Oak-Pine Forest	14	15.67	89.34
Pine-Oak Forest	14	22.75	61.54
Broadleaf Forest	1	1	100.00
Coniferous Forest	4	4	100.00

snakes *Leptodeira polysticta*, *Rhadinaea taeniata*, and *Crotalus molossus*, and the turtle *Kinosternon integrum*. In pine-oak forest alone we found the frog *Craugastor mexicanus*, the salamander *Thorius* sp. nov. 2, the lizards *Abronia oaxaca*, *Barisia planifrons*, and *Sceloporus microlepidotus*, and the snakes *Rhadinea fulvivittis*, *Thamnophis crysocephalus*,

and *Crotalus intermedius* (Appendix 1). In the conifer forest we found 11 species, the salamanders *Pseudoeurycea saltator*, *P. smithi*, and *Thorius macdougalli*, and the lizard *Mesaspis viridiflava* were only observed in this habitat. The broadleaf forest had five species all found in the other vegetation types (Fig. 5, Appendix 1).

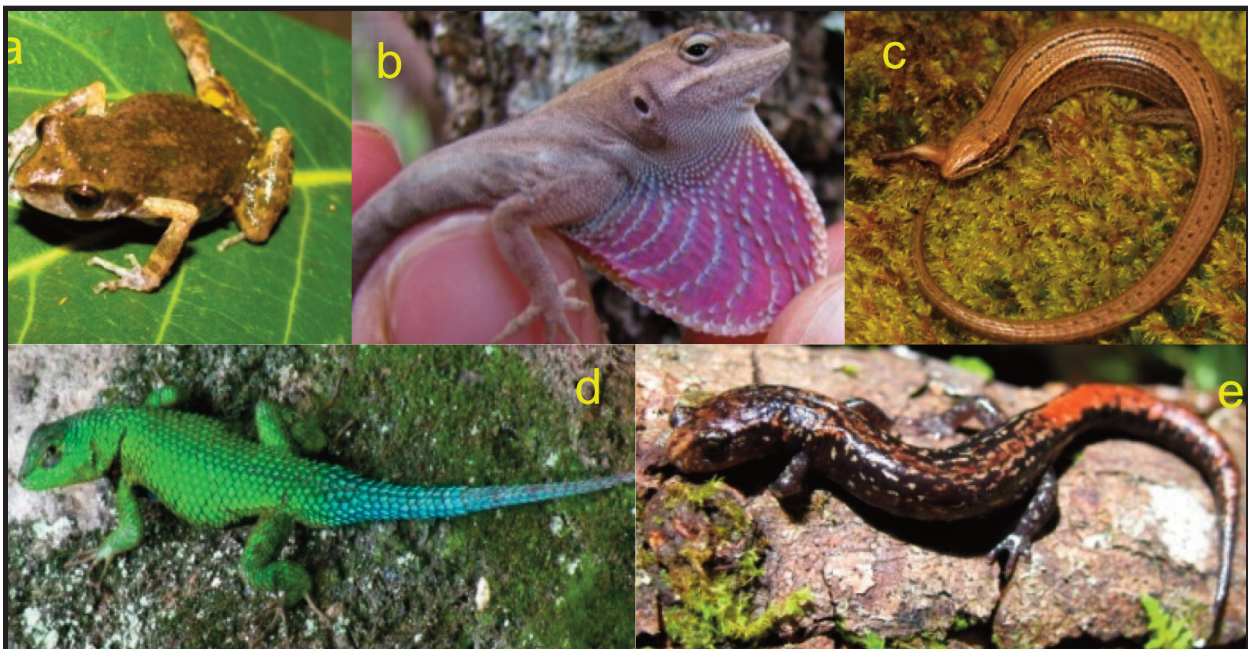


FIGURE 5. Most common species at the study site. a: *Craugastor mexicanus*, b: *Anolis quercorum*, c: *Mesaspis viridiflava*, d: *Sceloporus formosus*, e: *Pseudoeurycea juarezi*. All photographs by Regina Vega-Trejo.

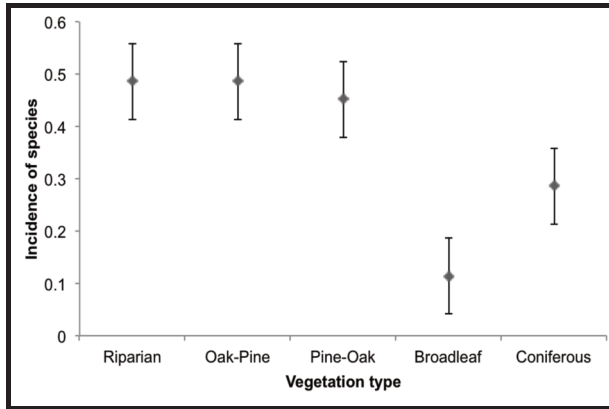


FIGURE 6. Friedman test for amphibians and reptiles. Points show means and lines show standard error.

Composition and abundance differences among habitats.—Species composition differed significantly among vegetation types ($Q_4 = 15.75$, $P < 0.003$). Differences in the abundance of amphibians and reptiles among vegetation types also were significant ($\chi^2_4 = 15.8$, $P < 0.003$). We found differences between broadleaf forest and conifer forest with oak-pine, pine-oak, and riparian vegetation in terms of the species of amphibians and snakes found in these habitats. Means for each vegetation type with standard

error show these differences (Fig. 6). Differences between communities were caused by the presence of the salamanders *Pseudoeurycea juarezi* and *Thorius narisovalis*, salamander species that were abundant in broadleaf forest and conifer forest, but were absent in the other three communities. Differences in reptiles were due to the greater abundance of the lizards *Sceloporus formosus* and *Anolis quercorum* in oak-pine, pine-oak, and riparian vegetation. The lizard *A. quercorum* was not present in broadleaf forest and conifer forest.

Similarity among habitats.—The phenogram based on the Sorensen index illustrated the same pattern as the results shown above (Fig. 7). Two main groups were recovered. The first was formed by the amphibian and reptiles communities in oak-pine forest and pine-oak forest (72% of similarity, sharing 13 species). Riparian vegetation joined to this group with a 47.5% similarity (ten shared species). The second group formed by the broadleaf forest and the conifer forest had a 60% similarity. These sites shared only five species with similar species abundance. Two main groups were very different and were joined at 18.12% similarity. The most different sites were broadleaf forest

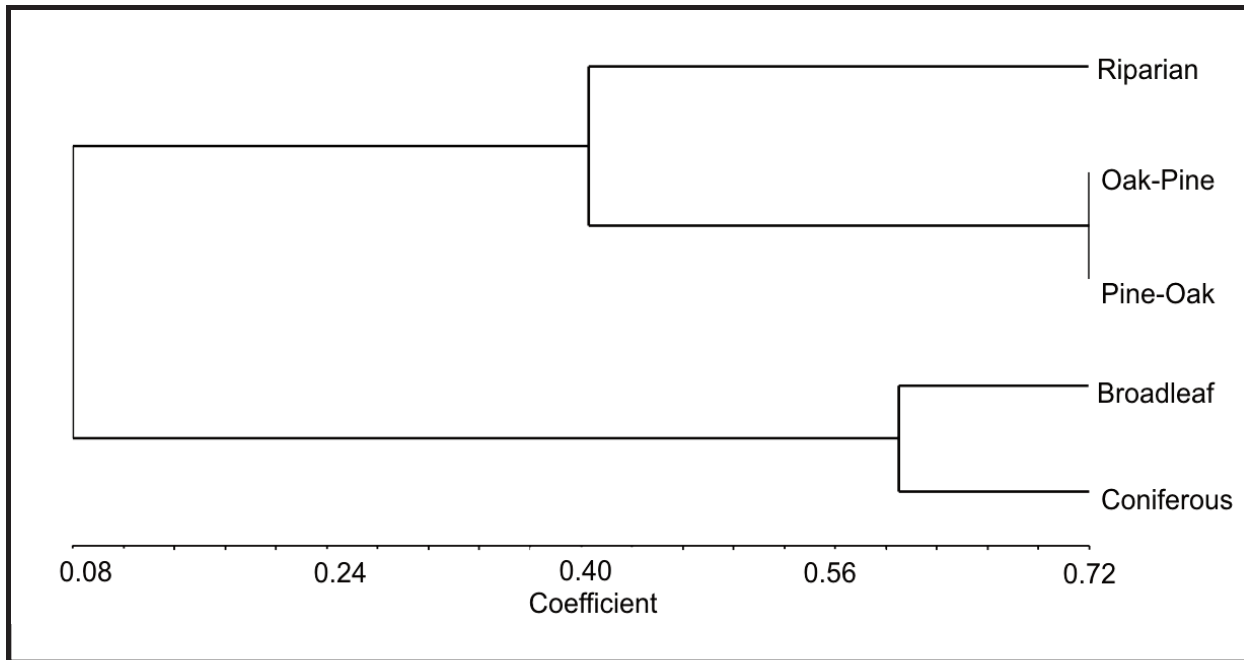


FIGURE 7. Sorensen phenogram for amphibians and reptiles.

and riparian vegetation with only 1% similarity, sharing a single species (see Appendix 1).

Distribution of relative abundance among habitats.—Rank abundance curves for amphibians showed that the dominant species in different vegetation types were not always the same, and that the arrangements of the species rank hierarchy based on the abundance varied considerably from site to site (Fig. 3b, codes of species in Appendix 1). In broadleaf forest and conifer forest the salamanders *Pseudoeurycea juarezi* (5) and *Thorius narisovalis* (10) were the first and second most abundant species, respectively. In contrast, in pine-oak forest the salamander *Thorius* sp. nov. 2 (11) was the most abundant followed by the frog *Craugastor mexicanus* (1), with this species being the most abundant in oak-pine forest. In the riparian vegetation the frogs *Eleutherodactylus nitidus* (2), *Incilius occidentalis* (3), and *Hyla euphorbiacea* (4) were equally abundant.

Rank abundance curves for reptiles showed different patterns. The lizard *Sceloporus formosus* (G) was found in all communities. This species was dominant in riparian vegetation, oak-pine forest, and broadleaf forest (the only reptile species found here), and second dominant in pine-oak forest and coniferous forest. The lizard *Anolis quercorum* (I) was the dominant species in pine-oak forest, while the lizard *Mesaspis viridiflava* (D) was dominant in coniferous forest (Fig. 4b, codes of species in Appendix 1).

Elevational distribution.—We found significant differences between amphibian and reptile community composition between elevation zones ($U = 352.5$, $P = 0.001$), with pronounced differences in composition between lower and higher elevation zones. The lower zone had 24 unique species while the higher zone had seven unique species. Both zones shared only five species with broad altitudinal range: the frog *Craugastor mexicanus*, and the lizards *Mesaspis viridiflava*, *Sceloporus aureolus*, *S. formosus*, and *S. microlepidotus*.

DISCUSSION

There has been relatively little work addressing the amphibian and reptile community structure in pristine habitats compared to other habitats (Jędrzejewska et al. 2003). Most studies have

compared disturbed sites to one another (e.g., Todd and Andrews 2008; Nuñeza et al. 2010; Hernández-Salinas and Ramírez-Bautista, 2012), but have no solid reference to a site without perturbation (Owens et al. 2008). Although pristine sites far from human development are becoming scarcer (Rouvinen et al. 2002), data from many of these sites remains unavailable (Novotny et al. 2007). In particular, coniferous forests within the Neotropics have lost considerable range because of timber exploitation (Food and Agriculture Administration of the United Nations. 2006. Tendencias y perspectivas del sector forestal en América Latina y el Caribe. Available from <http://www.fao.org> [Accessed March 2011]; Ceballos et al. 2009), and due to their economic importance almost all forests are now managed to some degree (Newton et al. 2006). Therefore, pristine coniferous forests are practically nonexistent (Paillet et al. 2010).

Although the Sierra de Juárez has been intensively surveyed (Peterson et al. 1993; Parra-Olea et al. 2005), new species are still being found (e.g., Ustach et al 2000, Hanken and Wake 2001; Nieto-Montes de Oca 2003; Flores-Villela et al. 2010). New species of salamanders have been recently described at a much faster rate than other amphibians (Flores-Villela and Canseco Márquez 2004). For example, during six months of surveys during this study, we found two new species of salamanders of the genus *Thorius* that are now in the process of being described. Oaxaca, where Sierra de Juárez is located, is the most diverse of the Mexican states (Flores-Villela and Gerez 1994; Casas-Andreu et al, 2004), and contains particularly rich salamander fauna in the highlands (Wake and Lynch 1976).

Species richness of amphibians and reptiles generally declines with elevation (Rahbek 1995), which is related to changes in vegetation, climate, temperature, and humidity (Marsh and Pearman 1997; Urbina-Cardona et al. 2006). By contrast, endemism increases with elevation (Flores-Villela 1993). Each vegetation type offers a number of habitats and microhabitats used differently by individual species (Huey 1991). Riparian vegetation and mixed pine-oak forests supported more lizards and snakes, whereas conifer and broadleaf forests contained more salamanders. Distribution, composition, and abundance of amphibians and reptiles depend directly on environmental features because they are ectothermic (Porter and Gates

1969). The difference in precipitation among low and high elevations was a total of 700 mm of total annual rainfall during our study period, causing higher humidity and lower temperatures at the highest elevation sites.

In our study sites, the vegetation type was directly associated with elevation. We often observed the same species of amphibians and reptiles in vegetation types at similar elevations. It has been suggested that differences in species composition and abundance can be associated with changes in elevation rather than changes in vegetation type (Fischer and Lindenmayer 2005). The herpetofaunal composition and abundance at lower elevations in pine-oak or oak-pine mixed forests, and riparian vegetation, differed substantially from that of higher elevations in coniferous and broadleaf forests (Appendix 1). The lizards *Sceloporus formosus*, *Anolis quercorum*, and *Plestiodon brevirostris* were the dominant species in lower elevations sites, while the salamanders *Pseudoeurycea juarezi*, and *Thorius narisovalis* were dominant in the higher sites. Based on abundance, amphibians were not an important component of the community at low elevations, and the only important reptile species at high elevations was the lizard *Mesaspis viridiflava*. These species are segregated by elevation, which is associated with species turnover.

Herpetological diversity is constrained by particular environmental features (Welsh 1990). Environmental changes related to elevation modify amphibian and reptile diversity in montane forests (Poynton et al. 2007). Reptile diversity decreases with altitude (Soares and Brito 2007), while salamanders tend to increase in species diversity above 1,200 m elevation (Wake and Lynch 1976; Parra-Olea 2002). We found this pattern in Yavesía (1,800 m elev.), although we found less diversity and abundance in anurans than other forests with similar conditions and fauna (e.g., Omiltemi, Guerrero southern México; Flores-Villela and Muñoz-Alonso 1993). The diversity found in Yavesía was relatively low, although sampling was done with similar effort by searching every potential microhabitat, as in other tropical studies (Peterson et al. 2004; Urbina-Cardona et al. 2006; Cabrera-Guzmán and Reynoso 2012). We do not reject the possibility of missing some species because arboreal species were not sampled since we only sampled species from ground level to two meters height. Overall, it

seems that in tropical coniferous forests, temperature and humidity constrain amphibian and reptile diversity more than microhabitat availability.

Apparently, reptile distributions are constrained by temperature, while amphibian distributions are constrained more by humidity (Wake and Lynch 1976; Heatwole 1982; Navas 2006). This pattern matches with higher temperatures in lower sites and higher humidity in higher sites found in Yavesía. At higher elevations, the relative humidity was over 95% 12 h per day, which may have explained the higher salamander abundance. At lower sites, salamanders were observed in more humid environments associated with streams within mixed forests (Crosswhite et al. 1999). Contrary to expectations, no salamanders were found in riparian vegetation. Salamanders in our survey were found in areas associated with trunks or rocks. In the sites with riparian vegetation, there was a more open canopy and there was more sunlight and less rock and logs.

In higher elevation sites lizard abundance was low and snakes were not observed. Low temperatures may constrain reptile distributions (Spellerberg 1972). In tropical temperate forests temperature does not vary greatly, and low temperatures are maintained during all seasons (Sarmiento 1986). Low temperatures during considerable periods affect reptiles because they need to cover certain periods of heating to keep their metabolism, independently of the elevation they live at (Navas 2003). Higher sites have more canopy cover, providing lower solar radiation that may affect reptile abundance (Pike et al. 2011). Although we did not measure solar radiation we observed a higher canopy cover at higher elevations. In our study this can be reflected in the lower temperatures registered in the higher sites. Basking sites and available hours for thermoregulation and activity could be lower, likely representing energetic constraints in reptile distributions (Zug 1993; Sears and Angilletta 2004). Temperature may also affect amphibians, contrast to reptiles they are able to change their physiology through ecological and behavioral strategies that allow acclimation to higher elevations (Navas 2006).

Community structure was similar among vegetation types at the same elevation, although distance between sites was considerable, and sites were separated either by fragmented landscapes or urban areas. Although it seems

that elevation was the most important factor, some species were restricted to particular vegetation types. For example, the frog *Hyla euphorbeacea*, the lizard *Phrynosoma braconneri*, the snakes *Leptodeira polysticta*, *Rhadinaea taeniata*, and *Crotalus molossus*, and the turtle *Kinosternon integrum*, were found only in riparian vegetation; the salamander *Thorius* sp. nov. 1, and the snake *Pituophis lineaticolis* in oak-pine forest; the salamander *Thorius* sp. nov. 2, and the snakes *Thamophis crysocephalus*, and *Crotalus intermedius* in pine-oak forest; and the salamanders *Pseudoeurycea saltator*, *P. smithi*, and *Thorius macdouglli*, and the lizard *Mesaspis viridiflava* in coniferous forest. Unique species can be affected by particular microenvironmental features that are defined by each vegetation type (Atauri and De Lucio 2001; Hampton et al. 2010). If these species can only be found on a particular vegetation type, despite adequate search effort, the alteration of each vegetation type may cause the extinction of unique species. This would be particularly dramatic for recently discovered new species (Wake and Campbell 2001).

In temperate regions, coniferous forests are the dominant arboreal vegetation (Norton 1996; Schmitt et al. 2009). However, in the tropics these forests are restricted to high elevations (Miranda and Sharp 1950; Ricketts et al. 2005), and surrounded by other kind of habitats (e.g. cloud forest, rainforest, dry forest, grasslands; Rzedowski 1998; Oviedo 2002) that provide faunal and floral elements to forest diversity (Rodríguez-Cabal et al. 2008). Temperate forests have low diversity compared to adjacent tropical rainforest (Barnosky et al. 2001; Koleff et al. 2003), but endemics tend to concentrate in the former (Flores-Villela 1993, Peterson et al. 1993; Armesto et al. 1998). Composition and community structure of tropical forests are different from those in northern temperate areas, and can be highly diverse with high species turnover (García et al. 2007). Amphibian and reptile diversity in mountain areas with tropical influence have been described in India, Madagascar, the Philippines, Colombia, Ecuador, and Peru (Brown and Alcalá 1961; Lynch 1997; Deepak and Vasudevan 2008; Raxworthy 2008; Ramírez et al. 2009; Nuñez et al. 2010). However, geological and biological components at these sites are different, making diversity comparisons difficult (DeStefano 2002; Dahl et al. 2009).

Mexico has many endemic amphibian and reptile species (Flores-Villela 1993; Campbell 1999). In Yavesía 83% of the herpetofauna is endemic to México, which represents 4.2% of all Mexican endemic herpetofauna (Flores-Villela and Canseco-Márquez 2004; Ochoa-Ochoa and Flores-Villela 2006; Wilson et al. 2010). High levels of endemism in the Sierra Norte of Oaxaca have been reported for different taxa (Lorence and García-Mendoza 1989 [flowering plants]; Luis et al. 1991 [butterflies]; Peterson and Navarro 2000 [birds]; Hanken and Wake 2001 [salamanders]; Monteagudo and León 2000 [mammals]) including amphibians and reptiles (Casas-Andreu et al. 2004, Flores-Villela et al. 2010). These species may be threatened due to forest exploitation. The Sierra Norte of Oaxaca covers 10% of the state surface and supports 28% of the total herpetofauna of the state of Oaxaca. The loss of pristine forest in the area will have a major impact in the biodiversity of tropical temperate forests.

CONCLUSIONS

The last remaining pristine forests in northern Oaxaca are endangered mainly because of timber exploitation (Ceballos et al. 2009). Surveyed forest remnants are surrounded by managed areas and may be targets for further exploitation in the near future both legal and illegal. Once forests are disturbed, they do not recover quickly. Baseline information of community structure provides the foundation for conserving biological diversity (Dodd 1992; Oliver and Beattie 1993; Russell et al. 2002). This information needs to be generated because it will be the reference for evaluating the degree of conservation of a site, or the goal in protection or restoration projects (Ponce Reyes et al. 2012).

Our study demonstrates that pristine forest harbor endemic communities of amphibians and reptiles in a small area associated with elevation change associated with vegetation type. Amphibians and reptiles are particularly threatened because of their dependence on microclimate as demonstrated by this study with the association of certain species to specific vegetation types. Exploitation is directed towards wood extraction from all vegetation types, eliminating habitats, and breaking the balance between amphibians and reptiles and their ecosystems. The Sierra de Juárez supports many endemic species, all of which are

threatened because of habitat degradation, fragmentation, or destruction. Forest management decisions applied to local scale can have a significant impact on local amphibians and reptile communities (Greenbaum and Komar 2005) and could help promote maintenance of local biodiversity.

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LITERATURE CITED

- Armesto, J.J., R. Rozzi, C. Smith-Ramirez, and M.T.K. Arroyo. 1998. Conservation targets in South American temperate forests. *Science* 282:1271–1272.
- Atauri, J.A., and J.V. De Lucio. 2001. The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. *Landscape Ecology* 16:147–159.
- Barnosky, A.D., E.A. Hadly, B.A. Maurer, and M.I. Christie. 2001. Temperate terrestrial vertebrate faunas in North and South America: interplay of ecology, evolution, and geography with biodiversity. *Conservation Biology* 15:658–674.
- Bengtsson, J., S.G. Nilsson, A. Franc, and P. Menozzi. 2000. Biodiversity, disturbances, ecosystem function and management of European forests. *Forest Ecology Management* 132:39–50.
- Brown, W.C., and A.C. Alcala. 1961. Populations of amphibians and reptiles in the submontane and montane forests of Cuernos de Negros, Philippine Islands. *Ecology* 42:628–636.
- Cabrera-Guzmán, E., and V.H. Reynoso. 2012. Amphibian and reptile communities of rainforest fragments: minimum patch size to support high richness and abundance. *Biodiversity and Conservation* 21:3243–3265.
- Campbell, J.A. 1999. Distribution patterns of amphibians in middle America. Pp. 111–209 *In* *Distribution Patterns of Amphibians: a Global Perspective*. Duellman, W.E. (Ed.). Johns Hopkins University Press, Baltimore, Maryland, USA.
- Casas-Andreu, G., F.R. Méndez De La Cruz, and X. Aguilar-Miguel. 2004. Anfibios y Reptiles. Pp. 375–390 *In* *Biodiversidad de Oaxaca*. Instituto de Biología, UNAM-Fondo Oaxaqueño para la Conservación de la Naturaleza. García-Mendoza, A.J., M.J. Ordóñez, and M. Briones-Salas (Eds.). World Wildlife Fund, México, Distrito Federal, México.
- Ceballos, G., M.M. Vale, C. Bonacic, J. Calvo-Alvarado, R. List, N. Bynum, R.A. Medellín, J.A. Simonetti, and J.P. Rodríguez. 2009. Conservation challenges for the Austral and Neotropical America section. *Conservation Biology* 23:811–817.
- Chao, A., R.L. Chazdon, R.K. Colwell, and T.-J. Shen. 2006. Abundance-based similarity indices and their estimation when there are unseen species in samples. *Biometrics* 62:361–371.
- Chao, A., W.H. Hwang, Y.C. Chen, and C.Y. Kuo. 2000. Estimating the number of shared species in two communities. *Statistica Sinica* 10:227–246.
- Chávez-León, G., A. Velázquez, A. Fregoso, and G. Bocco. 2004. Habitat associations of the Long-tailed Wood-partridge (*Dendroortyx macroura*) in a managed coniferous forest in Michoacán, Mexico. *Biodiversity Conservation* 13:1943–1960.
- Colwell, R.K. 2005. EstimateS: Statistical estimation of species richness and shared species from samples. Version 7.5. User's Guide and application available at: <http://purl.oclc.org/estimates>.
- Colwell, R., and J. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society London Series B* 345:101–118.
- Cromer, R.B., J.D. Lanham, and H.H. Hanlin. 2002. Herpetofaunal response to gap and skidder-rut wetland creation in a Southern Bottomland Hardwood Forest. *Forest Science* 48:407–413.
- Crosswhite, D.L., S.F. Fox, and R.E. Thill. 1999.

- Comparison of methods for monitoring reptiles and amphibians in upland forests of the Ouachita Mountains. *Proceedings of Oklahoma Academy of Sciences* 79:45–50.
- Dahl, C., V. Novotny, J. Moravec, and S.J. Richards. 2009. Beta diversity of frogs in the forests of New Guinea, Amazonia and Europe: contrasting tropical and temperate communities. *Journal of Biogeography* 36:896–904.
- Deepak, V., and K. Vasudevan. 2008. Density and microhabitat association of *Salea anamallayana* in Eravikulam National Park, Western Ghats, India. *Herpetological Journal* 18:165–170.
- deMaynadier, P.G., and M.L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. *Environmental Reviews* 3:230–261.
- DeStefano, S. 2002. Regional and national issues for forest wildlife research and management. *Forest Science* 48:181–189.
- Dodd, Jr., C.K. 1992. Biological diversity of a temporal pond herpetofauna in north Florida Sandhills. *Biodiversity Conservation* 1:125–142.
- Drumbrell, A.J., E.J. Clark, G.A. Frost, T.E. Randell, J.W. Pitchford, and J.K. Hill. 2008. Changes in species diversity following habitat disturbance are dependent on spatial scale: theoretical and empirical evidence. *Journal of Applied Ecology* 45:131–139.
- Fischer, J., and D.B. Lindenmayer. 2005. The sensitivity of lizards to elevation: A case study from south-eastern Australia. *Diversity and Distributions* 11:225–233.
- Flores-Villela, O. 1993. Herpetofauna of Mexico: distribution and endemism. Pp. 253–280 *In* Biological Diversity of Mexico: Origins and Distributions. Ramamoorthy, T.P., R. Bye, A. Lot, and J. Fa. (Eds.). Oxford University Press, New York, New York, USA.
- Flores-Villela, O., and L. Canseco-Márquez. 2004. Nuevas especies y cambios taxonómicos para la herpetofauna de México. *Acta Zoológica Mexicana (nueva serie)* 20:115–144.
- Flores-Villela, O., and P. Gerez. 1994. Biodiversidad y Conservación en México: Vertebrados, Vegetación y Uso del Suelo. CONABIO/UNAM, México, Distrito Federal, México.
- Flores-Villela, O., and A. Muñoz-Alonso. 1993. Anfibios y reptiles. Pp. 411–442 *In* Historia Natural del Parque Ecológico Estatal Omiltemi, Chilpancingo, Guerrero, México. Luna-Vega, I., and J. Llorente-Bousquets (Eds.). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Universidad Nacional Autónoma de México, México, Distrito Federal, México.
- Flores-Villela, O., L. Canseco-Márquez, and L. Ochoa-Ochoa. 2010. Geographic distribution and conservation of the herpetofauna of the highlands of Central Mexico. Pp. 303–321 *In* Conservation of Mesoamerican Amphibians and Reptiles. Wilson, L.D., J.H. Townsend, and J.D. Johnson (Eds.). Eagle Mountain Publishing Co., Eagle Mountain, Utah, USA.
- García, A., H. Solano-Rodríguez, and O. Flores-Villela. 2007. Patterns of alpha, beta and gamma diversity of the herpetofauna in Mexico's Pacific lowlands and adjacent interior valleys. *Animal Biodiversity and Conservation* 30:169–177.
- Gardner, T.A., J. Barlow, S.S. Navjot, and C.A. Peres. 2010. A multi-region assessment of tropical forest biodiversity in a human-modified world. *Biological Conservation* 143:2293–2300.
- Gardner, T.A., M.A. Ribeiro Jr., J. Barlow, T.C.S. Avila-Pires, M.S. Hoogmoed, and C.A. Peres. 2007. The biodiversity value of primary, secondary and plantation forests for a neotropical herpetofauna. *Conservation Biology* 21:775–787.
- Gardner, T.A., J. Barlow, I.S. Araujo, T.C. Ávila-Pires, A.B. Bonaldo, J.E. Costa, M.C. Esposito, L.V. Ferreira, J. Hawes, M.I. Hernandez, et al. 2008. The cost-effectiveness of biodiversity surveys in tropical forests. *Ecology Letters* 11:139–150.
- Gibbons, J.W., D.E. Scott, T.J. Ryan, K.A. Buhlmann, T.D. Tuberville, B.S. Metts, J.L. Greene, T. Mills, Y. Leiden, S. Poppy, and C.T. Winne. 2000. The global decline of reptiles, déjà vu amphibians. *BioScience* 50:653–666.
- Gibbs, J.P. 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. *Journal of Wildlife Management* 62:584–589.
- Goldingay, R., G. Daly, and F. Lemckert. 1996. Assessing the impacts of logging on reptiles and frogs in the montane forests of southern New South Wales. *Wildlife Research* 23:495–510.
- Greenbaum, E., and O. Komar. 2005. Threat

- assessment and conservation prioritization of the herpetofauna of El Salvador. *Biodiversity Conservation* 14:2377–2395.
- Greller, A.M. 1990. Comparison of humid forest zones in eastern Mexico and southeastern United States. *Bulletin of the Torrey Botanical Club* 117:382–396.
- Hampton, P.M., B.F. Neil, and K. Herriman. 2010. Impacts of active oil pumps and deer feed plots on amphibian and reptile assemblages in a floodplain. *American Midland Naturalist* 163:44–53.
- Hanken, J., and D.B. Wake. 2001. A seventh species of minute salamander (*Thorius*: Plethodontidae) from the Sierra de Juárez, Oaxaca, Mexico. *Herpetologica* 57:515–523.
- Heatwole, H. 1982. A review of structuring in herpetofaunal assemblages. Pp 1–9 *In* *Herpetofaunal Communities: a Symposium of the Society for the Study of Amphibians and Reptiles and the Herpetologists' League*. Scott, N.J., Jr. (Ed.). *Wildlife Research Report 13*. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C., USA.
- Hernandez-Salinas, U., and A. Ramírez-Bautista. 2012. Diversity of amphibian communities in four vegetation types of Hidalgo State, Mexico. *The Open Conservation Biology Journal* 6:1–11.
- Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C., USA.
- Huey, R.B. 1991. Physiological consequences of habitat selection. *American Naturalist* 137:S91–S115.
- Jędrzejewska, B., M. Brzeziński, and W. Jędrzejewski. 2003. Seasonal dynamics and breeding of amphibians in pristine forests (Białowieża National Park, E Poland) in dry years. *Folia Zoologica* 52:77–86.
- Jones, K.B. 1986. Amphibians and reptiles. Pp. 267–290 *In* *Inventory and Monitoring of Wildlife Habitat*. Cooperrider, A.Y., R.J. Boyd, and H.R. Stuart (Eds.). U.S. Department of Interior Bureau of Land Management Service Center, Denver, Colorado, USA.
- Josefsson, T., J. Olsson, and L. Östlund. 2010. Linking forest history and conservation efforts: Long-term impact of low-intensity timber harvest on forest structure and wood-inhabiting fungi in northern Sweden. *Biological Conservation* 143:1803–1811.
- Koleff, P., J.J. Lennon, and K.J. Gaston. 2003. Are there latitudinal gradients in species turnover? *Global Ecology and Biogeography* 12:483–498.
- Lindenmayer, D.B. 2010. Landscape change and the science of biodiversity conservation in tropical forests: A view from the temperate world. *Biological Conservation* 143:2405–2411.
- Lorence, D.H., and J. García-Mendoza. 1989. Oaxaca, México. Pp. 253–269 *In* *Floristic Inventory of Tropical Countries*. Campbell, D.G., and H.D. Hammond (Eds.). The New York Botanical Garden, New York, New York, USA.
- Luis, A., I. Vargas, and J. Llorente. 1991. Lepidopteroafauna de Oaxaca: distribución y fenología de los Papilionoidea de la Sierra de Juárez. *Publicaciones especiales del museo de Zoología* 3:1–119.
- Lynch, J.D., P. Ruiz-Carranza, and M.C. Ardilla-Robayo. 1997. Biogeographic patterns of Colombian frogs and toads. *Revisa de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 80:237–248.
- Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing Company, Malden, Massachusetts, USA.
- Marsh, D.M., and P.B. Pearman. 1997. Effects of habitat fragmentation on the abundance of two species of Leptodactylid frogs in an Andean montane forest. *Conservation Biology* 11:1323–1328.
- Miranda, F., and J. Sharp. 1950. Characteristics of the vegetation in certain temperate regions of eastern Mexico. *Ecology* 31:313–333.
- Monteagudo, D., and L. León. 2002. Estudio comparativo de los patrones de riqueza altitudinal de especies en mastofaunas de áreas montañosas mexicanas. *Revista Mexicana de Mastozoología* 6:60–82.
- Morissette, L., T. Pedersen, and M. Nilsen. 2009. Comparing pristine and depleted ecosystems: The Sørkjord, Norway versus the Gulf of St. Lawrence, Canada. Effects of intense fisheries on marine ecosystems. *Progress in Oceanography* 81:174–187.
- Navas, C.A. 2003. Herpetological diversity along Andean elevational gradients: Links with physiological ecology and evolutionary physiology. *Comparative Biochemistry Physiology* 133:469–485.
- Navas, C.A. 2006. Patterns of distribution of anurans in high Andean tropical elevations:

- Insights from integrating biogeography and evolutionary physiology. *Integrative Comparative Biology* 46:82–91.
- Newton, A.C., E. Marshall, K. Schreckenberg, D. Golicher, D.W. te Velde, F. Edouard, and E. Arancibia. 2006. Use of a Bayesian belief network to predict the impacts of commercializing non-timber forest products on livelihoods. *Ecology and Society* 11:24.
- Newton, A.C., L. Cayuela, C. Echeverría, J.J. Armesto, R.F. Del Castillo, D. Golicher, D. Geneletti, M. Gonzalez-Espinosa, A. Huth, F. López-Barrera, et al. 2009. Toward integrated analysis of human impacts on forest biodiversity: lessons from Latin America. *Ecology and Society* 14:2.
- Nieto-Montes De Oca, A. 2003. A new species of the *Geophis dubius* group (Squamata: Colubridae) from the Sierra de Juárez of Oaxaca, Mexico. *Herpetologica* 59: 572–585.
- Norton, T.W. 1996. Conservation of biological diversity in temperate and boreal forest ecosystems. *Forest Ecology Management* 85:1–7.
- Novotny, V., S.E. Miller, Y. Basset, M. Janda, G.P. Setliff, J. Hulcr, A.J.A. Stewart, J. Auga, K. Molem, M. Manumbor, et al. 2007. Low beta diversity of herbivorous insects in tropical forests. *Nature* 448:692–696.
- Nuñeza, O.M., F.B. Ates, and A.A. Alicante. 2010. Distribution of endemic and threatened herpetofauna in Mt. Malindang, Mindanao, Philippines. *Biodiversity Conservation* 19:503–518.
- Ochoa-Ochoa, L., and O. Flores-Villela. 2006. Areas de Diversidad y Endemismo de la Herpetofauna Mexicana, México, DF: Universidad Nacional Autónoma de México—Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, City, State, México.
- Oliver, I., and A.J. Beattie. 1993. A possible method for the rapid assessment of biodiversity. *Conservation Biology* 7:562–568.
- Oviedo, G. 2002. The Community Protected Natural Areas in the State of Oaxaca, Mexico. World Wildlife Fund, Gland, Switzerland.
- Owens, A.K., K.R. Moseley, T.S. McCay, S.B. Castleberry, J.C. Kilgo, and W.M. Ford. 2008. Amphibian and reptile community response to coarse woody debris manipulations in upland loblolly pine (*Pinus taeda*) forests. *Forest Ecology Management* 256:2078–2083.
- Paillet Y., L. Bergès, J. Hjältén, P. Odor, C. Avon, M. Bernhardt-Römermann, R.J. Bijlsma, L. De Bruyn, M. Fuhr, U. Grandin, et al. 2010. Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. *Conservation Biology* 24:101–112.
- Parra-Olea, G. 2002. Molecular phylogenetic relationships of neotropical salamanders of the genus *Pseudoeurycea*. *Molecular Phylogenetics and Evolution* 22:234–246.
- Parra-Olea, G., M. García-París, and D.B. Wake. 1999. Status of some populations of Mexican salamanders (Amphibia: Plethodontidae). *Revista de Biología Tropical* 47:217–223.
- Parra-Olea, G., M. García-París, J. Hanken, and D.B. Wake. 2005. Two new species of *Pseudoeurycea* (Caudata: Plethodontidae) from the mountains of Northern Oaxaca, Mexico. *Copeia* 3:461–469.
- Peterson, A.T., and A.G. Navarro-Sigüenza. 2000. Western Mexico: A significant centre of avian endemism and challenge for conservation action. *Cotinga* 14:42–46.
- Peterson, A.T., O. Flores-Villela, L. León-Paniagua, J.E. Llorente-Bousquets, M.A. Luis-Martínez, A.G. Navarro-Sigüenza, M.G. Torres-Chávez, and I. Vargas-Fernández. 1993. Conservation priorities in Mexico: moving up in the world. *Biodiversity Letters* 1:33–38.
- Peterson, A.T., L. Canseco, J.L. Contreras, G. Escalona-Segura, O. Flores-Villela, J. García-López, B. Hernández-Baños, C.A. Jiménez, L. León-Paniagua, S. Mendoza, et al. 2004. A preliminary biological survey of Cerro Piedra Larga, Oaxaca, Mexico: birds, mammals, reptiles, amphibians, and plants. *Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Zoología* 75:439–466.
- Pike, D.A., J.K. Webb, and R. Shine. 2011. Removing forest canopy restores a reptile assemblage. *Ecological Applications* 21:274–280.
- Ponce-Reyes, R., V.H. Reynoso-Rosales, J.E.M. Watson, J. Vanderwal, R.A. Fuller, R.L. Pressey, and H.P. Possingham. 2012. Vulnerability of cloud forest reserves in Mexico to climate change. *Nature Climate Change* 2:448–452.
- Porter, W.P., and D.M. Gates. 1969. Thermodynamic equilibria of animals with environment. *Ecological Monographs* 39:227–244.
- Poynton, J.C., S.P. Loader, E. Sherratt, and B.T. Clarke. 2007. Amphibian diversity in east

- African biodiversity hotspots: Altitudinal and latitudinal patterns. *Biodiversity Conservation* 16:1103–1118.
- Quintana-Ascencio, P.F., N. Ramírez-Marcial, M. González-Espinosa, and M. Martínez-Icó. 2004. Sapling survival and growth of coniferous and broad-leaved trees in successional highland habitats in Mexico. *Applied Vegetation Science* 7:81–88.
- Rahbek, C. 1995. The elevational gradient of species richness: a uniform pattern? *Ecography* 18:200–205.
- Raxworthy, C.J., R.G. Pearson, N. Rabibisoa, A.M. Rakotondrazafy, J.B. Ramanamanjato, A.P. Raselimanana, S. Wu, R.A. Nussbaum, and D.A. Stone. 2008. Extinction vulnerability of tropical montane endemism from warming and upslope displacement: a preliminary appraisal for the highest massif in Madagascar. *Global Change Biology* 14:1703–1720.
- Ricketts, T.H., E. Dinerstein, T. Boucher, T.M. Brooks, S.H. Butchart, M. Hoffman, J.F. Lamoreux, J. Morrison, M. Parr, J.D. Pilgrim, et al. 2005. Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences of the United States of America* 51:18497–18501.
- Rodríguez-Cabal, M.A., M.A. Nuñez, and A.S. Martínez. 2008. Quantity versus quality: Endemism and protected areas in the temperate forest of South America. *Austral Ecology* 33:730–736.
- Rohlf, F.J. 1998. NTSYS. Numerical taxonomy and multivariate analysis system. Version 2.02. Exeter Software, New York, New York, USA.
- Rouvinen, S., T. Kuuluvainen, and L. Karjalainen. 2002. Coarse woody debris in old *Pinus sylvestris* dominated forests along a geographic and human impact gradient in boreal Fennoscandia. *Canadian Journal of Forest Research* 32:2184–2200.
- Russell, K.R., D.C. Guynn, Jr., and H.G. Hanlin. 2002. Importance of small isolated wetlands for herpetofaunal diversity in managed, young growth forests in the Coastal Plain of South Carolina. *Forest Ecology Management* 163:43–59.
- Rzedowski, J. 1998. Diversidad y orígenes de la flora fanerogámica de México. Pp. 129–145 *In* *Diversidad Biológica de México. Orígenes y Distribución*. Ramamoorthy, T.P., R. Bye, A. Lot, and J. Fa. (Eds.). Oxford University Press, New York, New York, USA.
- Ramírez, S., P. Meza-Ramos, M. Yáñez-Muñoz, and J. Reyes. 2009. Asociaciones interespecíficas de anuros en cuatro gradientes altitudinales de la Reserva Biológica Tapichalaca, Zamora-Chinchipe, Ecuador. *Boletín Técnico* 8, Serie Zoológica, Centro de Investigaciones IASA Sangolquí, Ecuador 4: 35–49.
- Sarmiento, G. 1986. Ecological features of climate in high tropical mountains. Pp. 11–46 *In* *High Altitude Tropical Biogeography*. Vuilleumier, F., and M. Monasterio. (Eds.). Oxford University Press, New York, New York, USA.
- Schmitt, C.B., N.D. Burgess, L. Coad, A. Belokurov, C. Besançon, L. Boisrobert, A. Campbell, L. Fish, D. Gliddon, K. Humphries, V. Kapos, et al. 2009. Global analysis of the protection status of the world's forests. *Biological Conservation* 142:2122–2130.
- Scrocchi, G., and S. Kretzschmar. 1996. Guía de Métodos de Captura y Preparación de Anfibios y Reptiles para Estudios Científicos y Manejo de Colecciones Herpetológicas. Miscelanea 102. Fundación Miguel Lillo, Tucumán, Argentina.
- Sears, M.W., and M.J. Angilletta. 2004. Body size clines in *Sceloporus* lizards: Proximate mechanisms and demographic constraints. *Integrative and Comparative Biology* 44:433–442.
- Siegel, S. 1988. *Nonparametric Statistics for the Behavioral Sciences*. McGraw-Hill, New York, New York, USA.
- Soares, C., and J.C. Brito. 2007. Environmental correlates for species richness among amphibians and reptiles in a climate transition area. *Biodiversity Conservation* 16:1087–1102.
- Spellerberg, I.F. 1972. Temperature tolerances of Southeast Australian reptiles examined in relation to reptile thermoregulatory behaviour and distribution. *Oecologia* 1:23–46.
- Todd, B.D., and K.M. Andrews. 2008. Response of a reptile guild to forest harvesting. *Conservation Biology* 22:753–761.
- Trisurat, Y., R. Alkemade, and P.H. Verburg. 2010. Projecting land-use change and its consequences for biodiversity in northern Thailand. *Environmental Management* 45:626–639.
- Urbina-Cardona, J.N., M. Olivares-Pérez, and V.H. Reynoso. 2006. Herpetofauna diversity and microenvironment correlates across a pasture-edge-interior ecotone in tropical

- rainforest fragments in the Los Tuxtlas Biosphere Reserve of Veracruz, Mexico. *Biological Conservation* 132:61–75.
- Ustach, P.C., J.R. Mendelson III, R.W. McDiarmid, and J.A. Campbell. 2000. A new species of *Hyla* (Anura: Hylidae) from the Sierra Mixes, Oaxaca, México, with comments on ontogenetic variation in the tadpoles. *Herpetologica* 56:239–250.
- Wake, D.B. 1991. Declining amphibian populations. *Science*. 253:860.
- Wake, D.B., and J.A. Campbell. 2001. An aquatic Plethodontid salamander from Oaxaca, Mexico. *Herpetologica* 57:509–514.
- Wake, D., and J.F. Lynch. 1976. The distribution, ecology and evolutionary history of plethodontid salamanders in tropical America. *Science Bulletin of the Natural History Museum of Los Angeles City* 25:1–65.
- Welsh, Jr., H.H. 1990. Relictual amphibians and old-growth forests. *Conservation Biology* 4:309–319.
- Wilson, L.D., J.H. Townsend and J.D. Johnson. 2010. *Conservation of the Mesoamerican Amphibians and Reptiles*. Eagle Mountain, Eagle Mountain, Utah. 812 p.
- Zar, J.H. 2010. *Biostatistical Analysis*. Prentice Hall, Saddle River, New Jersey, USA.
- Zug, R.G. 1993. *Herpetology: an Introductory Biology of Amphibians and Reptiles*. Academic Press, Inc., San Diego, California, USA.



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VÍCTOR HUGO REYNOSO obtained his Bachelors and Masters degrees at the Faculty of Sciences (Biology) at the Universidad Nacional Autónoma de México (UNAM), in México City, and his Ph.D. at McGill University in Montréal, Quebec. His research in the Institute of Biology at UNAM is focused on understanding the effects of degradation, fragmentation, and habitat destruction in the amphibian and reptile communities in tropical forests (rain forest, cloud forest, and dry forest); the phylogeny, phylogeography, and population genetics of important reptile groups (turtles, crocodiles, tuataras, iguanas, and rattlesnakes). He has founded a National wide iguana conservation working group that has evolved into the National group for the conservation of priority reptile species. (Photographed by Víctor Hugo Reynoso).



OSCAR A. FLORES-VILLELA is a Mexican native; his father was from El Salvador and his mother is from Mexico City. He has lived in Mexico and El Salvador, but has spent most of his life in Mexico City. His early collections formed the nucleus for what has grown into the herpetological collection at the Universidad Nacional Autónoma de México, Museo de Zoología Facultad de Ciencias (MZFC), of which he is one of two curators. The holdings of this collection constitute the largest herpetological resource in México, with over 37,000 preserved specimens and the first Mexican collection of frozen tissues. This collection began some years ago when he was a freshman at the School of Biology in UNAM and, together with two classmates, formed a laboratory to study amphibians and reptiles. He has directed an active group of students in systematic herpetology and conservation at UNAM for the last few years. He has published 110 scientific papers and book chapters, and has edited or co-authored 12 books pertaining to the Mexican herpetofauna and its conservation. He spent two years at Brigham Young University in Utah, working in collaboration with Dr. Jack W. Sites and learning techniques in molecular systematics. He also spent two years at the University of Texas, Arlington working with Jonathan A. Campbell on the herpetofauna of Mexico. He is a founder of the Mexican Herpetological Society. Currently he has four undergraduate students, one Master student, and two Ph.D. students, all working on conservation, systematic herpetology, or faunistic studies in México. (Photographed by Luis Canseco-Márquez).

Herpetological Conservation and Biology

APPENDIX 1. Number of individuals found of each species per vegetation type. Vegetation types are: RV – Riparian vegetation, OP – Oak-pine forest, PO – Pine-oak forest, BL – Broadleaf forest, CF – Coniferous forest. Red List annotates if the species in listed in the Mexican Red List of Threatened Species. Endemic species (*).

Species	Vegetation Type					Red List	Species Code
	RV	OP	PO	BL	CF		
<i>Craugastor mexicanus</i> *		19	2	2	13		1
<i>Eleutherodactylus nitidus</i> *	5	6					2
<i>Incilius occidentalis</i> *	5	1	1				3
<i>Hyla euphorbiacea</i> *	5						4
<i>Pseudoeurycea juarezi</i> *				49	44	X	5
<i>Pseudoeurycea smithi</i> *					1		6
<i>Pseudoeurycea saltator</i> *					1		7
<i>Thorius boreas</i> *				2	2		8
<i>Thorius narisovalis</i> *				23	26	X	9
<i>Thorius macdougalli</i> *					1		10
<i>Thorius sp nov 1</i>		1					11
<i>Thorius sp nov 2</i>			9				12
<i>Abronia oaxacae</i> *		2	1			X	A
<i>Barisia planifrons</i> *		2	5			X	B
<i>Gerrhonotus liocephalus</i> *	1	2				X	C
<i>Mesaspis viridiflava</i> *					37	X	D
<i>Phrynosoma branonnierei</i> *	2						E
<i>Sceloporus aureolus</i> *	15	18	1		9		F
<i>Sceloporus formosus</i> *	212	69	46	2	16		G
<i>Sceloporus microlepidotus</i> *		1	3		13	X	H
<i>Anolis quercorum</i> *	24	69	72				I
<i>Plestiodon brevirostris</i>		2	39				J
<i>Conopsis megalodon</i> *	4	7	1				K
<i>Geophis dubius</i> *	5	2	4			X	L
<i>Leptodeira polysticta</i>	1						M
<i>Pituophis lineaticollis</i>		1					N
<i>Rhadinaea fulvivittis</i> *		1	1				O
<i>Rhadinaea taeniata aemula</i> *	1						P
<i>Salvadora intermedia</i> *	3	2				X	Q
<i>Thamnophis crysocephalus</i> *			1			X	R
<i>Crotalus intermedius</i> *			1			X	S
<i>Crotalus molossus</i>	1					X	T
<i>Crotalus ravus</i> *	1	1	2			X	U
<i>Ophryacus undulatus</i> *	1		2			X	V
<i>Kinosternon integrum</i>	1					X	W