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ORIGINAL ARTICLE

Taxonomic and functional diversity of the amphibian and reptile communities of the state of Durango, Mexico

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Abstract

Taxonomic and functional diversity metrics have been used together to describe functional patterns through species richness in a given area or region. Many scientists have shown that these two metrics can be positively correlated; nevertheless, other studies have found the opposite. In either case, the usefulness of both metrics has helped to develop more reasoned conservation strategies in areas where biodiversity loss is occurring at an accelerated rate. In this study, we calculated metrics of both taxonomic and functional diversity in amphibian and reptile communities located in a variety of vegetation types (xeric scrub, pine forest, pine-oak forest, cloud forest, oak forest, and tropical dry forest) in the state of Durango. Using species richness (157 species: 36 amphibians and 121 reptiles) for the state of Durango, we found that the amphibian communities present in pine forest and pine-oak forest showed high values of taxonomic diversity (high Delta + values), meaning that the communities in these vegetation types are composed of a complex network of families and genera. The same result was true of reptiles present in oak forest, tropical dry forest, and xeric scrub. The communities formed by the snakes showed high values of functional richness, functional evenness, and functional dispersion in all vegetation types, as did the lizard communities present in xeric scrub. This indicates that the ecological functions of lizards and snakes (i.e., predators; pest controllers; links in the trophic chain) are an integral element of the functioning of these ecosystems. These results showed that vegetation types with greater taxonomic and functional diversity in amphibians and reptiles are sites that promote the sustainability of an ecosystem in particular ways, making them more suitable for conservation of these vertebrates. The information from this study can be useful in developing protection programs and implementing conservation strategies for several biological groups in particular areas of Durango and the Sierra Madre Occidental, helping to ensure the permanence of the remarkable biota of northern Mexico.

Keywords Species richness · Community · Vegetation types · Herpetofauna · Ecoregion · Biogeography

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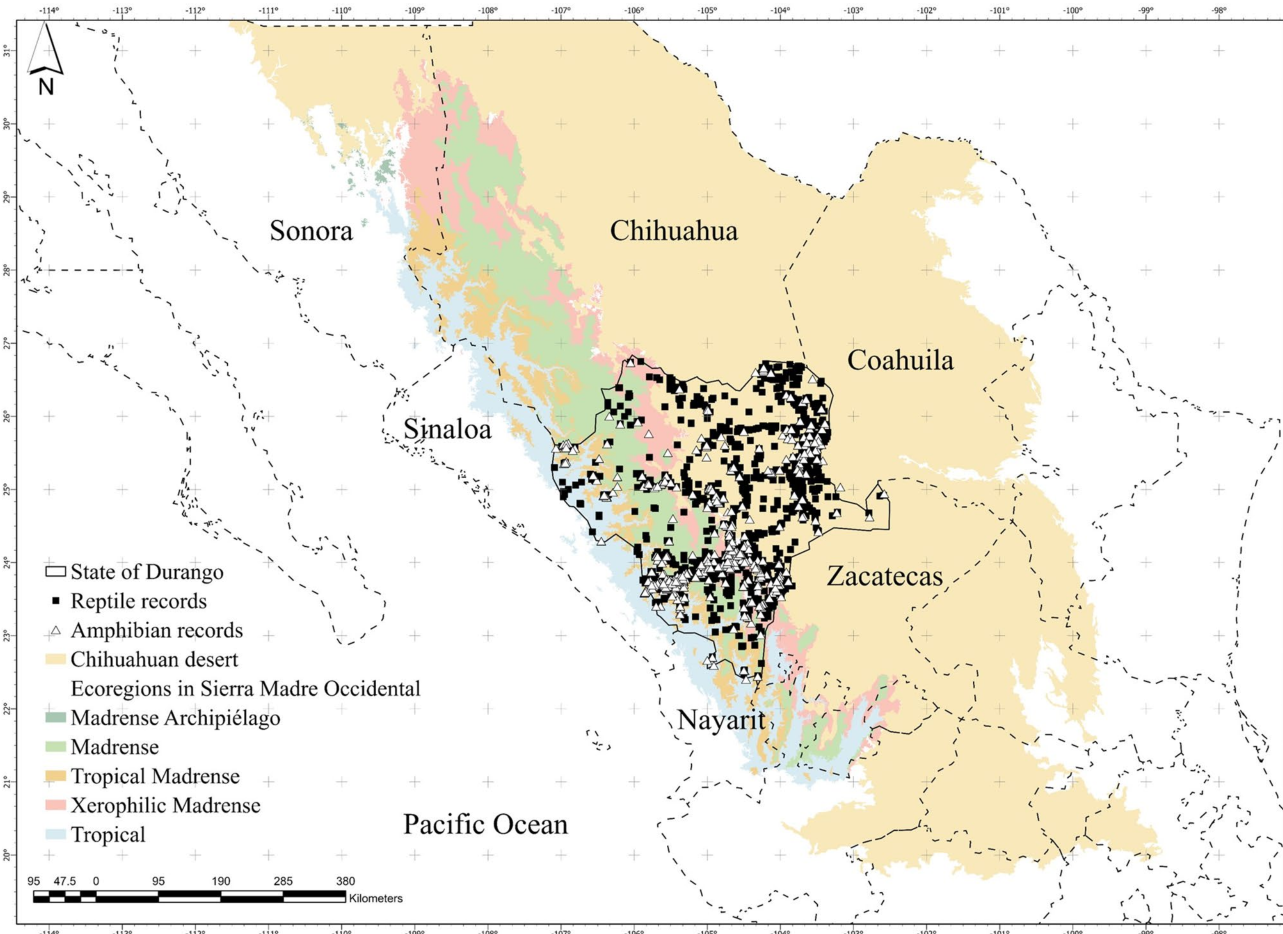
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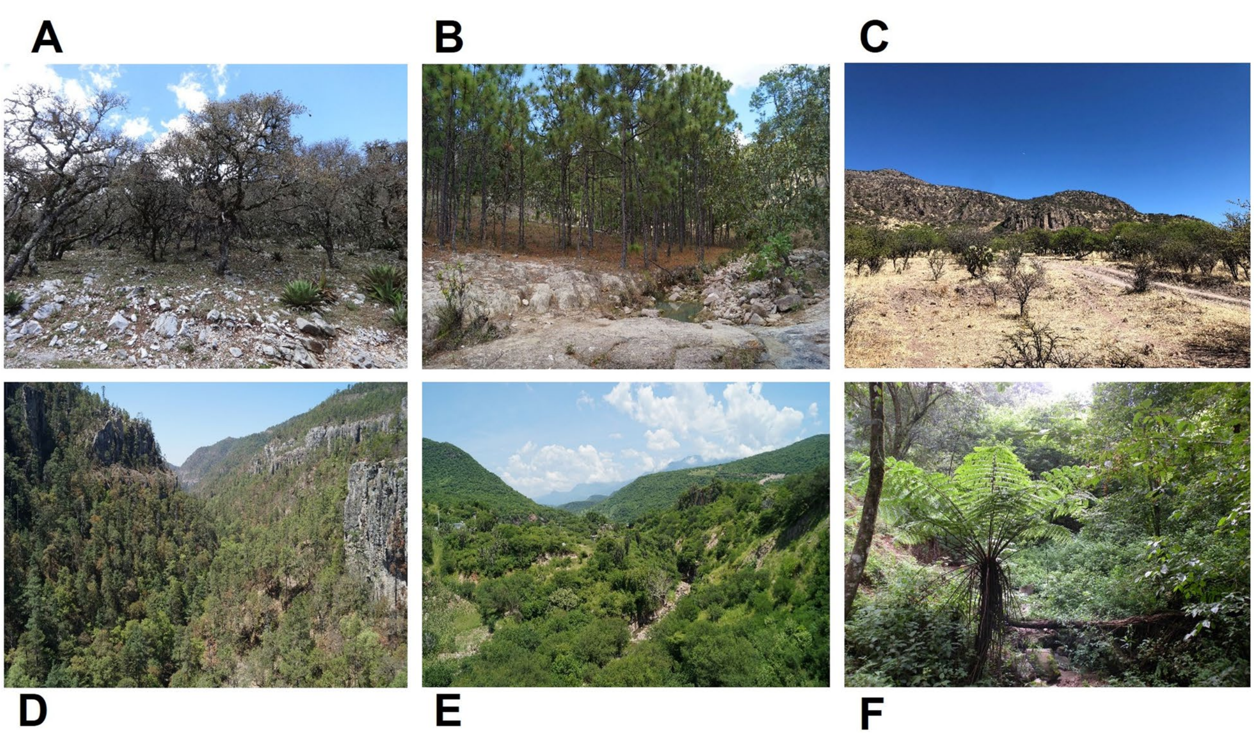
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◂**Fig. 1** Amphibian and reptile records and vegetation types used in this study. **A** Oak forest (dry season), Pablillo, in the municipality of Galeana, Nuevo León, at an elevation of 2580 m; **B** Oak-pine forest (dry season), El Duraznito, in the municipality of El Nayar, Nayarit, at an elevation of 2200 m; **C** Xeric scrub (dry season), Rancho El Bufalo, in the municipality of Canatál, Durango, at an elevation of 2025 m; **D** Pine forest (dry season), Salto del Agua Llovida, Durango, Durango, at an elevation of 1900 m; **E** Tropical dry forest (wet season), La Guerra, in the municipality of El Nayar, Nayarit, at an elevation of 465 m; **F** Cloud forest (wet season), Medio Monte, in the municipality of San Bartolo Tutotepec, Hidalgo, at an elevation of 1800 m. Photographs by Uriel Hernández-Salinas

Introduction

Geographic regions with a complex topography favor diversity, species richness, turnover of species among sites, and functionality of ecosystems (Chen et al., 2011). An example of a complex geographic area is Mexico, which has been subject to countless vicariance events that have resulted in the formation of barriers and corridors for upland and lowland species. Mexico is also the product of two great biogeographical regions (Neartic and Neotropical), which together give rise to the Trans-Mexican Volcanic Belt (Halffter, 1976; Halffter et al., 2008; Morrone, 2015), producing one of the most outstanding faunas in the world, including amphibians (431) and reptiles (989) (numbers updated to March 08, 2023; Ramírez-Bautista in press).

Due to the complex evolutionary and biogeographic history of the herpetofauna of Mexico, its analysis can be approached through numerous different metrics such as, phylogenetic, genetic, ecological, evolutionary, taxonomic, and functional metrics (Cruz-Elizalde et al., 2022). The relationship between these last two metrics (taxonomic and functional diversity) has been controversial, since taxonomic diversity and the functioning of ecosystems are not clear yet; however, the functional diversity approach can be used to explain this relationship (Cadotte et al., 2011; Cilleros et al., 2016; Larson et al., 2021).

At the end of the twentieth century, Clarke and Warwick (1998, 1999) and Warwick and Clarke (1995, 1998), introduced the concept of taxonomic diversity as an extension of species richness and diversity. They consider that a community with closely related species is less biodiverse in a phylogenetic sense than a community with low relatedness among species. Based on this concept, the average taxonomic index Delta + ($\Delta +$) and average taxonomic variation Lambda + ($\Lambda +$) were used to distinguish the degree of taxonomic relationship among plant and animal communities within the same ecosystem.

The concept of functional diversity was introduced by Faith (1996) and applied analytically by Petchey and Gaston (2002). According to Faith (1996), functional diversity is the key to understanding the relationship between the structure of communities and ecosystem function, considering first that the functional traits of species (type of diet, reproduction, behavior) are the most important characteristics determining the proper functioning of ecosystems (Violle et al., 2007). In addition, several studies have pointed out that the association between taxonomic and functional diversity is not always significant or predictable, because functional diversity components such as evenness and dispersion are independent of the number of species in the community (Jarzyna & Jetz, 2018; Mason et al., 2005; Morelli et al., 2018; Mouchet et al., 2010; Villéger et al., 2008).

The taxonomic diversity of animal communities present in various vegetation types or ecosystems of Mexico is high, and each community has functional features determined by its evolutionary history in its area of distribution, origin (Nearctic or Neotropical), ecological interactions, and use of resources (microhabitat and food), which together are the result of the evolutionary process that species have undergone within their habitats over time (Ricklefs & Miller, 1999). Amphibians and reptiles are one of the richest groups in Mexico; with almost 70% of them regarded as country endemic, and consequently representing very particular functional characteristics. For example, in the case of amphibians, their life cycles take place in both aquatic and terrestrial environments, which provide different functional features (oxygenation of water bodies, insect predators; Zug et al., 2001) according to their stage of development. Reptiles, particularly some groups of snakes and lizards, contribute to the environment with functional features in their diet (e.g., specialists or generalists; Pianka, 1966), show both modes of reproduction in the same families (viviparous and oviparous; e.g., Phrynosomatidae, Colubridae; Klauber, 1982; Tinkle et al., 1970), and exhibit different foraging tactics (sit-and-wait, widely-foraging; Pianka, 1966), and diverse reproductive cycles (seasonal, annual, continuous, among others; Tinkle et al., 1970; Calderon-Mandujano 2011; Sánchez, 2011). However, functional and taxonomic analyses on these groups have been practically null (Berriozabal-Islas et al., 2017; Cruz-Elizalde et al., 2022; Peña-Joya et al., 2020). The communities of amphibians and reptiles of the state of Durango represent suitable study models for taxonomic and functional analysis, since the herpetofauna of this state is among the richest in northern Mexico, distributed along four ecoregions (arid and semiarid, quebradas, sierra, and valleys; González-Elizondo et al., 2007, 2012; Fig. 1), and three biogeographic provinces (Sierra Madre Occidental, Chihuahuan Desert, and Mexican Plateau; Espinosa-Organista et al., 2008; Morrone, 2001). These facts confer a high probability of occurrence of different assemblages of species, and therefore different functional traits (e.g., ecological, morphological, and behavioral characteristics) in each community, which makes it worthy of being explored under an evolutionary scenario for the many biological groups.