

## Article

# The Distribution, Similarity, and Conservation Status of the Amphibians and Reptiles of the Biogeographic Provinces of Northwestern Mexico

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**Abstract:** The herpetofaunal diversity of northwestern Mexico, encompassing the Californian, Baja California, and Sonoran Desert biogeographic provinces, is characterized by relatively low species richness but a high degree of endemism. This region, particularly the islands of the Gulf of California, is recognized as a biodiversity hotspot. However, amphibian and reptile species in this area, especially those on the Gulf islands, are facing significant threats to their survival, including non-native species, habitat loss, and climate change. These factors pose considerable challenges to their conservation. In this study, we compiled updated lists of amphibian and reptile species across these three provinces, assessed their conservation status, identified the threats they face, and compared them with those in neighboring biogeographic provinces. Our analysis recorded a total of 228 species, comprising 29 amphibians and 199 reptiles, with a notable proportion of endemics, particularly in Baja California. Amphibians, due to the region's arid conditions, are underrepresented and generally face a lower level of conservation concern. In contrast, reptiles, especially those on the islands, are at higher risk, primarily due to habitat loss, invasive species, and climate change. Of the 228 species, one amphibian and 21 reptiles are classified in a category of conservation concern (Vulnerable, Endangered, Critically Endangered) by the International Union for Conservation of Nature (IUCN) Red List. In addition, 47 species (one amphibian and 46 reptiles) are listed as threatened (A) or at risk of extinction (P) by the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT). These findings emphasize the urgent need for conservation strategies, particularly for island reptile species, that involve collaboration among scientists, local communities, and federal and state authorities to address these threats and safeguard the region's herpetofauna. Similarity analysis revealed significant ecological connectivity among the amphibian and reptile communities across the three provinces. The similarity in species between the Californian, Baja California, and Sonoran Desert provinces highlights the role of historical climatic events, geographic barriers, and ecological factors in shaping species distributions of amphibians and reptiles in northwestern Mexico.

**Keywords:** Californian; Baja California; Sonoran Desert; herpetofauna; endemism; conservation status; invasive species; biodiversity hotspot; habitat loss



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## 1. Introduction

Mexico is widely recognized for its extraordinary biodiversity, which is a result of its rugged topography, geographical position at the intersection of the Nearctic and Neotrop-

ical regions, and its proximity to the Pacific and Atlantic Oceans (National Commission for the Understanding and Use of Biodiversity [CONABIO]) [1]. This unique geographical setting contributes to the definition of 14 biogeographic provinces, which include regions with distinct affinities: 4 with Neotropical characteristics, 5 with Nearctic traits, and 5 transitional zones [2,3]. However, the distribution of biodiversity across these provinces is not homogeneous, particularly for amphibians and reptiles. There is a clear gradient with the richness decreasing from south to north [4]. Moreover, four of the transitional provinces (Sierra Madre del Sur, Sierra Madre Oriental, Transvolcanic Belt, and Chiapas Highlands) house the richest diversity. These are followed by the Neotropical provinces, while the northernmost provinces show a noticeable decline in species richness [4]. Among the northern biogeographic provinces of Mexico, the Californian, Baja California, and Sonoran Desert provinces stand out for their relatively low amphibian and reptile species richness. This pattern can be attributed to the harsh environmental conditions in these areas, which are dominated by extreme aridity, limiting the presence of amphibians, which generally require more humid environments for survival [5–7]. Despite this limitation, the region is home to a unique assemblage of species, many of which are endemic due to the geographic isolation created by the vast desert landscapes, the arid climate, and the extensive marine archipelagos in the Gulf of California and along the Pacific coast of the Baja California Peninsula [8]. The islands of this region, especially those in the Gulf of California, are known to host numerous endemic species of reptiles, highlighting the importance of these areas as centers of speciation (see [9]). Moreover, the Gulf of California is recognized for its exceptional biodiversity and high levels of endemism among reptiles [8,10–13], plants [14,15], and marine species [16]. The Baja California Peninsula is also an area of high conservation value for reptiles and amphibians [17].

Although the richness of amphibian species in these provinces is relatively low compared to other biogeographic provinces of Mexico, the region holds significant ecological value. This is particularly true in the case of its reptilian fauna, with many species adapted to the harsh desert environments and a number of species being endemic to the region [10,18–20]. The combination of environmental isolation, a complex geological origin and evolution of this region, geographic barriers, and the existence of distinct ecological zones has made this region a hotspot for herpetofaunal diversity [11], despite the overall lower species richness.

While much of the herpetofauna of northwestern Mexico is relatively well studied [8,10,18–21] especially in terms of its endemic species, research has largely focused on the islands of the Gulf of California and the Pacific Ocean. Studies have also been conducted at the state level in Baja California, Baja California Sur, and Sonora, or on the Peninsula de Baja California as a region [8,10,11,18–20]. However, there has yet to be a comprehensive study that integrates the amphibian and reptile species across the three biogeographic provinces of Californian, Baja California, and the Sonoran Desert. Furthermore, the conservation status of the species in these provinces and their relationship with neighboring biogeographic regions are still understudied.

The proximity of these provinces to the US states of Arizona and California, however, introduces a complex layer of challenges for conservation. The region's location at the Mexico–United States border necessitates cross-border cooperation to address conservation issues effectively [22]. The movement of species across political boundaries, especially in the face of habitat fragmentation, climate change, and human activity, requires cooperation to protect the herpetofauna of northwestern Mexico. The border wall and other human interventions further complicate conservation efforts by limiting species movement and habitat connectivity across this shared landscape [23–25].

Here, we provide a list of the amphibian and reptile species currently known to inhabit the biogeographic provinces of Californian, Baja California, and the Sonoran Desert. We focus on their conservation status, the threats they face, and compare the species composition across this region and neighboring provinces. By doing so, we hope to contribute to a more comprehensive understanding of the herpetofauna of northwestern Mexico and the conservation challenges that arise from its unique ecological, geographical, and political context.

## 2. Methods

### 2.1. Physiography

The biogeographic provinces of California, Baja California, and the Sonoran Desert in northwestern Mexico share a diverse and complex geography, shaped by a variety of landforms and climatic zones. The Californian province, the smallest of Mexico's biogeographic provinces, lies in the extreme northwest of the country. It is bordered to the south by the Baja California province, to the east by the Sonoran Desert province, and to the west by the Pacific Ocean (modified from [3]). The Baja California province spans three-quarters of the Baja California Peninsula. Its borders touch the Sonoran Desert to the north and the Californian province to the northwest, with the Gulf of California to the east and the Pacific Ocean to the west (modified from [3]). The Sonoran Desert covers the northeastern tip of Baja California, the western half of Sonora, and a small portion of northern Sinaloa. This province is bordered by the Californian and Baja California provinces to the northwest, the Gulf of California to the west, and the Pacific Lowlands and Chihuahuan Desert to the south and east, respectively (modified from [3]). These provinces are distinguished by their topography, with the Baja California Peninsula featuring the rugged Peninsular Range that runs from the northwest to the southeast, creating a complex mountainous landscape that reaches 3100 m in Sierra San Pedro Martir. The Sonoran Desert consists mainly of an extensive coastal plain with small, isolated mountain ranges [3] (Figure 1). The region also includes extensive archipelagos, with 16 islands on the Pacific side of the Baja California Peninsula and over 100 islands and islets in the Gulf of California, 39 of which are large. These islands have evolved a unique reptilian fauna, with numerous endemic species [10]. Table 1 and Figure 1 and Supplementary Figures S1 and S2 present a summary of the general physiographic characteristics of the region and its neighboring provinces.

**Table 1.** General physiographic characteristics of the northwestern Mexico region, including the Californian, Baja California, and Sonoran Desert Provinces and the neighboring biogeographic provinces, the Chihuahuan Desert and the Pacific Lowlands. This table provides species richness for amphibians and reptiles, surface area, perimeter, longitude and latitude of the centroid, and altitudinal range.

| Biogeographic Province | Amphibians | Reptiles | Surface Area (km <sup>2</sup> ) | Perimeter (km) | Longitude (°) | Latitude (°) | Altitudinal Range (m) |
|------------------------|------------|----------|---------------------------------|----------------|---------------|--------------|-----------------------|
| Californian            | 12         | 55       | 24,691                          | 1402           | −116.036      | 31.40506     | 3100                  |
| Baja Californian       | 7          | 110      | 100,715                         | 5674           | −112.645      | 26.84351     | 2161                  |
| Sonoran Desert         | 19         | 105      | 119,763                         | 5581           | −112.265      | 30.07016     | 1800                  |
| Chihuahuan Desert      | 53         | 208      | 578,002                         | 15,481         | −103.73       | 26.19336     | 2600                  |
| Pacific Lowlands       | 76         | 249      | 187,113                         | 26,517         | −105.558      | 20.35502     | 2200                  |

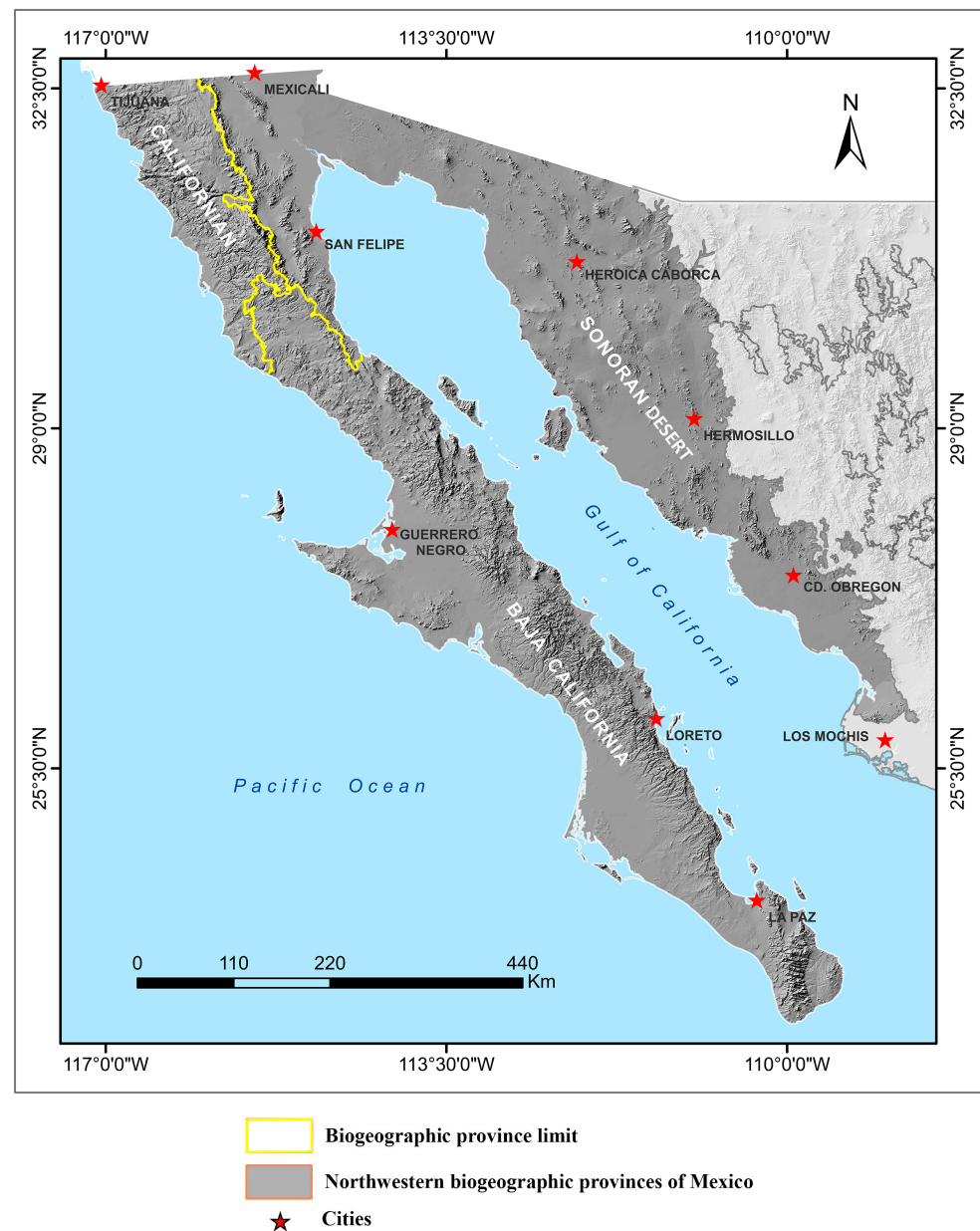


**Figure 1.** Topographic map of the three biogeographic provinces of northwestern Mexico: Californian, Baja California, and Sonoran Desert [26].

Climatically, the region is predominantly extremely arid, with significant variation in temperature and precipitation [27]. Most of Baja California and the Sonoran Desert experience an extremely arid climate, except in areas such as the Sierra La Laguna in Baja California where the lower elevations are arid and the higher elevations have a temperate climate. The eastern edge of the Sonoran Desert, bordering the Pacific Lowlands and Chihuahuan Desert, also has an arid climate. The Californian province features primarily arid conditions, with temperate and semi-cold climates found at higher elevations in the Sierra Juárez and Sierra San Pedro Martir. The southern end of the Californian province, near the border with Baja California, experiences an extremely arid climate [27] (Figure 2).

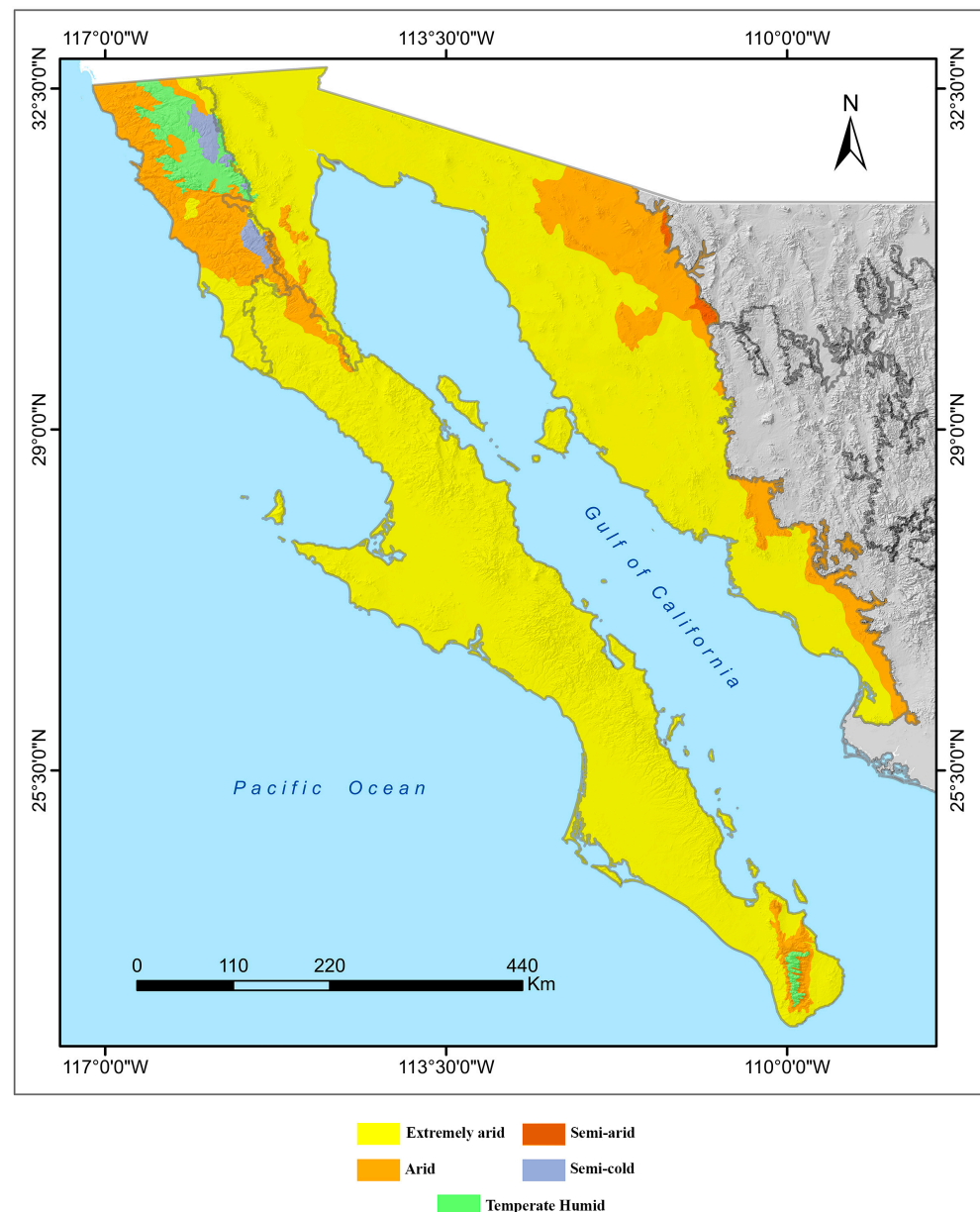


**Figure 2.** Climate map of the biogeographic provinces of northwestern Mexico (Californian, Baja California, and Sonoran Desert) [27].

Desert scrub dominates the majority of the region's extremely arid areas [28] (Figure 3). Grasslands mingle with scrub in the Sonoran Desert, particularly where it borders the Chihuahuan Desert and Pacific Lowlands. Sandy desert vegetation is prevalent in the sand dunes of the northwest Sonoran Desert and the central part of the Baja California Peninsula [28]. Additionally, patches of low deciduous forest can be found in the middle and southern portions of the Peninsula, as well as in the southeastern reaches of the Sonoran Desert [28]. In contrast, the Californian province is characterized by Chaparral vegetation, with small patches of temperate forest at higher elevations of the Sierra Juárez and Sierra San Pedro Martir (Instituto Nacional de Estadística y Geografía [INEGI] [28]; Figure 3).

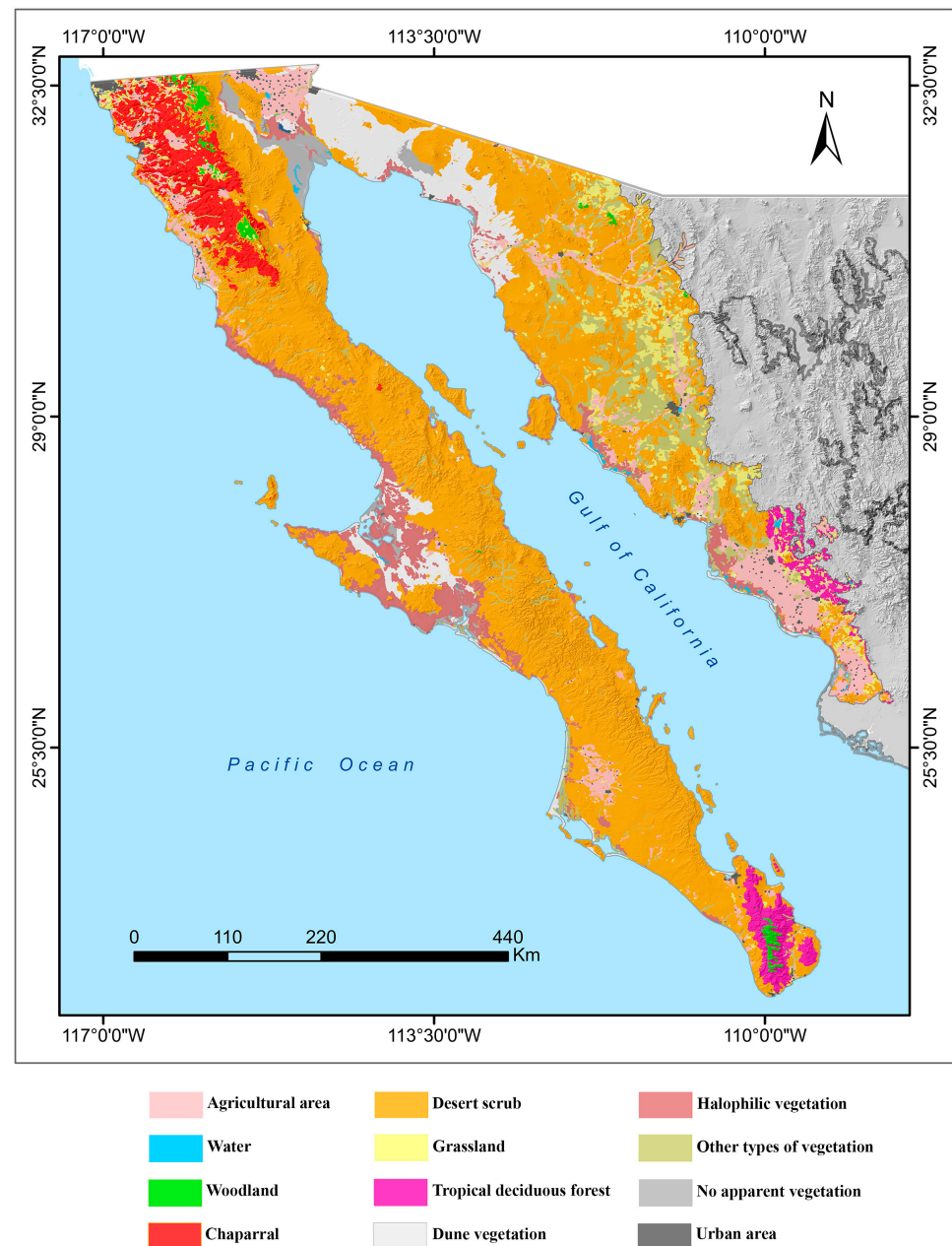


**Figure 3.** Vegetation map of the biogeographic provinces of northwestern Mexico (Californian, Baja California, and Sonoran Desert) [28].

## 2.2. Methodology

We collected and updated species lists for amphibians and reptiles for all of the Mexican states included in the Californian, Baja California, and Sonoran biogeographic provinces (Californian: Baja California; Baja California: Baja California Sur and Baja California; Sonoran Desert: Sonora and Baja California), provided by [29] and updated with [4]. We also compiled the list of amphibian and reptile species for the neighboring biogeographic provinces of Chihuahuan Desert [30] and Pacific Lowlands [31]. We verified species records using VertNet (version 2020-07-04, VertNet, University of Colorado, Boulder, CO, USA), Global Biodiversity Information Facility (GBIF) (<https://www.gbif.org>, accessed on 20 November 2024, GBIF Secretariat, Copenhagen, Denmark), and additional sources, and found no inconsistencies with the published state lists provided by [29], which were compiled by regional experts and peer-reviewed. These lists incorporate data from VertNet, GBIF, museum collections, literature reviews, and fieldwork, further supporting their reliability.

bility. For amphibian taxonomy, we referenced both Amphibian Species of the World [32] and AmphibiaWeb [33] to ensure comprehensive and up-to-date nomenclature. While we primarily followed [32], we adopted names from [33] in specific cases where nomenclature differs (e.g., using *Rana* instead of *Lithobates*) to maintain consistency with historical usage and prevailing trends in the literature. For reptiles, we used the Reptile Database [34], which is widely recognized as a global reference for valid species and current scientific and common names. We selected these taxonomic sources because they are authoritative, frequently updated, and widely used within the herpetological community. We refined the state checklists using the definition of the Californian, Baja California, and Sonoran Desert biogeographic provinces of [2,3,35,36] to create species lists for these three provinces, as well as the two neighboring provinces. In addition, we recorded the conservation status and population trend of each species given in the International Union for Conservation of Nature's (IUCN) Red List [37], the listing status for the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT) [38], and Environmental Vulnerability Scores (EVSs) based on a species' geographic distribution, ecological distribution, and anthropogenic impacts from [39,40]. We calculated Jaccard distances for each pair of biogeographic provinces for amphibians and reptiles separately. We obtained five geospatial estimates using the map of biotic provinces of Mexico by [2] on a Lambert Conformal Conic projection in Datum WGS84 in ArcGIS 10.8.1 (Environmental Systems Research Institute, Inc., Redlands, CA, USA): (1) the length of shared borders between the biogeographic provinces using the Polygon Neighbors Tool; (2) the straight-line distance between the centroids of the biogeographic provinces using the Feature to Point Tool and Point Distance; (3) the territorial area using the Calculate Geometry Tool; (4) the perimeter of each biogeographic province also using the Calculate Geometry Tool; and (5) the elevational range for each biogeographic province from the minimum and maximum contour curves of the map (Table 1). We used Spearman's  $\rho$  to examine the relationships between Jaccard distances and the geospatial estimates. We used JMP Pro 17.2.0 (JMP Statistical Discovery LLC, Cary, NC, USA) for all analyses.

### 3. Results and Discussion

#### 3.1. Species Richness and Endemism

The biogeographic provinces of northwestern Mexico host a diverse array of 228 native amphibian and reptile species, belonging to 33 families (8 amphibian families and 25 reptile families) and 64 genera (16 amphibian genera and 48 reptile genera) (Supplementary Table S1). Among these species, 29 are amphibians (25 anurans and 4 salamanders) and 199 are reptiles (1 crocodilian, 109 lizards, 75 snakes, and 14 turtles) (Table 2, Supplementary Table S1). The family with the greatest diversity of amphibians is Bufonidae, with 10 species. For reptiles, the most species-rich families are Phrynosomatidae with 38 species and Colubridae with 40 species (Supplementary Table S1). Additionally, nine species have been introduced to the northwestern Mexican provinces: the clawed toad (*Xenopus laevis*, introduced to Californian), Berlandier's frog (*Rana berlandieri*, introduced to Californian and the Sonoran Desert), the common bullfrog (*Rana catesbeiana*, introduced to Baja California and the Sonoran Desert), the Forrer's leopard frog (*Rana forreri*, introduced to Baja California, but naturally occurring in the Sonoran Desert), the stump-toed gecko (*Gehyra mutilata*, introduced to Baja California), the common house gecko (*Hemidactylus frenatus*, introduced to Baja California and the Sonoran Desert), the Mediterranean house gecko (*Hemidactylus turcicus*, introduced to the Sonoran Desert), the Brahminy blindsnake (*Indotyphlops braminus*, introduced to the Californian, Baja California, and Sonoran Desert), and the spiny softshell (*Apalone spinifera*, introduced to the Sonoran Desert) (Supplementary Table S1).

**Table 2.** Number of amphibian and reptile species, as well as the total number of herpetofauna species, in each biogeographic province of northwestern Mexico. The table also includes the total number of amphibian and reptile species across the entire region (Regional Total).

| Biogeographic Province | Amphibians | Reptiles | Total Herpetofauna |
|------------------------|------------|----------|--------------------|
| Californian            | 12         | 55       | 67                 |
| Baja California        | 7          | 110      | 117                |
| Sonoran Desert         | 19         | 105      | 124                |
| Regional Total         | 29         | 199      | 228                |

According to [4], Mexico is home to 1399 species of native amphibians and reptiles, comprising 435 amphibians and 964 reptiles. These species belong to 55 families (16 amphibian and 39 reptile) and 210 genera (55 amphibian and 155 reptile) (see also [41]). The biogeographic provinces of northwestern Mexico include 60.0% of the families (50.0% of amphibian families, 64.1% of reptile families), 30.5% of the genera (29.1% of amphibian genera, 31.0% of reptile genera), and 16.3% of the species (6.7% of amphibian species, 20.6% of reptile species) found in Mexico.

The Sonoran Desert has the greatest diversity of amphibians and reptiles among the three biogeographic provinces of northwestern Mexico, hosting a total of 124 species (19 amphibians and 105 reptiles) (Supplementary Table S1). In contrast, the Californian province is home to 67 species (12 amphibians and 55 reptiles), while the Baja California province hosts 117 species (seven amphibians and 110 reptiles) (Table 2; Supplementary Table S1).

The Californian province is home to 12 amphibian species, all of which are shared between the United States and Mexico. Among the 55 reptile species in this province, three are endemic to the province, and five are shared with the Baja California Peninsula. An additional 41 species are shared with the United States (Supplementary Table S1). Six marine reptiles, including five sea turtles and one sea snake, are also present (Supplementary Table S1).

The Baja California province is home to a diverse herpetofauna, with seven native amphibian species, all of which are shared with the United States. This biogeographic province also houses 110 reptile species, 67 of which are endemic to Mexico. Among these, 60 species are unique to Baja California, while five are shared with the Californian province. Additionally, two species are endemic to Mexico, but not to Baja California. This high level of endemism is a reflection of the Peninsula's unique geographical and geological history, as well as that of its associated islands. The islands associated with the Baja California Peninsula are known to have substantial species richness for amphibians and reptiles [8,9]. Baja California is further enriched by 37 species shared with the United States and six marine reptile species, including five sea turtles and one sea snake. In addition, the San Esteban chuckwalla (*Sauromalus varius*) has been translocated to Isla Roca Lobos in the Baja California province [11,42].

The Sonoran Desert, in contrast, is home to 19 amphibian species, four of which are endemic to Mexico. The remaining species are shared with the United States or range into Central or South America. For reptiles, 14 of the 105 species are endemic to the Sonoran Desert, 10 are endemic to Mexico, and 70 are shared with the United States. Five species have a distribution ranging from the United States to Central or South America, while six marine reptiles, including five sea turtles and one sea snake, are also found in this province. Additionally, the Baja spiny-tailed iguana (*Sauromalus hispidus*) has been translocated by the Seri people to islands off the coast of the Sonoran Desert province, where it is now regarded as an introduced species [19].

The Sonoran Desert's higher diversity is largely due to its continental nature. Unlike the Californian and Baja California provinces, which are separated by the Gulf of California and function similarly to large islands, the Sonoran Desert benefits from continuous land connections to other mainland provinces. This geographical continuity facilitates a greater exchange of species and allows for more opportunities for colonization and diversification, leading to the higher overall herpetofaunal diversity observed in this province. In contrast, the Californian and Baja California provinces are more isolated from the Mexican mainland. In particular, Baja California is effectively cut off from mainland Mexico by the Gulf of California, restricting species exchange. This isolation has contributed to the comparatively lower diversity of amphibians and reptiles in these regions. Baja California hosts only 117 species, with seven amphibians and 110 reptiles, and the Californian province supports 67 species (12 amphibians and 55 reptiles). This limited gene flow within isolated/insular populations regions can promote the development of unique species assemblages, contributing to high levels of endemism and shaping the diversity of local herpetofaunal communities.

In addition to the geographical isolation, the extreme aridity and harsh climate across all three provinces play a significant role in shaping the herpetofaunal communities. The predominantly arid environment in these regions is generally inhospitable to amphibians, which need moist conditions to reproduce and survive [5–7]. As a result, amphibians are underrepresented across the three provinces, with 12 species in the Californian, 7 species in Baja California, and 19 species in the Sonoran Desert (Table 2 and Supplementary Table S1). The climatic conditions of the region further limit the establishment and persistence of amphibian populations, as they are more sensitive to changes in moisture availability and temperature [5–7]. Thus, the Sonoran Desert supports the highest overall diversity of amphibians and reptiles, mainly due to its continental connection to other biogeographic provinces and more favorable ecological conditions for reptiles. The isolated nature of the Baja California and Californian provinces, compounded by their arid climates, contributes to their relatively lower herpetofaunal diversity.

Of the 29 amphibian species occurring in these biogeographic provinces, four are endemic to Mexico (*Anaxyrus kelloggi*, *Incilius mazatlanensis*, *Tlalocohyla smithii*, and *Rana magnaocularis*). However, no amphibian species is restricted to a specific biogeographic province within northwestern Mexico. In contrast, a much higher proportion of reptile species is endemic to this region. Of the 199 reptile species present in northwestern Mexico, 77 are endemic or microendemic to one of these provinces: three species are endemic to the Californian province, 60 species are endemic to Baja California, and 14 species are endemic to the Sonoran Desert. Additionally, five species are shared between the Californian and Baja Californian provinces, being endemic to the Baja California Peninsula (*Sceloporus zosteromus*, *Phyllodactylus xanti*, *Aspidoscelis labialis*, *Pituophis vertebralis*, and *Crotalus enyo*). Northwestern Mexico, particularly the Baja California peninsula, is home to a remarkable number of endemic reptile species, which is reflective of the region's unique geographical and ecological conditions. Baja California alone harbors 60 endemic reptile species, a large share of regional reptile endemism. This high level of reptile endemism can be attributed to the numerous islands scattered throughout the Gulf of California [8], which create isolated habitats for species, leading to speciation through geographic isolation [43,44]. Furthermore, the Baja California Peninsula's isolation from the mainland by the Gulf of California and the Sonoran Desert has acted as a barrier, promoting the development of distinct reptile populations that have evolved separately from mainland species over time [21]. This geographical separation has fostered a unique and diverse herpetofaunal community, particularly among reptiles.

### 3.2. Similarities Among Provinces

The Jaccard distances of amphibians and reptiles were positively correlated ( $n = 10$ , Spearman's  $\rho = 0.6727$ ,  $p = 0.0330$ ; Figure 4), suggesting that the factors driving differences and similarity of the amphibian and reptile faunas in these provinces are likely similar (e.g., isolation, diversity of habitats). Jaccard distances between pairs of provinces for amphibians were not correlated with the length of the shared border ( $n = 10$ , Spearman's  $\rho = 0.5753$ ,  $p = 0.0819$ ) or with the distance between their geographic centroids ( $n = 10$ , Spearman's  $\rho = -0.6242$ ,  $p = 0.0537$ ). The Jaccard distances between pairs of provinces for reptiles were positively correlated with the length of the shared border ( $n = 10$ , Spearman's  $\rho = 0.6566$ ,  $p = 0.0392$ ; Figure 5), and were not correlated with the distance between their geographic centroids ( $n = 10$ , Spearman's  $\rho = -0.5879$ ,  $p = 0.0739$ ). These significant and nearly significant correlations suggest that geographic proximity likely contributes to the similarity of the herpetofaunal species in these provinces, probably since geographic proximity leads to greater exchange of species and similar environments.

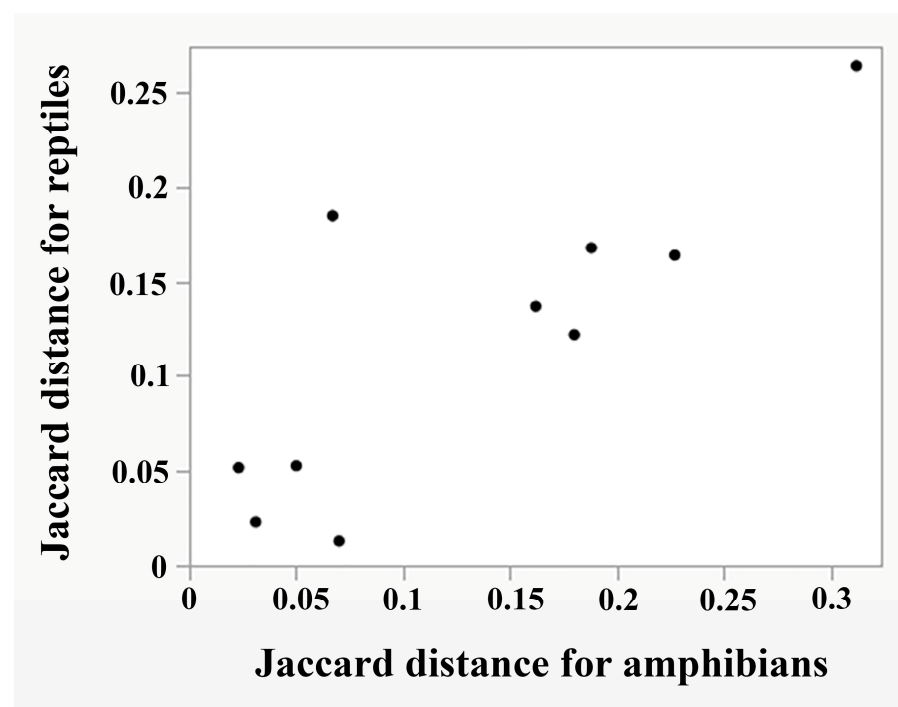


**Figure 4.** The correlation between the Jaccard distance of amphibians and reptiles among the biogeographic provinces of northwestern Mexico and its neighboring biogeographic provinces.

The species richness of amphibians and reptiles in a province were not correlated with its surface area (amphibians:  $n = 5$ , Spearman's  $\rho = 0.80$ ,  $p = 0.10$ ); reptiles:  $n = 5$ , Spearman's  $\rho = 0.80$ ,  $p = 0.10$ ), the longitude of its geographic centroid (amphibians:  $n = 5$ , Spearman's  $\rho = -0.80$ ,  $p = 0.10$ ); reptiles:  $n = 5$ , Spearman's  $\rho = -0.80$ ,  $p = 0.10$ ), or the latitude of its geographic centroid ( $n = 5$ , Spearman's  $\rho = -0.70$ ,  $p = 0.19$ ). However, the number of reptile species in a province was strongly positively correlated with the latitude of its geographic centroid ( $n = 5$ , Spearman's  $\rho = -1.00$ ,  $p < 0.0001$ ; Figure 6). The numbers of amphibian and reptile species in a province were not correlated with its altitudinal range (amphibians:  $n = 5$ , Spearman's  $\rho = 0.10$ ,  $p = 0.87$ ); reptiles:  $n = 5$ , Spearman's  $\rho = -0.10$ ,  $p = 0.87$ ). These results suggest that biogeographic variables are generally not driving the richness of amphibians and in many cases reptiles. However, reptiles demonstrate the well-known species latitudinal gradient.

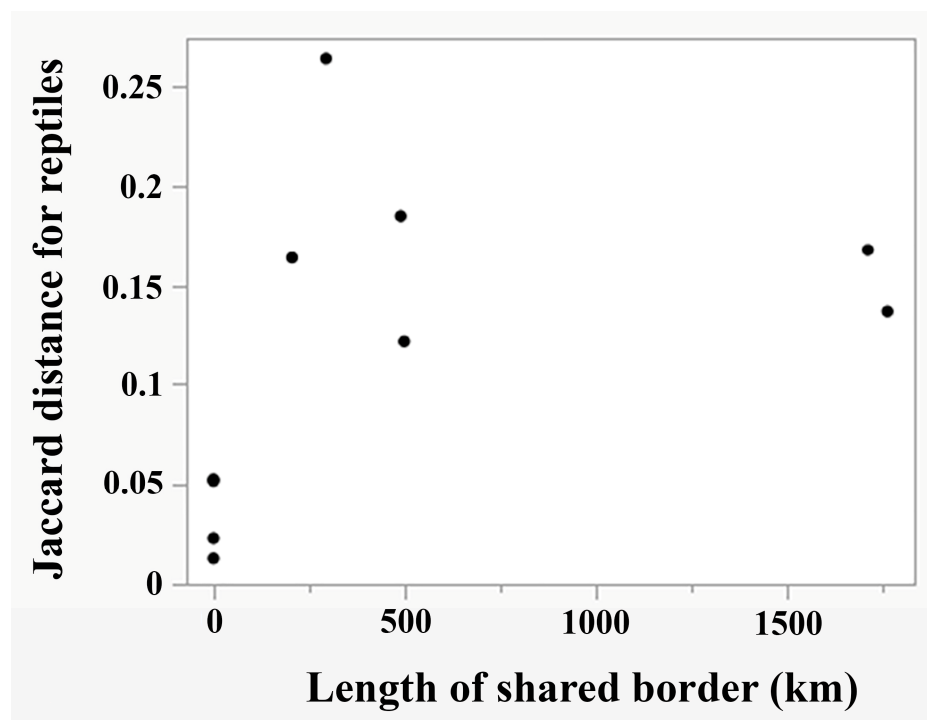


**Figure 5.** The correlation between the length of the shared border between neighboring biogeographic provinces and the biogeographic province of northwestern Mexico (Californian, Baja California, and Sonoran Desert) and the Jaccard distance of reptiles.

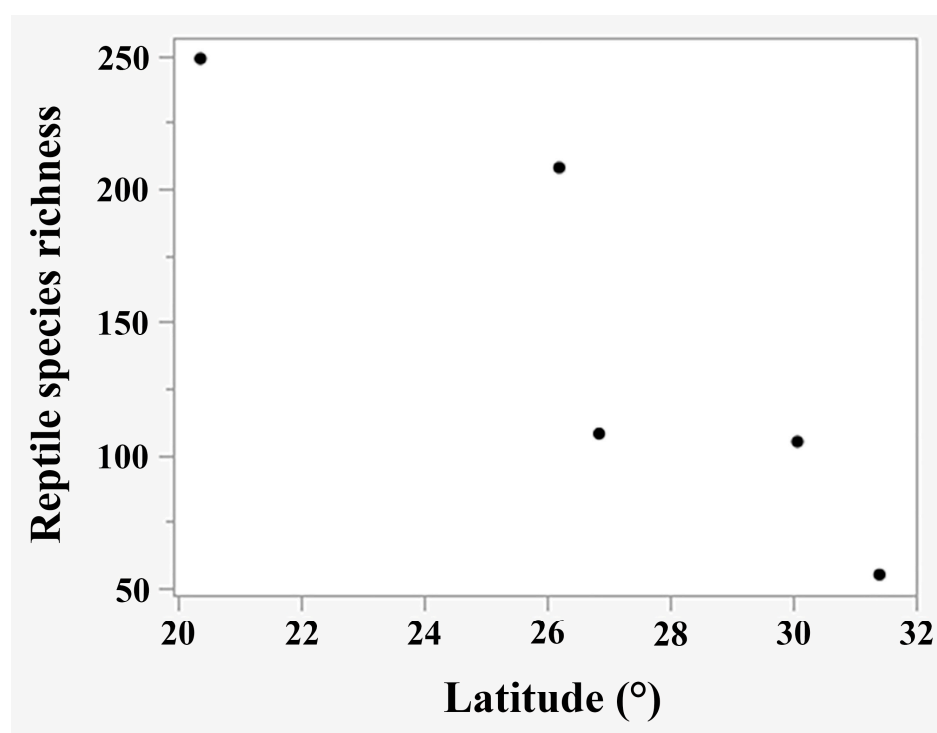


**Figure 6.** The relationship between latitude of the centroid for the biogeographic provinces of northwestern Mexico (Californian, Baja California, and Sonoran Desert) and its neighboring biogeographic province and the reptile species richness.

The biogeographic provinces of Baja California and the Californian region, despite having the fewest amphibian species in northwestern Mexico (7 and 12 species, respectively), share five species between them (Table 3A). These species represent 41.7% of the

amphibian fauna in the Californian province and 71.4% in the Baja California province (Table 3B), suggesting a high degree of similarity in the amphibian communities of these two regions. Several factors could explain this close relationship, including shared habitat types, past ecological connections such as land bridges or periods of climatic similarity, and comparable environmental conditions supporting similar amphibian species [45,46].

**Table 3.** (A) Number of amphibian species shared among the biogeographic provinces of northwestern Mexico and neighboring provinces. The species richness for each province is listed in parentheses next to the province name in the table. Numbers represent the species count in the column province that are shared with the row province. (B) Percentage of amphibian species shared among the biogeographic provinces of northwestern Mexico and neighboring regions. These percentages represent the proportion of species in the column province that are shared with the row province.

| <b>(A) Number of amphibian species</b> |                    |                        |                       |                         |                      |
|----------------------------------------|--------------------|------------------------|-----------------------|-------------------------|----------------------|
|                                        | <b>Californian</b> | <b>Baja California</b> | <b>Sonoran Desert</b> | <b>Pacific Lowlands</b> | <b>Chihuahuan D.</b> |
| <b>Californian (12)</b>                | -                  | 5                      | 2                     | 2                       | 2                    |
| <b>Baja California (7)</b>             | 5                  | -                      | 5                     | 4                       | 4                    |
| <b>Sonoran Desert (19)</b>             | 2                  | 5                      | -                     | 15                      | 11                   |
| <b>Pacific Lowlands (76)</b>           | 2                  | 4                      | 15                    | -                       | 18                   |
| <b>Chihuahuan D. (53)</b>              | 2                  | 4                      | 11                    | 18                      | -                    |

| <b>(B) Percentage of amphibian species</b> |                    |                        |                       |                         |                      |
|--------------------------------------------|--------------------|------------------------|-----------------------|-------------------------|----------------------|
|                                            | <b>Californian</b> | <b>Baja California</b> | <b>Sonoran Desert</b> | <b>Pacific Lowlands</b> | <b>Chihuahuan D.</b> |
| <b>Californian</b>                         | -                  | 41.7                   | 16.7                  | 16.7                    | 16.7                 |
| <b>Baja California</b>                     | 71.4               | -                      | 71.4                  | 57.1                    | 57.1                 |
| <b>Sonoran Desert</b>                      | 10.5               | 26.3                   | -                     | 78.9                    | 57.9                 |
| <b>Pacific Lowlands</b>                    | 2.6                | 5.3                    | 19.7                  | -                       | 23.7                 |
| <b>Chihuahuan D.</b>                       | 3.8                | 7.5                    | 20.8                  | 34                      | -                    |

Baja California and Sonora share five species of amphibians; the Californian and Sonora provinces only share two species. The greater geographic separation between the Sonoran Desert and both the Californian and Baja California provinces, as well as distinct environmental conditions and biogeographic history, likely contribute to the reduced similarity between these regions. Historical factors, such as the role of past climatic events or shifts in vegetation zones, may have also played a role in shaping the amphibian communities found in the Sonoran Desert [47]. Four species of amphibians are common to the Pacific Lowlands and the Californian, Baja California, and Sonoran Desert provinces. Specifically, two species are shared between the Pacific Lowlands and the Californian province, four with Baja California, and 15 with the Sonoran Desert. These shared species are indicative of ecological overlaps, particularly in lowland and coastal habitats that are present across these provinces [48,49].

The Chihuahuan Desert shares 2 amphibian species with the Californian province, 4 with Baja California, 11 with the Sonoran Desert, and 18 with the Pacific Lowlands. This merger points to the broader connectivity between the Chihuahuan Desert and these other provinces, likely shaped by its transitional position between the arid regions of the north and the more tropical lowlands [50]. The Chihuahuan Desert's amphibian fauna is thus influenced by both desert-adapted species and those found in nearby lowland areas, facilitating a greater species overlap across these provinces.

There was a nearly significant correlation between geographic proximity and Jaccard distances among the five neighboring provinces for amphibians ( $n = 10$ , Spearman's  $\rho = -0.6242$ ,  $p = 0.054$ ). Provinces that are geographically closer or historically connected,

such as Baja California and Californian, tend to share more similar amphibian communities. This can be attributed to factors like easier dispersal, shared evolutionary histories, and the presence of similar habitat types or climate conditions that promote species overlap [45,46]. In contrast, provinces that are more geographically isolated, such as the Chihuahuan Desert, exhibit a greater distance in clustering, reflecting their unique environmental characteristics and historical isolation [51].

Furthermore, similar environmental conditions across these regions, such as climate, habitat types, and vegetation, serve as important drivers in shaping amphibian communities [51]. Species with similar ecological requirements are more likely to coexist in regions with shared climatic and habitat characteristics, reinforcing the clustering observed in the analysis [48,52]. Historical factors, such as the influence of past geological events (e.g., land connections or climatic fluctuations) and long-term ecological processes, also significantly impact the distribution and composition of amphibian species in the region [50].

For reptiles, the Californian and Baja California provinces share 35 species between them (Table 4A), which represent 63.6% of the reptile species in the Californian province and 31.8% in the Baja California province (Table 4B). While the Spearman analysis did not find a significant correlation between the distance between the geographic centroids of provinces and the degree of species overlap, the high number of shared species between these two provinces likely reflects their close ecological similarities and the long-shared border between them. This strong overlap could be attributed to similar environmental conditions, such as coastal and semi-arid habitats, which may support similar reptile species. Additionally, historical factors, like past land connections and climatic shifts, could have facilitated the exchange of species between these regions.

**Table 4.** (A) Number of reptile species shared among the biogeographic provinces of northwestern Mexico and neighboring provinces. The species richness for each province is listed in parentheses next to the province name in the table. Numbers represent the species count in the column province that are shared with the row province. (B) Percentage of reptile species shared among the biogeographic provinces of northwestern Mexico and neighboring regions. These percentages represent the proportion of species in the column province that are shared with the row province.

| (A) Number of reptile species |             |                 |                |                  |               |
|-------------------------------|-------------|-----------------|----------------|------------------|---------------|
|                               | Californian | Baja California | Sonoran Desert | Pacific Lowlands | Chihuahuan D. |
| Californian (55)              | -           | 35              | 26             | 15               | 6             |
| Baja California (110)         | 35          | -               | 31             | 18               | 4             |
| Sonoran Desert (105)          | 26          | 31              | -              | 51               | 34            |
| Pacific Lowlands (249)        | 15          | 18              | 51             | -                | 55            |
| Chihuahuan D. (209)           | 6           | 4               | 34             | 55               | -             |

| (B) Percentage of reptile species |             |                 |                |                  |               |
|-----------------------------------|-------------|-----------------|----------------|------------------|---------------|
|                                   | Californian | Baja California | Sonoran Desert | Pacific Lowlands | Chihuahuan D. |
| Californian                       | -           | 63.6            | 47.3           | 27.3             | 10.9          |
| Baja California                   | 31.8        | -               | 28.2           | 16.4             | 3.6           |
| Sonoran Desert                    | 24.8        | 29.5            | -              | 48.6             | 32.4          |
| Pacific Lowlands                  | 6           | 7.2             | 20.5           | -                | 22.1          |
| Chihuahuan D.                     | 2.9         | 1.9             | 16.3           | 26.3             | -             |

Baja California and the Sonoran Desert share 31 reptile species, while the Californian and Sonoran provinces share 26 species (Table 4). These shared species suggest some overlap in the reptile fauna of these regions, although the proportion is lower compared to the Californian and Baja California overlap. The geographic proximity of Baja California

and the Sonoran Desert, coupled with shared desert habitats, may explain the greater species overlap between these two provinces. Conversely, the Californian province's more coastal and Mediterranean climates may limit the degree of overlap with the Sonoran Desert, which is characterized by more arid conditions. The species shared between these provinces likely represent those that can adapt to a wide range of environments, demonstrating the flexibility of certain reptile species in occupying different desert habitats.

The Pacific Lowlands exhibit a notable degree of overlap with all the other provinces. Specifically, they share 15 reptile species with the Californian province, 18 with Baja California, 51 with the Sonoran Desert, and 55 with the Chihuahuan Desert (Table 4). This extensive overlap suggests that the Pacific Lowlands may serve as a critical corridor for reptile species, linking the desert provinces with more tropical and coastal environments. The Pacific Lowlands' diverse range of habitats—ranging from coastal dunes and lowland forests to desert scrub—likely supports a wide variety of reptile species, promoting this interprovincial overlap. The greater number of shared species between the Pacific Lowlands and the Sonoran Desert (51 species) and the Chihuahuan Desert (55 species) further highlights the region's role as a transitional zone between these more arid regions and the lowland tropics [31].

The Chihuahuan Desert shares six reptile species with the Californian province, four with Baja California, 34 with the Sonoran Desert, and 55 with the Pacific Lowlands (Table 4). These shared species underscore the Chihuahuan Desert's transitional role between the more arid northern deserts and the tropical lowlands to the south. The Chihuahuan Desert, with its unique mix of arid and semi-arid environments, likely facilitates a broad overlap with neighboring provinces, especially with the Pacific Lowlands, which have a higher species diversity. The Chihuahuan Desert's reptile fauna reflects both its desert-adapted species as well as species from neighboring regions, contributing to the observed overlap with the Sonoran Desert and the Pacific Lowlands [30].

Similar environmental factors, such as temperature, habitat type, and vegetation, are important drivers in shaping reptile communities. Regions that share similar climate and habitat types are more likely to have similar reptile communities due to the overlapping ecological niches and the adaptation of species to these specific conditions [4]. Additionally, historical factors such as climatic changes, land connections, and past ecological events have likely shaped the distribution and composition of reptile species in these biogeographic provinces.

The patterns of species overlap among provinces in both amphibians and reptiles suggest that ecological and geographical factors play a key role in shaping the composition of these vertebrate communities in northwestern Mexico. While the similarities between amphibians and reptiles differ in terms of specific species and ecological preferences, the degree of overlap between neighboring provinces for both groups can largely be attributed to shared habitat types, climate conditions, and historical connections. The Spearman analyses highlighted the importance of geographic proximity, particularly the length of shared borders, in influencing species overlap among provinces, especially for reptiles. In contrast, for amphibians, other factors such as past climatic events and ecological connectivity may explain the observed patterns. Overall, the shared species across these provinces underscore the strong influence of environmental and historical factors in shaping the biogeographic provinces of the region, highlighting the importance of both past and present ecological processes in determining species distributions.

### 3.3. Conservation Status

Of the 228 native species of amphibians and reptiles in northwestern Mexico, 22 species (11.1% = 22/199 evaluated) are listed on the IUCN Red List as Vulnerable, Endangered,

or Critically Endangered (IUCN 2024) [37]. Additionally, 47 species (20.6% = 47/228 evaluated) are classified by the Secretaría del Medio Ambiente y Recursos Naturales de México (SEMARNAT) [38] as either threatened (A) or at risk of extinction (P). Furthermore, 98 species (47.8% = 98/205 evaluated) are classified as high-risk according to the Environmental Vulnerability Score (EVS) [39,40] (Tables 5 and 6, Supplementary Table S1, Figure 7).

Overall, amphibians in northwestern Mexico generally exhibit low levels of conservation concern according to the IUCN Red List [37] and are classified in low-risk categories by [37]. The Californian and Baja California biogeographic provinces are home to the only amphibian species listed as Endangered by [36] and threatened by [37]. In contrast, the Sonoran Desert does not host any species that appear on the IUCN Red List [36] or fall within any SEMARNAT risk categories [38]. Among amphibians, only one species, the Arroyo Toad (*Anaxyrus californicus*), is listed as Endangered (EN) on the IUCN Red List [37], representing 3.44% (1/29 evaluated) of amphibian species in this province. This same species is the sole amphibian categorized as threatened (A) by [38], accounting for 3.44% (1/29 evaluated). Additionally, four amphibian species (13.8% = 4/29 evaluated) are classified as high-risk based on the EVS [39] (Tables 5 and 6, Figure 7). In addition, the three salamander species native to the Californian province (*Aneides lugubris*, *Batrachoseps major*, and *Ensatina eschscholtzii*), as well as the little Mexican toad (*Anaxyrus kelloggi*) in the Sonoran Desert province, are classified as high-risk on the EVS (Supplementary Table S1; [39]).

**Table 5.** The number of native species in different taxa in the biogeographic provinces of northwestern Mexico that are included in each IUCN Red List category: Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR) [37]. EVS is the mean Environmental Vulnerability Score for a taxon (an EVS  $\geq 14$  is high vulnerability [39,40]). The SEMARNAT column provides the number of species in a particular taxon that are Not Listed (NL), Subject to Special Protection (Pr), Threatened (A), and In Danger of Extinction (P) according to [38].

| Scientific Name            | Genera    | Species    | IUCN<br>DD, LC, NT, VU,<br>EN, CR | EVS         | SEMARNAT<br>NL, Pr, A, P |
|----------------------------|-----------|------------|-----------------------------------|-------------|--------------------------|
| <b>Class Amphibia</b>      |           |            |                                   |             |                          |
| <b>Order Anura</b>         | <b>12</b> | <b>25</b>  | <b>0, 21, 3, 0, 1, 0</b>          | <b>9.2</b>  | <b>20, 4, 1, 0</b>       |
| Bufonidae                  | 3         | 10         | 0, 9, 0, 0, 1, 0                  | 9.6         | 8, 1, 1, 0               |
| Hylidae                    | 4         | 5          | 0, 5, 0, 0, 0, 0                  | 9.2         | 5, 0, 0, 0               |
| Leptodactylidae            | 1         | 1          | 0, 1, 0, 0, 0, 0                  | 6           | 1, 0, 0, 0               |
| Microhylidae               | 1         | 1          | 0, 1, 0, 0, 0, 0                  | 8           | 1, 0, 0, 0               |
| Ranidae                    | 1         | 5          | 0, 3, 2, 0, 0, 0                  | 3.6         | 2, 3, 0, 0               |
| Scaphiopodidae             | 2         | 3          | 0, 2, 1, 0, 0, 0                  | 7           | 3, 0, 0, 0               |
| <b>Order Caudata</b>       | <b>4</b>  | <b>4</b>   | <b>0, 4, 0, 0, 0, 0</b>           | <b>13.2</b> | <b>2, 2, 0, 0</b>        |
| Ambystomatidae             | 1         | 1          | 0, 1, 0, 0, 0, 0                  | 10          | 1, 0, 0, 0               |
| Plethodontidae             | 3         | 3          | 0, 3, 0, 0, 0, 0                  | 14          | 1, 2, 0, 0               |
| <b>Subtotal</b>            | <b>16</b> | <b>29</b>  | <b>0, 25, 3, 0, 1, 0</b>          | <b>10</b>   | <b>22, 6, 1, 0</b>       |
| <b>Class Reptilia</b>      |           |            |                                   |             |                          |
| <b>Order Crocodylia</b>    | <b>1</b>  | <b>1</b>   | <b>0, 0, 0, 1, 0, 0</b>           | <b>14</b>   | <b>0, 1, 0, 0</b>        |
| Crocodylidae               | 1         | 1          | 0, 0, 0, 1, 0, 0                  | 14          | 0, 1, 0, 0               |
| <b>Order Squamata</b>      | <b>37</b> | <b>184</b> | <b>3, 134, 7, 10, 2, 1</b>        | <b>13.2</b> | <b>101, 43, 39, 1</b>    |
| <b>Suborder Lacertilia</b> | <b>12</b> | <b>109</b> | <b>0, 78, 7, 10, 2, 0</b>         | <b>14.1</b> | <b>57, 27, 24, 1</b>     |
| Anguidae                   | 1         | 5          | 0, 5, 0, 0, 0, 0                  | 13.8        | 3, 2, 0, 0               |

Table 5. Cont.

| Scientific Name           | Genera    | Species    | IUCN                        | EVS         | SEMARNAT              |
|---------------------------|-----------|------------|-----------------------------|-------------|-----------------------|
|                           |           |            | DD, LC, NT, VU,<br>EN, CR   |             | NL, Pr, A, P          |
| Anniellidae               | 1         | 2          | 0, 1, 0, 0, 1, 0            | 12.5        | 1, 1, 0, 0            |
| Bipedidae                 | 1         | 1          | 0, 1, 0, 0, 0, 0            | 14          | 0, 1, 0, 0            |
| Crotaphytidae             | 2         | 7          | 0, 7, 0, 0, 0, 0            | 13.3        | 6, 1, 0, 0            |
| Eublepharidae             | 1         | 3          | 0, 3, 0, 0, 0, 0            | 14.3        | 2, 1, 0, 0            |
| Helodermatidae            | 1         | 1          | 0, 0, 1, 0, 0, 0            | 15          | 0, 0, 1, 0            |
| Iguanidae                 | 3         | 11         | 0, 4, 1, 4, 1, 0            | 15.7        | 5, 2, 4, 0            |
| Phrynosomatidae           | 9         | 38         | 0, 30, 3, 4, 0, 0           | 13.6        | 19, 5, 13, 1          |
| Phyllodactylidae          | 1         | 10         | 0, 5, 1, 0, 0, 0            | 14.6        | 5, 4, 1, 0            |
| Scincidae                 | 1         | 4          | 0, 4, 0, 0, 0, 0            | 12.3        | 2, 2, 0, 0            |
| Teiidae                   | 1         | 21         | 0, 16, 1, 2, 0, 0           | 14.8        | 8, 8, 5, 0            |
| Xantusidae                | 1         | 6          | 0, 2, 0, 0, 0, 0            | 14.8        | 6, 0, 0, 0            |
| <b>Suborder Serpentes</b> | <b>25</b> | <b>75</b>  | <b>3, 56, 0, 0, 0, 1</b>    | <b>11.7</b> | <b>44, 16, 15, 0</b>  |
| Boidae                    | 2         | 2          | 0, 1, 0, 0, 0, 0            | 10          | 1, 0, 1, 0            |
| Colubridae                | 15        | 40         | 3, 29, 0, 0, 0, 0           | 11.4        | 31, 4, 5, 0           |
| Dipsadidae                | 2         | 5          | 0, 4, 0, 0, 0, 0            | 7.8         | 1, 3, 1, 0            |
| Elapidae                  | 3         | 3          | 0, 3, 0, 0, 0, 0            | 14.5        | 1, 1, 1, 0            |
| Leptotyphlopidae          | 1         | 2          | 0, 1, 0, 0, 0, 0            | 11          | 2, 0, 0, 0            |
| Natricidae                | 1         | 6          | 0, 6, 0, 0, 0, 0            | 10.7        | 1, 0, 5, 0            |
| Viperidae                 | 1         | 17         | 0, 12, 0, 0, 0, 1           | 14.2        | 7, 8, 2, 0            |
| <b>Order Testudines</b>   | <b>10</b> | <b>14</b>  | <b>1, 2, 2, 5, 1, 1</b>     | <b>15.3</b> | <b>5, 3, 0, 6</b>     |
| Chelonidae                | 4         | 4          | 0, 0, 0, 2, 1, 1            | -           | 0, 0, 0, 4            |
| Dermochelyidae            | 1         | 1          | 0, 0, 0, 1, 0, 0            | -           | 0, 0, 0, 1            |
| Emydidae                  | 3         | 4          | 0, 0, 1, 1, 0, 0            | 17.3        | 3, 1, 0, 0            |
| Kinosternidae             | 1         | 4          | 1, 2, 1, 0, 0, 0            | 13.5        | 1, 2, 0, 1            |
| Testudinidae              | 1         | 1          | 0, 0, 0, 1, 0, 0            | 15          | 1, 0, 0, 0            |
| <b>Subtotal</b>           | <b>48</b> | <b>199</b> | <b>4, 136, 9, 16, 3, 2</b>  | <b>13.3</b> | <b>106, 47, 39, 7</b> |
| <b>Total</b>              | <b>64</b> | <b>228</b> | <b>4, 161, 12, 16, 4, 2</b> | <b>12.8</b> | <b>128, 53, 40, 7</b> |

**Table 6.** Number of amphibian and reptile species categorized under conservation concern (Vulnerable, Endangered, or Critically Endangered) according to the IUCN Red List [37], the risk categories of Threatened (A) or at risk of extinction (P) as reported by the Mexican government [38], and those classified as high-risk by the Environmental Vulnerability Score (EVS) [39,40]. The term CCS refers to Conservation Concern Status (i.e., Vulnerable, Endangered, or Critically Endangered). Total in each column refers to the number of species evaluated, whereas Regional Total indicates the total number of amphibian or reptile species across the biogeographic provinces of Californian, Baja California, and Sonoran Desert in northwestern Mexico.

|                   | IUCN |       | SEMARNAT      |       | EVS       |       |
|-------------------|------|-------|---------------|-------|-----------|-------|
|                   | CCS  | Total | Risk Category | Total | High-Risk | Total |
| <b>Amphibians</b> |      |       |               |       |           |       |
| Californian       | 1    | 12    | 1             | 12    | 3         | 12    |
| Baja California   | 1    | 7     | 1             | 7     | 0         | 7     |
| Sonoran Desert    | 0    | 19    | 0             | 19    | 1         | 19    |
| Regional Total    | 1    | 29    | 1             | 29    | 4         | 29    |
| <b>Reptiles</b>   |      |       |               |       |           |       |
| Californian       | 8    | 49    | 15            | 55    | 8         | 44    |
| Baja California   | 12   | 93    | 31            | 110   | 51        | 92    |
| Sonoran Desert    | 13   | 96    | 21            | 105   | 38        | 91    |
| Regional Total    | 21   | 170   | 46            | 199   | 93        | 176   |

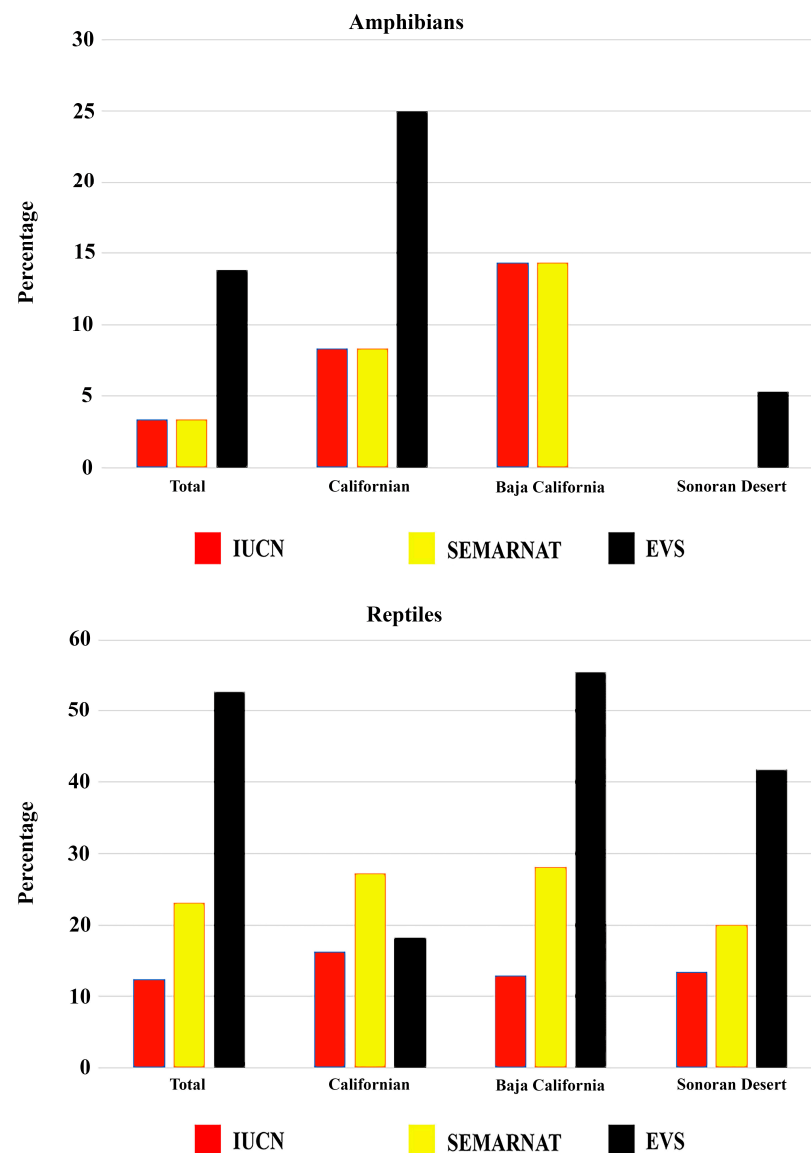


**Figure 7.** Percentage of amphibian and reptile species with conservation concern status [37], categorized as threatened (A) or in danger of extinction (P) by the Mexican government [38], or deemed to have a high Environmental Vulnerability Score (EVS) [39,40], for the biogeographic provinces of northwestern Mexico: Californian, Baja California, and Sonoran Desert.

In contrast to amphibians, reptiles in the biogeographic provinces of northwestern Mexico exhibit a higher proportion of species facing conservation concerns. Specifically, 12.4% (21/170 evaluated) are listed in some category of conservation concern on the IUCN Red List [37], 23.1% (46/199 evaluated) are classified as threatened (A) or at risk of extinction (P) by the Mexican government [38], and 53.4% (94/176 evaluated) are considered high-risk according to the Environmental Vulnerability Score (EVS) [40] (Tables 5 and 6; Supplementary Table S1, Figure 7). The proportion of reptile species listed in some conservation concern category is similar across the three biogeographic provinces of northwestern Mexico. The Californian province has 16.3% (8/49 evaluated) of its reptile species in a conservation concern category, Baja California has 12.9% (12/93 evaluated), and the Sonoran Desert province has 13.5% (13/96 evaluated) (Table 6, Supplementary Table S1, Figure 7).

The 21 reptile species included in the IUCN Red List with conservation concerns consist of 16 listed as Vulnerable, three as Endangered, and two as Critically Endangered. Of these, 11 species are endemic to islands within one of the three biogeographic provinces:

*Ctenosaura conspicuosa*, *Ctenosaura nolascentis*, *Sauromalus hispidus*, *Sauromalus klauberi*, *Sauromalus varius*, *Uta encantadae*, *Uta lowei*, *Uta palmeri*, *Uta tumidarostra*, *Aspidoscelis martyris*, and *Crotalus catalinensis*. Another species, *Anniella geronimensis*, is endemic to the southwestern portion of the Californian province, while *Aspidoscelis labialis* is restricted to the northern half of the Baja California Peninsula, inhabiting both the Californian and Baja Californian provinces. Two additional species, *Trachemys yaquia* and *Gopherus morafkai*, are found within the Sonoran Desert province. Furthermore, *Crocodylus acutus*, although widely distributed from southern Sonora to northern South America, also has populations in southern Florida, USA, and the Caribbean. The final five species on the list are sea turtles with a circumglobal distribution: *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea*. Additionally, four species are classified as Data Deficient (DD) and 31 species have yet to be assessed. Many of these unassessed species were recently elevated to full species status, having previously been considered subspecies of more widely distributed species [53,54]. As a result, it is likely that additional species will be evaluated in the near future, suggesting that the actual number of species in need of conservation attention may exceed the current figures listed on the IUCN Red List [37]. These newly elevated species should be the subject of targeted research to assess their conservation status and determine if there are any specific threats to their long-term stability.

The species listed as Vulnerable, Endangered, or Critically Endangered on the IUCN Red List face a range of significant threats. *Anniella geronimensis* and *Aspidoscelis labialis* are primarily threatened by habitat loss due to the expansion of agriculture and urbanization, as well as the use of off-road vehicles in their coastal habitats [37]. In contrast, *Ctenosaura conspicuosa*, *Ctenosaura nolascentis*, *Sauromalus hispidus*, *Sauromalus klauberi*, and *Sauromalus varius*, all of which are island species, face threats from extreme weather events, frequent droughts, and climate change. Additionally, the introduction of non-native species such as rodents, feral cats, and goats, though feral cats have been eradicated from these islands, further endangers their populations [37]. Island species like *Uta encantadae*, *Uta lowei*, *Uta palmeri*, *Uta tumidarostra*, and *Aspidoscelis martyris* are experiencing habitat loss due to the reduction in the extent and quality of their habitats [37]. *Crotalus catalinensis*, another island species, is at risk from illegal collection for the pet trade and human-induced killing [37]. *Trachemys yaquia* is threatened by habitat loss due to agricultural expansion and dam construction, whereas *Gopherus morafkai* faces a range of pressures, including severe weather, climate change, habitat conversion for livestock grazing, the introduction of buffelgrass, and illegal collection for the pet trade and human consumption [37]. *Crocodylus acutus* was hunted and overexploited for its hide from the 1930s until it was protected in the 1970s, and is now showing signs of recovery thanks to ongoing conservation efforts in the countries within its range [37].

The provinces of northwestern Mexico appear to be particularly important for the conservation of sea turtles (e.g., [55]). However, the five sea turtle species in northwestern Mexico (*Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea*) face several shared threats. Bycatch in fisheries is a major concern, as many turtles are accidentally captured in trawl nets, longlines, and other fishing gear [56–58]. Habitat degradation caused by coastal development; including construction, tourism, and boat traffic, potentially negatively impacts essential nesting beaches and foraging areas [37,59,60]. The poaching of eggs and adults continues to pose a significant threat, with illegal harvesting for consumption endangering populations [37,57,61,62]. Heavy metal contamination of the sea turtles in the region has been observed [63]. Diseases, such as Chelonid herpes virus 5, may threaten sea turtles in the region [64].

The conservation threats to the amphibians and reptiles of the provinces of northwestern Mexico are numerous (see [8]). Invasive species are a significant threat to the amphibian and reptile species of the region [65–68]. In addition, domestic or feral wildlife, such as horses, burros, goats, and cows, can have negative effects on ecosystems in the region, resulting in lowered abundances of lizards [69,70]. Habitat fragmentation has led to the extirpation of populations of *Urosaurus nigricauda* in the Sonoran Desert [71]. Amphibians in the provinces of northwestern Mexico are also susceptible to the chytrid fungus, *Batrachochytrium dendrobatidis* [72,73], with infected populations being found that exhibit high levels of prevalence and infection intensity [74]. Global climate change is another critical factor that compounds the threats faced by amphibians and reptiles in northwestern Mexico [75–77]. In particular, the conservation of species of reptiles on islands is highly threatened resulting from a combination of natural and human-induced factors [9,78]. These species are particularly vulnerable due to their geographic isolation, small population sizes, and the specialized ecological niches they occupy [79]. Moreover, many of these island endemics are facing severe threats from invasive species and global climate change [76].

Efforts have been made to eradicate feral dogs and cats from several islands in the Gulf of California, including Ángel de la Guarda and San Esteban, in order to reduce predation pressure on endemic species such as *Ctenosaura conspicuosa*, *Sauromalus hispidus*, and *Sauromalus varius* [37]. However, other invasive mammals, such as rats, continue to occur on some islands, posing an ongoing threat to the survival of these reptile species [37].

The conservation of amphibians and reptiles in the biogeographic provinces of northwestern Mexico will require targeted management efforts, including habitat restoration, invasive species eradication, and the establishment of protected areas to minimize human impact (e.g., [80]). The eradication of invasive species, such as *Rana catesbeiana*, is likely to improve the conservation status of some native species of amphibians (see [81]). In particular, the eradication of invasive mammals on islands is crucial, as these species pose a significant threat to native wildlife [82,83], and eradication can have positive outcomes for island faunas [84]. Preventing new invasive species from reaching these vulnerable ecosystems will be a particularly important conservation goal [85]. Therefore, the eradication of invasive mammals and ongoing monitoring should remain central components of conservation strategies, alongside habitat restoration and adaptive management approaches, to safeguard the unique herpetofauna of the region in the face of climate change. In addition, habitat restoration in Baja California has increased the species richness of reptiles compared to unrestored disturbed sites [86]. Furthermore, increased collaboration between scientists, local communities, governments, and conservation organizations can help promote effective conservation policies [87,88]. Campaigns to reduce human impact on these fragile ecosystems, as well as fostering local stewardship, will be essential in ensuring long-term conservation success [89,90]. By addressing both the immediate threats of invasive species and the long-term impacts of climate change, we can better protect the unique and irreplaceable amphibian and reptile species of the biogeographic provinces of northwestern Mexico and ensure that they continue to thrive for future generations.

#### 4. Conclusions

The biogeographic provinces of northwestern Mexico harbor a rich and diverse herpetofauna, with 228 native amphibian and reptile species including 33 families and 64 genera. The region is particularly significant for its high levels of reptile endemism, especially in Baja California, although amphibian diversity remains lower due to the region's arid conditions. The Sonoran Desert stands out for its rich species diversity, while the Baja California and Californian provinces also exhibit a notably low amphibian richness. However,

amphibians in the region are more widely distributed, with no species restricted to a single province, whereas reptiles show much greater levels of endemism, with several species confined to specific provinces. These findings underscore the ecological importance of the region, particularly for reptile conservation, and highlight the growing threat posed by non-native species, stressing the need for sustained monitoring and management efforts to protect the endemic species.

Geographically, the distribution patterns of amphibians and reptiles in northwestern Mexico reveal key differences between the two groups. While amphibians display limited endemism, sharing many species with the United States and Central/South America, reptiles show much higher regional endemism. Baja California, in particular, is home to a substantial number of endemic reptile species, influenced by its geographical isolation and harsh climatic conditions. On the other hand, the Sonoran Desert, benefiting from its continental connection, supports the greatest species diversity for both groups, highlighting the role of geographic continuity in facilitating species exchange and diversification. These distribution patterns emphasize the critical importance of preserving the region's unique herpetofaunal communities, especially the endemic reptiles of Baja California, which evolved in response to the region's unique ecological and historical conditions.

In light of these findings, the conservation of amphibians and reptiles in northwestern Mexico presents both challenges and urgent needs. While amphibians face relatively fewer immediate threats, reptiles, particularly those endemic to islands, are vulnerable to habitat loss, invasive species, and climate change. Island species, isolated and adapted to specialized habitats, face compounded pressures from both natural and anthropogenic factors. Consequently, efforts to eradicate invasive species, mitigate climate change impacts, and restore habitats are crucial for the survival of these species. Collaborative conservation strategies, both locally and internationally, will be essential in securing the future of this unique herpetofauna, ensuring their resilience in the face of escalating environmental challenges.

The observed biogeographic patterns in the amphibian and reptile communities across northwestern Mexico are shaped by a combination of geographic proximity, environmental conditions, and historical factors. Despite some differences in species composition, with provinces like Baja California and the Californian provinces showing high species overlap due to shared habitat types and close geographic proximity, the analysis suggests that, while geographic factors such as shared borders influence reptile communities, climatic conditions and habitat types are likely more significant drivers for amphibians. These findings emphasize the complex interplay between ecological and historical forces in shaping the biogeographic provinces of the region, illustrating how both amphibian and reptile species respond to common environmental influences in northwestern Mexico.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/d17050304/s1>, Supplementary Table S1: Amphibians and reptiles of the biogeographic provinces of northwestern Mexico. Supplementary Figure S1: Topography map of the Chihuahuan Desert biogeographic province of Mexico. Supplementary Figure S2: Topographic map of the Pacific Lowlands biogeographic province of Mexico.

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