# The Influence of Environmental Variables on High Priority Areas of Conservation for Amphibians in North American Drylands

by

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ABSTRACT

Climate change is becoming an ever-increasing issue for conservation efforts, especially in dryland ecosystems where natural resources are already scarce for native species. This is increasingly true for native amphibians in the area, which are already experiencing threats to their range by human intervention, disease, and invasive species. The objectives of this study are to 1) identify how climate change impacts the distribution of native and non-native amphibian species and high priority conservation areas (HPCA) in the drylands of the Southwest United States and northern Mexico; 2) Describe the relationship between environmental variables and spatial configurations of HPCA; 3) Explore how amphibians distributions and HPCA may respond under climate change scenarios; 4) Investigate the projected change in drivers of climate change; 5) Investigate how climate change will impact the critical areas for conservation of native amphibians. Distribution maps were obtained for the 220 resident native and non-native amphibian species, and complementarity-based analysis was used to identify HPCA for amphibians. We used 34 predictor variables grouped into three categories, and ranked based on their influence in determining HPCA. Finally, Zonation, species richness, and rarity-weighted richness (RWR) were evaluated to identify complementarity to HPCA. Results show that water-related variables and -related variables such as temperature and solar radiation were the best indicators of amphibian conservation HPCA. Zonation also proved to be the best method for identifying these HPCA.

This study is the first to investigate the impact of climate change on site complementarity. The results from this study will open new inquiries for biogeography

and conservation biology and also have a functional use for natural resource managers in the United States and Mexico to monitor changes to these areas and plan for recovery if needed.

Keywords: Climate change, Zonation, Complementarity, High priority areas for conservation, Rarity-weighted richness

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# INTRODUCTION

The decline in amphibian population and abundance has been staggering in the last decade, with 40.7% of amphibian species globally threatened (Lannoo 2005, Pounds 2001, Stuart et al. 2004, Luedtke et al. 2023). At the same time, science continues to investigate the driving causes. Many threats and concerns have been linked to amphibian population declines, including environmental pollution, invasive species, disease, and anthropogenic habitat alteration (Lannoo 2005, Blaustein et al. 2002, Beebee et al. 2005). Habitat alteration, which encompasses habitat loss and degradation, is among the most significant threats to amphibian diversity (Cushman 2006). Habitat alteration includes urbanization (e.g., housing and agricultural development), water withdrawals and stream diversions, pollution, and deforestation (Decena et al. 2020).

Modifications to the habitat often result in unsuitability for amphibians (Hamer and McDonnell 2008, Heinrichs et al. 2016). Habitat loss and fragmentation often reduce the number of suitable locations for amphibians, increase the isolation of populations, and increase the likelihood of extinction due to reduced genetic diversity within populations (Cushman 2006). Isolation and habitat alteration can be especially detrimental to dryland amphibian populations that utilize more limited environmental features to facilitate movement between water sources and migration to breeding sites (Hinderer et al. 2021). For example, the Chiricahua Leopard Frog (*Rana chiricahuensis*) is a native species to the drylands of central, southeastern Arizona, southwestern New Mexico, and northern Mexico (Platz and Mecham 1979, Stebbins 1985). This species has become threatened partially due to habitat alteration, which limits the available water sources and cattle tanks the species utilizes (Hinderer et al. 2021, Team 2008). Recent studies have shown that climate will significantly modify the habitat suitability of desert areas, especially for amphibians (Albuquerque et al. 2024, Griffis-Kyle et al. 2018).

One way to mitigate the impacts of habitat alteration and avoid changes in habitat suitability is to map and highlight potential areas with high habitat suitability for conservation (Hereafter, high-priority conservation areas -HPCA). HPCA pinpoint crucial conservation locations for safeguarding species and thus necessitate urgent conservation efforts (Albuquerque and Beier 2015a). Therefore, identifying priority habitats is crucial for developing and implementing effective conservation and management plans (Epele et al. 2021).

The identification of HPCA, however, depends on knowledge about species distribution. Currently, 11% of all amphibian species do not have enough information for implement conservation measurements, and therefore recorded as data deficient by the International Union for Conservation of Nature (IUCN, Luedtke et al. 2023). Because of this incomplete knowledge, scientists use proxies for biodiversity, also known as biodiversity surrogates (Williams et al. 2006). Surrogates are accurately mapped environmental or taxonomic characteristics such as soil types, climatic conditions, or easily observed occurrences of species in the planning area (Albuquerque and Beier 2017, Beier and Albuquerque 2016). Examples of common biodiversity surrogates include the importance of sites for conservation, often expressed by Zonation (Di Minin et al. 2014), rarity-weighted richness (RWR, Williams et al. 1996), and species richness. Zonation is a commonly used proprietary software that aids spatial conservation planning through a complementarity-based approach (Moilanen et al., 2009). Zonation aims to represent all conservation targets in the smallest number of sites. Similarly, RWR seeks to represent the maximum number of species in a given number of sites (Margules and Pressey 2000). RWR is a summation of the rarity scores of all the species at a select site and acts as a dependable method for representing species (Albuquerque and Beier 2015b). Rarity scores are calculated by taking the inverse of the number of species occurrences in one site (Albuquerque and Beier 2015b, Williams et al. 1996). RWR performs as an alternative spatial conservation planning tool that assigns higher priority rankings to sites offering unique species. Species richness is a common estimate of biodiversity, ranking sites by most overall species present (Albuquerque and Beier 2015b, Brown et al. 2007). In previous studies, both Zonation and RWR surrogates have successfully solved maximum coverage problems (Moilanen et al. 2009, William et al. 1996). Maximum coverage problems attempt to select the most amount of species represented across the sites selected when there are financial or resource limitations that do not allow for every site to be selected (Church et al. 1996, Alagador et al. 2020).

Another emerging factor influencing the spatial configuration of HPCA is climate. Recently, Albuquerque and Beier (2015a) investigated the distribution of HPCA in vertebrates, including amphibians, birds, and mammals, at a global scale, and they reported that climate-related predictors are the major drivers of the spatial configuration of HPCA. If climate has a pivotal influence on the spatial configuration of HPCA, then the location of these areas may change in the future. Thus, identifying HPCA without accounting for climate change may lead to quickly antiquated results. Exploring various climate change scenarios could improve how sites are selected and have greater impacts on the conservation of species of concern (Albuquerque et al. 2018). To explore climate change impacts, studies often explore four Shared Socioeconomic Pathways (SSPs), as defined by the Intergovernmental Panel on Climate Change Special Report Emission Scenarios (Nakicenovic & Swart 2000) to model various scenarios depicting the predicted impacts of climate change on HPCA to the years 2081-2100. SSPs are pathways that represent possible outcomes for the ecosystem and society over a century timescale without the implementation of new climate policies ('O'Neill et al. 2014, Scenarios 2000).

The major goals of our study were to provide a geographic distribution of current HPCA for resident amphibian species in drylands of the SW United States and Mexico, and to elucidate potential changes between current and future HPCA's spatial configurations. Specifically, we aimed to (1) provide the geographical distribution of HPCA for North American dryland amphibians, (2) evaluate which proxy for biodiversity (Zonation, RWR, and species richness) is most effective for identifying HPCA, (3) identify the association between the spatial configuration of HPCA of amphibians and environmental variables, and (4) identify the potential effect of climate change on the spatial configurations of HPCA.

## MATERIALS AND METHODS

### STUDY AREA

Our study area includes the Southwest United States and Northern Mexico, comprising the largest continuous dryland area experiencing a major multi-year drought

(Hughes et al. 2008). The study area encompasses all four dryland subtypes: hyper-arid, arid, semi-arid, and dry sub humid, based on increasing aridity and decreasing moisture. Each subtype displays varying levels of biodiversity and species richness and encompasses 41.3% of land coverage on Earth altogether (Safriel et al. 2005). We used the Convention on Biological Diversity and the United Nations Convention to Combat Desertification (UNCCD) and Map (UNEP-UCMC. 2007) to define the dryland ecosystems across the SW United States and Northern Mexico. Drylands north of Nevada, Utah, and Colorado were excluded from the study area to primarily focus on the geographic area of the Southwest United States and Northern Mexico. We removed portions of northern California, central Colorado, and eastern Texas from our study area because they do not exhibit the same qualities as our other dryland systems, and the amphibian species present within them reflect this (Webb. 1950, Deitch et al. 2017).

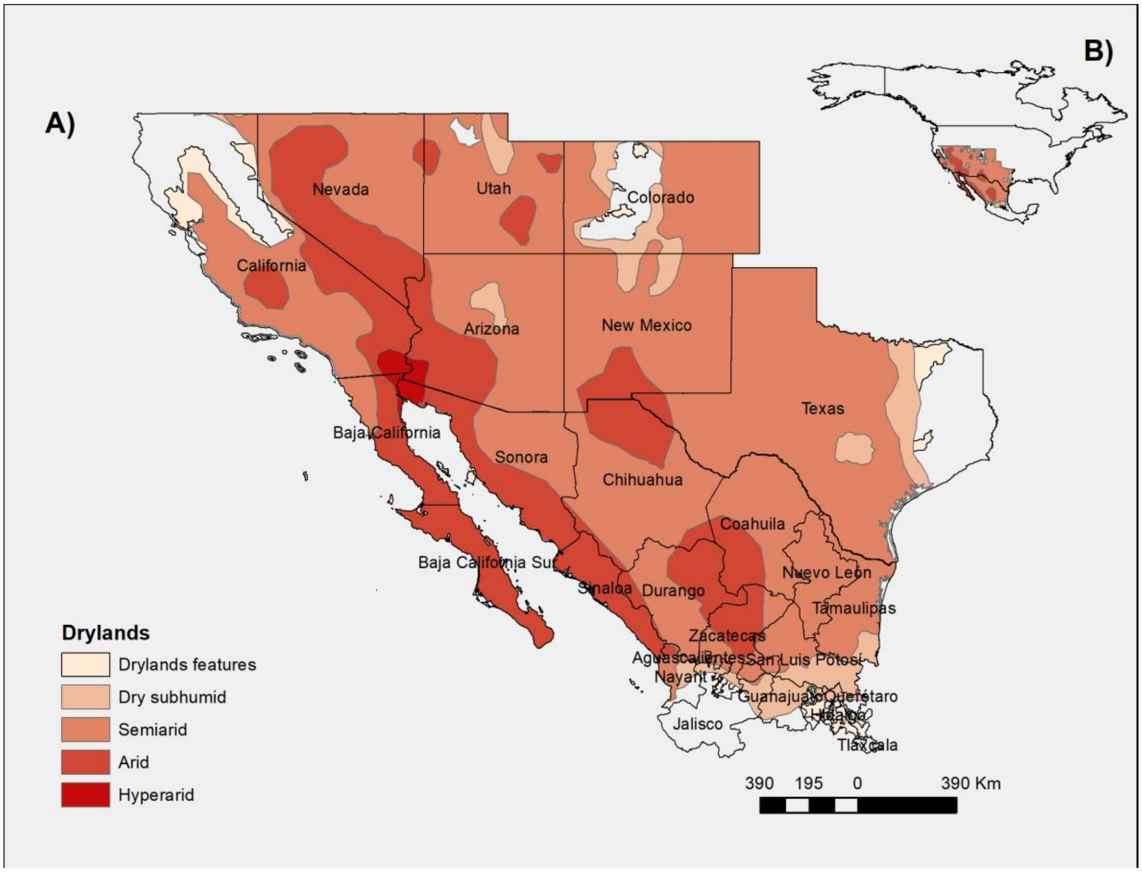


***Figure 1.*** Geographic depiction of drylands in the Southwest United States and Mexico (A), and its location related to North America (B)

## DATA SOURCE

**Biological Data.** We obtained global distribution range maps for 7,209 amphibian species from the IUCN Red List spatial data (IUCN 2022). We processed these range maps in *R* (R Core Team 2021). Then we used the referencing species' natural ranges on Amphibia Web (Amphibia Web 2023) to identify resident species, individuals with at least three-fourths of their annual cycle living in a given area (Red List Technical Group 2018) of the Southwest United States and Northern Mexico. This process left 211 amphibian species within our study area to conduct our analysis.

**Environmental Data.** We selected 34 environmental variables to determine the relationship between environmental changes and HPCA for amphibians, and all variables were processed in *R* for analysis. The first 19 were bioclimatic variables extracted from WorldClim (Fick and Hijimans 2017). We obtained 12 measures of solar radiation, expressed as monthly values from 1970-2000, from WorldClim (Fick and Hijmans 2017). We then used these solar radiation values to calculate solar radiation's mean, minimum, maximum, and standard deviation. Both bioclimate and solar radiation variables are at a 2.5-minute resolution. We also obtained ten topographic measures from EarthEnv (Robinson et al. 2014) and a Topographic wetness index (TWI), from Marthews et al. (2015a and 2015b). We used R and the *aggregate* (Hijmans 2023) function to rescale the topographic variables to 2.5-minute cells.

## DATA PREPARATION

We compiled data from several sources and underwent a rigorous cleaning procedure, including removal of NAs, cropping data to our study area extent, and creating a grid cell. We removed records that lacked a coordinate system, did not overlap with our study area, and had errors, missing values, or incomplete data. To create a matrix of presence and absence, we overlaid each amphibian range map to a grid of ~2.5min cells, the same resolution as our environmental variables. We considered a 'presence', each grid cell overlapping the species range. Cells with no overlapping ranges were considered as 'absences'.

## RARITY-WEIGHTED RICHNESS

We used the grid cell and presence/absence matrix to estimate species richness and RWR (William et al. 1996). Rather than identifying sites solely by the richness and amount of species, RWR identifies sites with overall richness, emphasizing the rarity of species (Albuquerque and Gregory 2017). We estimated our RWR values by multiplying our presence/absence values by the inverse sum of occurrences for that site, summing the values. When applied to these commonly designated locations with a lower priority ranking, RWR does not imply a lack of importance for conservation. Rather, the priority is linked to the conservation objective of attaining broad-scale protection within resource constraints. (William et al. 1996).

## THE IMPORTANCE OF A SITE FOR CONSERVATION

We implemented Zonation (Moilanen et al. 2009), a complementarity-based algorithm that estimates the importance of sites for conservation. Zonation produces a hierarchical priority ranking of the grid cells for each taxon from zero to one and removes cells that are not indispensable to the core area of the species (Albuquerque and Beier 2015b). Complementarity is the proportion of species that one region contributes to an area not otherwise represented in other sites (Vane-Wright et al. 1991, Colwell and Coddington 1994). We first extracted the Zonation values from our dataset for our study area. Then, to estimate the HPCA of complementarity, we selected the top 30% of grid cells from our study area (Albuquerque et al. 2024). We chose this percentage because the Convention on Biological Diversity (CBD) expects 30% of natural areas to be protected by 2030 (CBD 2022).

## EVALUATING SURROGATES

We built species accumulation curves to evaluate the efficacy of our surrogate solutions for selecting HPCA. We also built species accumulation curves using random solutions (999 curves). The species accumulation curves were built for Zonation, RWR, and species richness and tested against a random solution. We implemented and evaluated a species accumulation curve for a random solution as our control surrogate to evaluate the efficiency of our surrogate approach. Zonation was used as our reference point in the species accumulation curve analysis because it produces near-optimum solutions and performs as a tool to measure the optimization of our surrogates.

We then added the surrogates to a Species Accumulation Index (SAI) to evaluate their efficacy. SAI is commonly used to assess and contrast substitute strategies (Rodrigues and Brooks 2007). It measures the number of species represented by the surrogate (RWR or richness), denoted by *S*. This value is compared against two reference points: *R*, which represents the average number of species that appear at least once in the same number of randomly chosen sites, and *O*, which indicates the highest possible number of species that can be represented at least once in that number of sites (Albuquerque and Beier 2015b). SAI values are rated from negative to positive infinity, with positive SAI values indicating the percent effectiveness of the surrogate. A negative SAI yields results worse than the random solution, and a zero SAI yields results no better than the random selection. The effectiveness of each solution was measured across 30 targets from 0.5% to 30%, increasing incrementally by 1% (Beier and Albuquerque 2016).

**IDENTIFYING DRIVERS OF HPCA DISTRIBUTION**

We minimized the dimensionality of the data by implementing a varimax-rotated principal component analysis (PCA) (Chan 2004). PCA highlights sets of uncorrelated environmental variables and describes environmental gradients within the data. We utilized the Kaiser rule (Kaiser 1960) to select components or factors to maintain in the PCA analyses. The Kaiser rule drops any component with eigenvalues or variance less than one. From the correlation matrix of the PCA scores, we identified the variables most correlated with each factor. Then, we selected the variables most correlated with complementarity values, as expressed by Zonation.

We used random forest models to investigate the relationship between HPCA selection and our environmental variables (Svetnik et al., 2003, Albuquerque et al. 2015a, Astudillo-Scalia et al. 2020). The Random Forest approach that uses multiple decision tree outputs to reach a single result (Breiman 2001). Specifically, the algorithm uses about 1/3 of the cases are left out of the sample, also known as Out of Bag data (OOB) (Breiman, 2001). OOB data is be used as an estimator of variable importance. We ran our random forest model with the raw variables to investigate the importance of variables.

## CLIMATE CHANGE SCENARIOS

The four SSP pathways each represented a different future scenario with varying emissions predictions: ssp 126 represented low emission scenarios, ssp 245 and ssp 370 represented intermediate emission scenarios, and ssp 585 represented high emission scenarios ('O'Neill et al. 2014, Scenarios 2000). Our maps display the top 30% of complementarity values.

## RESULTS

The PCA analysis and the Keiser criteria identified six axes with eigenvalues greater than one (Table 1). The first axis included topographical variables, while the second represented a combination of temperature and elevation. The third and fifth encompassed mostly temperature and energy variables. The fourth axis included measures of temperature and solar radiation. Altogether, the axes explained 90% of environmental variance. Among the selected PCA axes, the variables most correlated with complementarity were mean diurnal range, minimum temperature of coldest month, temperature annual range, precipitation of coldest quarter, precipitation of wettest quarter, and terrain ruggedness index- median.

Table 1

***Principal components analysis of the environmental variables obtained for the SW United States and México drylands. Variables include measures of temperature, precipitation, solar radiation, and topography. Bold values represent the highest correlation with each PC score. Variables highlighted in red are the variables most correlated to complementarity values as expressed by Zonation (correlation coefficients are displayed in the Correlation column).***

| | | | PCA Scores | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **RC1** | **RC4** | **RC2** | **RC6** | **RC3** | **RC5** | **Correlation** |
| **Bioclimates** | | | | | | | |
| Annual Mean Temperature | -0.13 | 0.47 | **0.85** | 0.14 | 0.04 | 0.11 | 0.239 |
| Mean Diurnal Range | -0.1 | -0.06 | -0.3 | 0.01 | **0.78** | 0.23 | -0.199 |
| Isothermality | 0.19 | **0.84** | 0.01 | 0.2 | 0.41 | 0 | 0.261 |
| Temperature Seasonality | -0.23 | **-0.91** | -0.1 | -0.22 | -0.11 | 0.11 | -0.425 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Max Temperature of Warmest Month | -0.27 | -0.13 | **0.89** | -0.07 | 0.17 | 0.11 | 0.008 |
| Min Temperature of Coldest Month | 0.04 | 0.64 | **0.75** | 0.13 | 0.01 | -0.08 | 0.368 |
| Temperature Annual Range | -0.24 | **-0.86** | -0.26 | -0.2 | 0.11 | 0.17 | -0.457 |
| Mean Temperature of Wettest Quarter | -0.23 | 0.23 | 0.51 | 0.3 | 0.06 | **0.6** | -0.026 |
| Mean Temperature of Driest Quarter | 0.15 | 0.28 | **0.64** | -0.09 | 0.26 | -0.43 | 0.310 |
| Mean Temperature of Warmest Quarter | -0.27 | 0.03 | **0.94** | 0.03 | 0.01 | 0.16 | 0.065 |
| Mean Temperature of Coldest Quarter | -0.01 | 0.67 | **0.71** | 0.18 | 0.09 | 0.02 | 0.332 |
| Annual Precipitation | 0.1 | 0.24 | 0.05 | **0.82** | -0.45 | -0.15 | 0.450 |
| Precipitation of Wettest Month | 0.17 | 0.39 | 0.1 | **0.87** | -0.09 | -0.1 | 0.458 |
| Precipitation of Driest Month | -0.11 | -0.19 | -0.1 | 0.23 | **-0.87** | 0.08 | 0.017 |
| Precipitation Seasonality | 0.03 | 0.58 | 0.18 | 0.42 | 0.56 | -0.03 | 0.209 |
| Precipitation of Wettest Quarter | 0.19 | 0.4 | 0.05 | **0.87** | -0.05 | -0.13 | 0.459 |
| Precipitation of Driest Quarter | -0.08 | -0.17 | -0.06 | 0.26 | **-0.87** | 0.05 | 0.072 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Precipitation of Warmest Quarter | 0.14 | 0.34 | 0.01 | **0.83** | -0.05 | 0.28 | 0.192 |
| Precipitation of Coldest Quarter | 0.21 | -0.12 | 0.09 | 0.32 | -0.24 | **-0.79** | 0.497 |
| **Solar radiation** | | | | | | | |
| Solar radiation - minimum | 0.12 | **0.62** | 0.32 | 0.27 | 0.36 | 0.41 | 0.191 |
| Solar radiation - maximum | 0.01 | **-0.88** | 0.02 | -0.25 | 0.25 | -0.19 | -0.192 |
| Solar radiation - mean | 0.14 | -0.17 | 0.33 | 0 | **0.71** | 0.21 | -0.035 |
| Solar radiation - standard deviation | -0.07 | **-0.85** | -0.14 | -0.3 | -0.05 | -0.36 | -0.208 |
| **Topography** | | | | | | | |
| Elevation - median | 0.32 | -0.07 | **-0.86** | -0.05 | 0.17 | 0.18 | -0.165 |
| Elevation - standard deviation | **0.97** | 0.08 | -0.07 | 0.02 | 0.06 | 0.01 | 0.128 |
| Roughness- median | **0.94** | 0.08 | -0.14 | 0.17 | -0.01 | -0.09 | 0.157 |
| Roughness - standard deviation | **0.97** | 0.08 | -0.09 | 0.02 | 0.05 | -0.01 | 0.128 |
| Slope - median | **0.93** | 0.07 | -0.14 | 0.16 | -0.02 | -0.1 | 0.153 |
| Slope - standard deviation | **0.98** | 0.08 | -0.11 | 0.04 | 0.04 | -0.03 | 0.134 |
| Topographic position index- median | **-0.56** | -0.08 | -0.16 | 0.09 | -0.08 | 0.03 | -0.110 |
| Topographic position index-- | **0.96** | 0.1 | -0.1 | 0.15 | 0.04 | -0.03 | 0.160 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| standard deviation | | | | | | | |
| Terrain ruggedness index- median | **0.94** | 0.08 | -0.14 | 0.18 | -0.01 | -0.09 | 0.161 |
| Terrain ruggedness index - standard deviation | **0.97** | 0.08 | -0.08 | 0.01 | 0.05 | 0 | 0.129 |
| Topographic index | **-0.87** | 0.01 | 0.23 | -0.07 | 0 | 0.07 | -0.139 |
| **SS loadings** | **9.09** | **6.38** | **5.51** | **3.96** | **3.77** | **1.89** | |
| **Cumulative Var** | **0.27** | **0.45** | **0.62** | **0.73** | **0.84** | **0.90** | |

Patterns of Zonation, RWR, and HPCA displayed high values throughout continuous corridors across California, central Texas, and western Mexico. Richness displayed high values in central Texas and along the Southwestern border of Mexico in our study area. Secondary spots of high richness values were also displayed in SW and NE Mexico (Sinaloa, Tamaulipas, and San Luis Potosí). Zonation was displayed as the best depiction of the high values with the solution. It also reveals isolated areas of high values in New Mexico, Arizona, Nevada, and Utah that did not yield the same results under the other solutions. RWR produced similarly high values as Zonation but could not depict the same level of connectivity between the isolated HPCA.

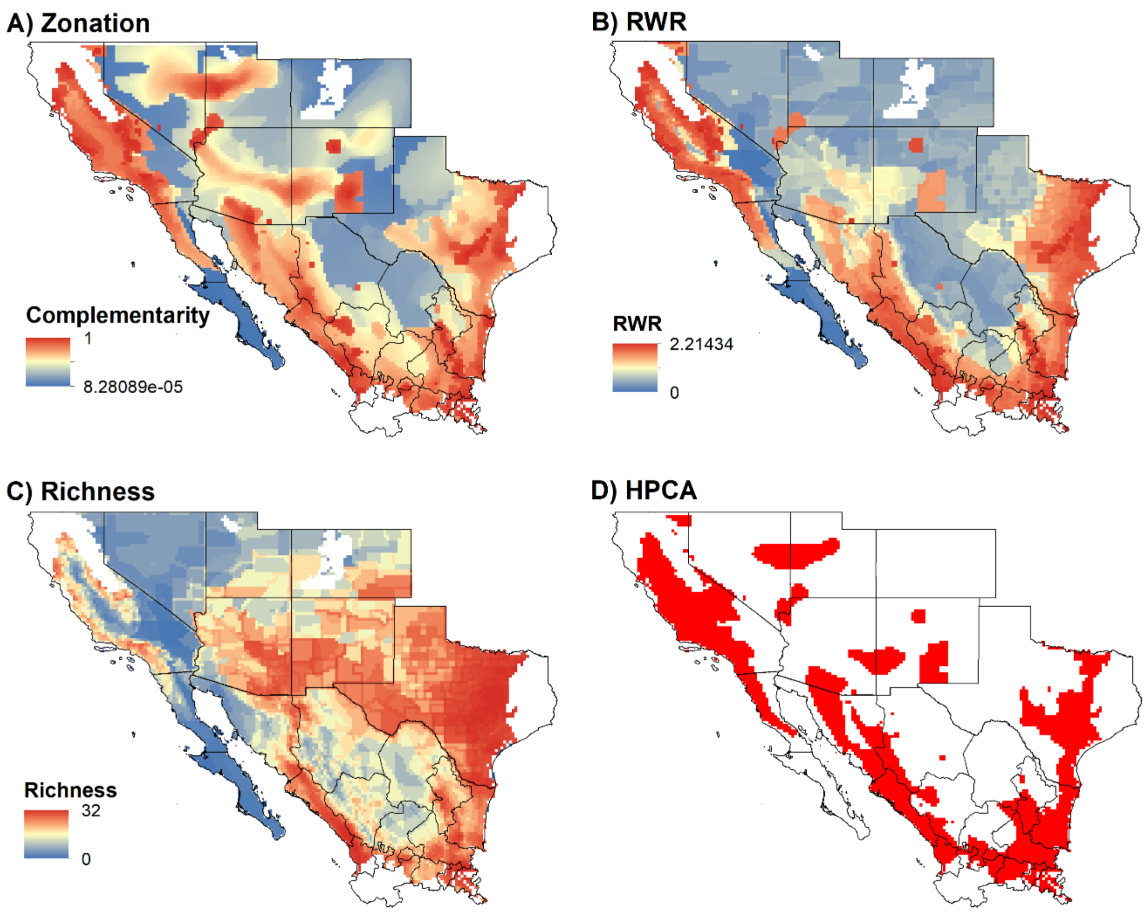


***Figure 2.*** Geographic distribution of high priority conservation areas for amphibians in Southwest drylands using different methods to select sites (A) Zonation, (B) rarity-weighted richness, (C) species richness. (D) D represents the high priority conservation areas (HPCA) identified as the most important areas for amphibian conservation.

Zonation proved to be the best solution for representing amphibians in the dryland systems of the Southwest United States and Northern Mexico. RWR performed nearly as well as the Zonation solution in selecting the most amount of species within the fewest number of sites. Species richness, however, was a poor solution for selecting species with richness performing no better than the random solution simulations of our model.

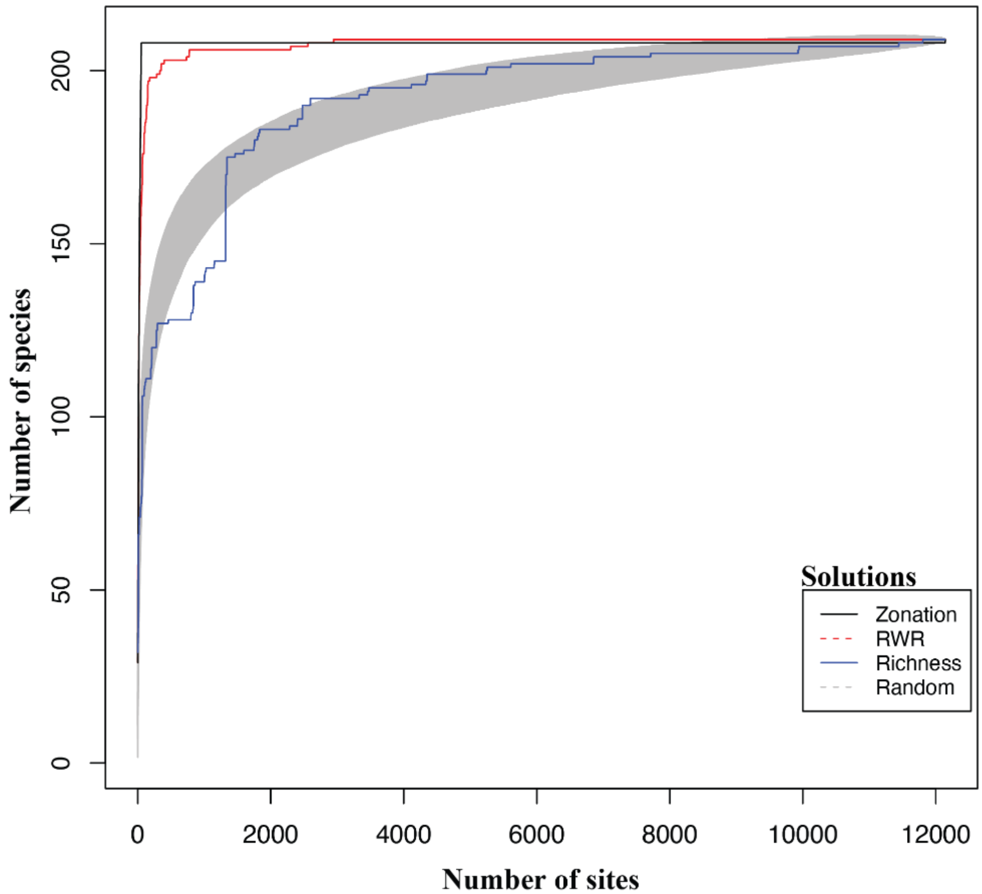


***Figure 3.*** Species accumulation curves depicting Zonation, rarity-weighted richness (RWR), richness, and random solutions selecting species for conservation and the number of sites each solution needed to reach the target number of amphibian species in the study (220).

According to random forest models, precipitation and energy were the most influential variables in explaining the spatial distribution of site complementarity and HPCA (Figure 4). The top four most influential variables were precipitation of the coldest quarter, mean diurnal range, minimum temperature of the coldest month, and precipitation of the wettest quarter. The environmental variables explained 78.47% of the variance within our model.

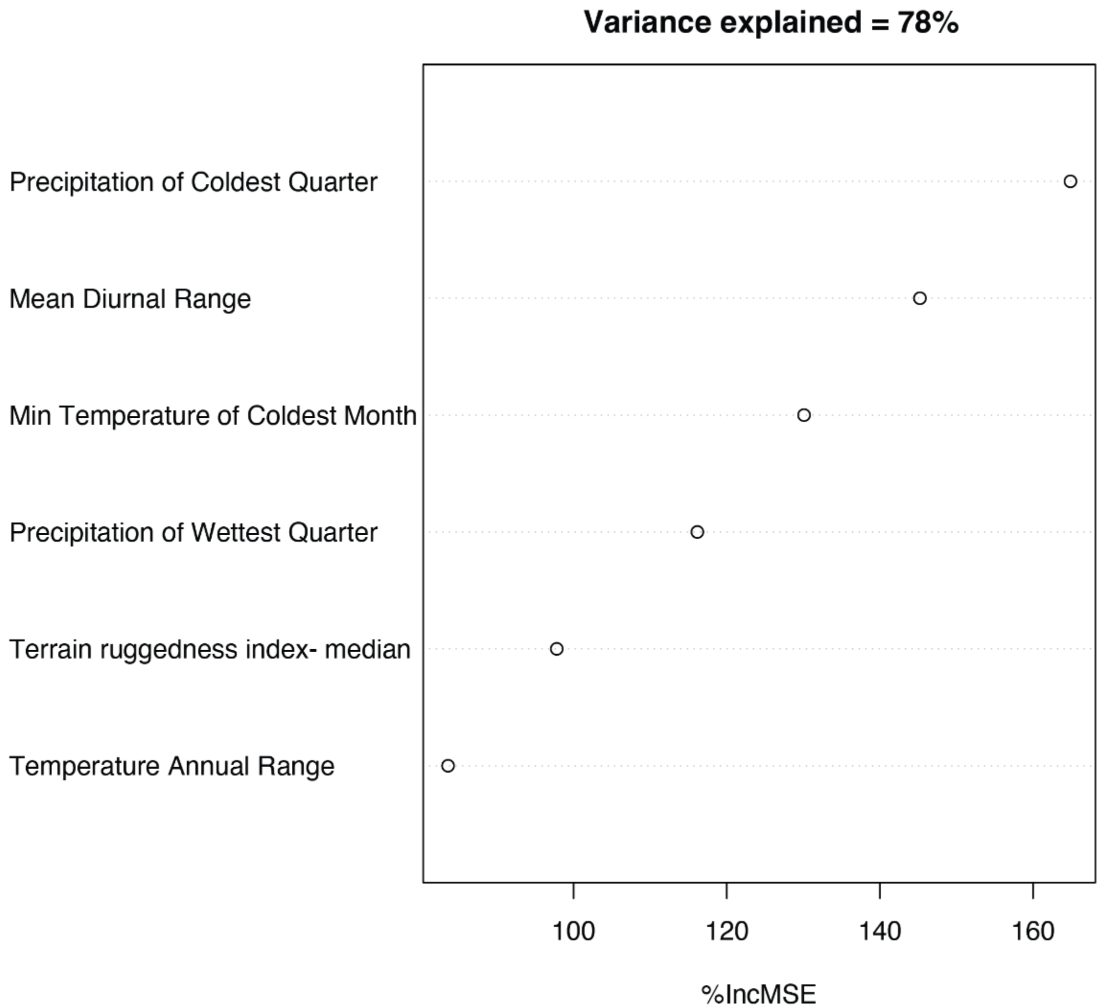


***Figure 4.*** Variable importance for random forest model, identifying which variables were most important to the spatial configurations of important conservation areas for amphibians in drylands of SW United States and Mexico. %IncMSE- Mean Decrease Accuracy. Results also indicate how the model accuracy decreases when that variable is removed.

The climate change scenarios displayed overall changes in the HPCA for all four scenarios for 2081-2100 (Figure 5). The greatest changes in HPCA were observed for ssp370 (30.09%) and ssp585 (32.09%). The most loss of HPCA was seen in the isolated dryland sites of Nevada, Utah, New Mexico, and Arizona. The most gains of HPCA were seen along the western coast of Mexico and central Texas across all climate change scenarios.

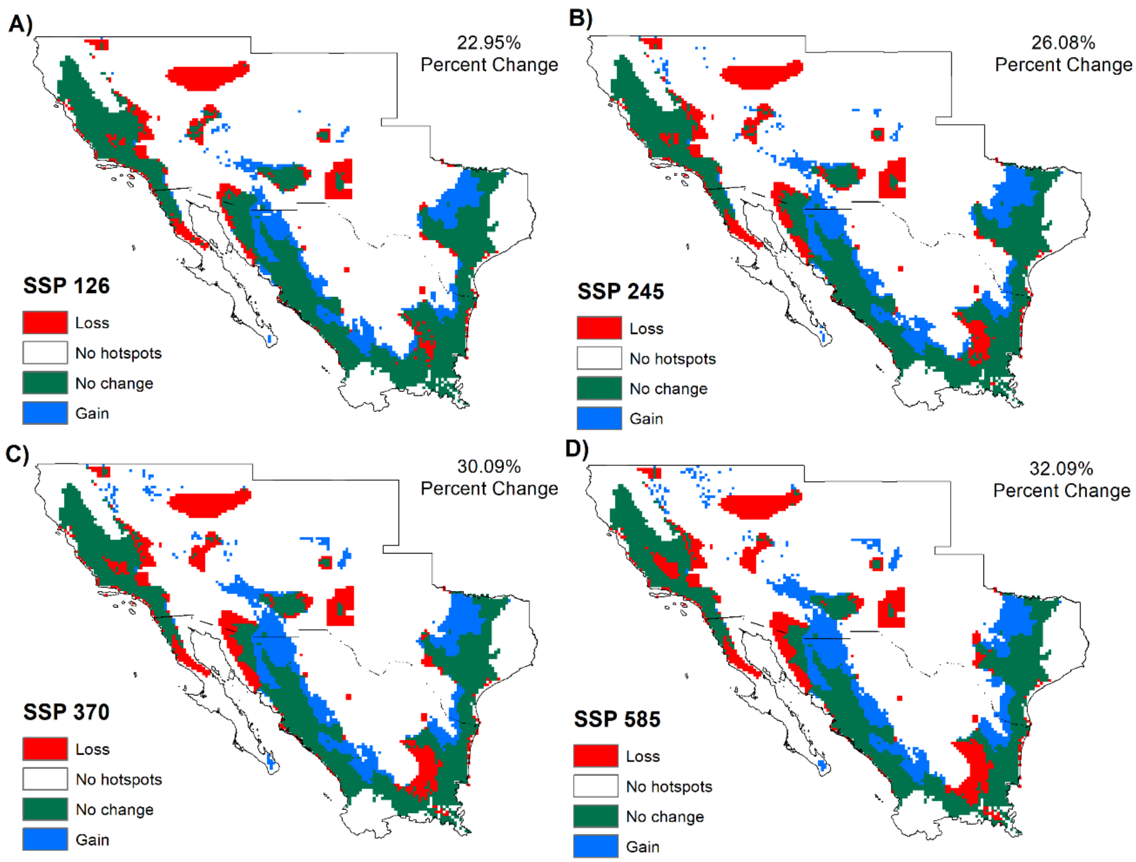


***Figure 5.*** Future geographic distribution of high priority conservation areas for amphibians in Southwest drylands. Red cells represent a predicted loss, white cells represent no HPCA, green cells represent no change, and blue cells represent a predicted gain.

The climate change scenarios also display significant overlap between the current HPCA and the predicted future HPCA. The highest values were observed for the most optimistic scenarios (SSP 126 and 245), with a 77.05% overlap of suitable habitat between the two models. The lowest overlap was noted in the most pessimistic scenarios (SSP 370 – 69.91%, and SSP 570 - 67.91%).

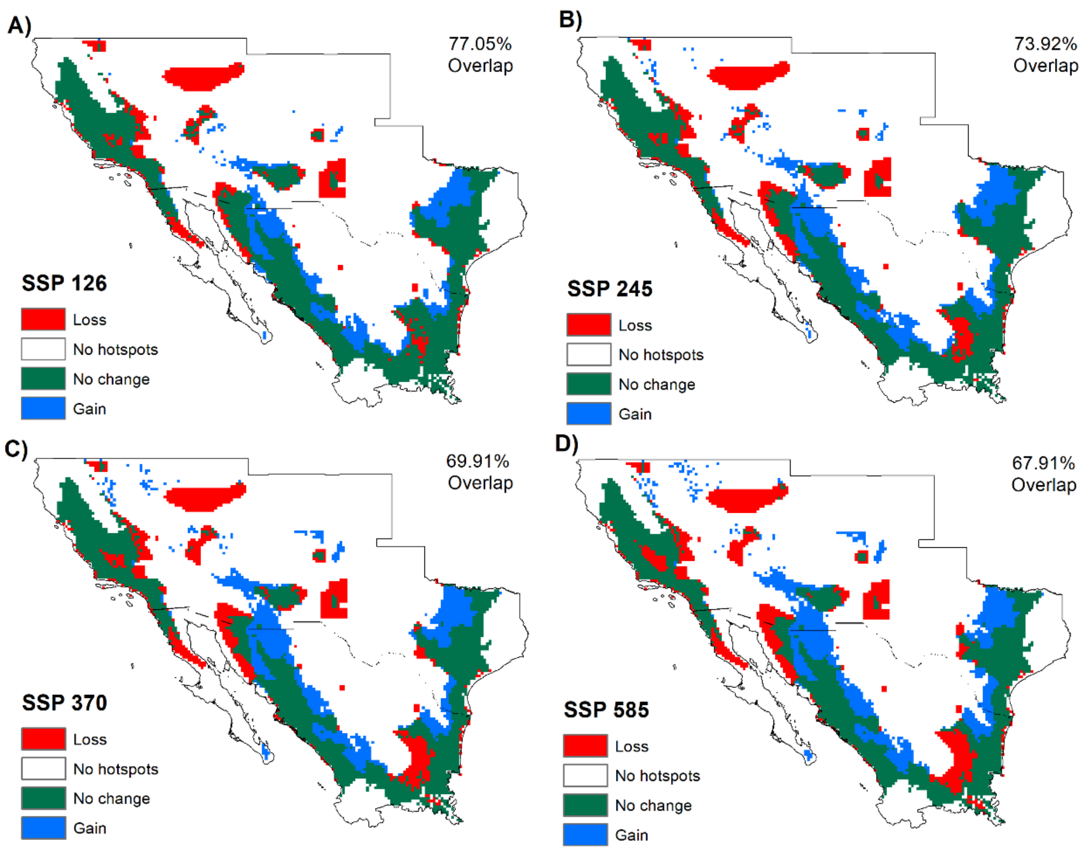


***Figure 6.*** Geographic distribution for predicted overlap between current HPCA and future HPCA in the Southwest drylands. Red cells represent a predicted loss, white cells represent no HPCA, green cells represent no change, and blue cells represent a predicted gain.

# DISCUSSION

## SURROGATE ANALYSIS

Zonation was the most successful surrogate for identifying the HPCA for amphibians within the dryland systems of the Southwest United States and Northern Mexico. Zonation was chosen as the standard surrogate because hierarchical prioritization produces near-optimum solutions for target-based planning to meet the lowest cost targets (Moilanen 2007). Zonation works best due to its heuristic algorithm and process of iteratively removing the least valuable cells and keeping the most important ones until the end (Di Minin et al. 2014). The algorithm identifies that a least valuable cell would have low species occurrences while a high-priority cell would have many occurrences (Di Minin et al. 2014). The Zonation approach identified the HPCA for amphibian conservation and showed the connectivity between the more isolated HPCA found in Arizona, New Mexico, Utah, and Nevada (Figure 1).

Results indicated that RWR was an efficient surrogate of amphibians in the drylands southwest of the United States and Mexico. Rarity indices such as RWR have proven to be efficient surrogates for biodiversity when optimizing efficiency when planning conservation (Astudillo-Scalia and Albuquerque 2019). RWR has proven to be a reliable measure of complementarity and could be used as an alternative approach to Zonation for conservation planning, and is supported by previous studies evaluating rarity indices within terrestrial systems (Albuquerque and Beier 2015b, Albuquerque et al. 2019). RWR identifies HPCA with isolated range-restricted species while simultaneously illustrating sites with assemblages of rare and common species (Albuquerque and Gregory 2017). Rarity indices also offer alternative solutions Zonation by prioritizing sites with endemic, vulnerable, or rare species rather than more common ones (Astudillo-Scalia and Albuquerque 2019).

According to our SAI results, identifying HPCA through richness was less efficient at representing amphibians. Our results show richness performed worse than Zonation and RWR at selecting species, performing no better than the random solution based on our SAI (Figure 2). Our results are in tandem with previous studies that have displayed that richness is not a viable metric to predict or identify areas for conservation (Fleishman et al. 2006). The poor performance of richness could be explained by the homogeneity of the species assemblage in areas with high species richness within the study, meaning areas with high species richness have greater numbers of overlapping species with other sites. In contrast, areas with rarer endemic species occur in areas with low overall species richness. Richness is a historic statistic for conservation planning, but its simplicity results in the spatial overlap that can cause under-representation of species compared to Zonation and other rarity indice approaches (Astudillo-Scalia and Albuquerque 2020). Richness as a surrogate highlights significant overlap between species ranges, which results in redundancy when selecting HPCA (Albuquerque and Gregory 2017).

**BIOGEOGRAPHY**

Our study is unique in its novelty as it is the first to investigate the spatial configurations of HPCA for amphibians in the drylands of the Southwest United States and Northern Mexico. HPCA included a wide range of amphibians in arid ecosystems (Figure 1). The geographic HPCA for amphibians displays two continuous corridors from

California to Baja California, and from Southern Arizona along the western coast of Mexico, across the southern border of the study area, and back up the eastern coast of Mexico through Central Texas. HPCA are also seen in isolated areas in the SW United States, most notably in Nevada, Arizona, New Mexico, and Utah. Climate conditions, especially water availability, primarily constrain the spatial configuration of HPCA observed herein. Ours agrees with previous studies that support our results by identifying water, temperature, and solar radiation as driving factors for amphibian distributions (Hawkins et al. 2003, Wake and Vredenburg 2008, Albuquerque et al. 2024).

Our results provide support for the tenet that environmental variables strongly influence the spatial configuration of HPCA in terrestrial (Albuquerque and Beier 2015a, Albuquerque et al. 2019) and marine (Astudillo-Scalia and Albuquerque 2020) realms. In all these cases, climate, represented by water and energy-related variables, was the most influential over the location of HPCA. The relevance of water-related variables to the spatial distribution of HPCA of amphibians could be related to their life-history as many species have biphasic life cycles with aquatic larval forms. Water as a resource is integral to amphibian life history because their semi-permeable skin lacks structures to prevent water loss (Thorston 1955). Water is also a requirement for amphibians that conduct cutaneous respiration, which is more efficient and important to them than respiration via the lungs (Wake and Vredenburg 2008). Desiccation threatens amphibians living in drylands, especially amphibians in the Southwest United States, which has been experiencing intense drought conditions for the past decade and is predicted to continue (Seager et al. 2007). The high importance of energy-related variables in explaining the spatial distribution of HPCA could be related to amphibians' physiology. Amphibians are ectothermic vertebrates that require environmental inputs, such as air temperature, to aid them in thermoregulation, and as ectotherms, they are particularly sensitive to temperature changes, both high and low, in their environment (Huey 1982). Body temperature influences amphibian metabolic rates and activity (Buckley et al. 2012).

Dry climates pose a unique challenge to amphibians due to the lack of available water and the increased risk of dissection, especially in dry and hot climates. However, many dryland amphibians have developed unique adaptations such as becoming fossorial, covering their bodies in wax, etc., allowing amphibian persistence in a hostile environment (Shoemaker 1988). Besides their adaptations, the United States and Northern Mexico's dryland systems harbor unique habitats that contain rich pockets of biodiversity (Gudka et al. 2014) that dryland amphibians can exploit.

The importance of the spatial configurations of our HPCA lies within their ability to act as a broad-scale framework for conservation managers to identify the most important areas to begin finer-scale conservation attempts. Effective conservation plans are created at local and regional levels because they require stakeholders and government bodies to enact pertinent policies (Fleishman and Brown 2019). Our study does not intend to overshadow local conservation attempts but rather empower them by investigating the larger picture and identifying HPCA across the drylands of the southwest.

**IMPACTS OF CLIMATE CHANGE**

Our future climate change models serve as predictions for the HPCA from 2081 to 2100. The SSP models act as a reference to estimate the influence climate change and various policy approaches will have on the environment ('O'Neill et al. 2014). Our results display a significant change in the HPCA from the current model to the future model under simulated climate change. Our climate change analysis displays an overall change in suitability for amphibians, ranging from a 23% change in the most optimistic scenario to 32% in the most pessimistic scenario (Figure 5). Any change in suitability is alarming for dryland amphibian conservation due to the lack of currently available suitability the taxa faces in arid environments (Dayton and Fitzgerald 2006). Our climate change scenarios also included overlap between the current HPCA and the predictive future HPCA models. There was a predicted 77.05% to 67.91% overlap between the most optimistic to pessimistic scenarios (SSP 126- SSP 585, Figure 6). This overlap between the current and future models is important because it displays suitable habitats for dryland amphibians that will remain after simulated climate change. By employing predictive modeling such as the SSP climate change scenarios, conservation managers can identify sites most at risk of degradation and plan for these scenarios. Conservation managers can also focus their efforts on the green/ unchanged areas because many areas that gained suitability in the future were connected to core portions of unaffected habitat (Figures 5 & 6). In addition, creating corridors for migration to the predicted HPCA could allow for the movement of at-risk amphibian populations to more suitable habitats.

Spatial analysis tools have allowed scientists to predict how climate change will impact habitat suitability and how it impacts species distributions. However, climate change may also cause previously protected areas to no longer efficiently protect species as a changing climate drives species' distribution to alter from their historic ranges

(Alagador et al. 2014). For future research, we suggest identifying unprotected areas that offer high conservation value to dryland amphibians. Conventional conservation practices do not always account for changes in suitability and species range over time in light of climate change, and we advocate the integration of a dynamic complementarity-based conservation approach that accounts for these predicted shifts (Araújo 2009). Results also provide evidence that climate should be regarded as a potential indicator for future amphibian conservation projects in the drylands of the Southwest United States and Northern Mexico.

We understand the limitations of our study as we did not account for landscape connectivity within our models. Our models used occurrence data for all the amphibian species within our study area, but we did not include specific biological information about each species in our model. Our models are curated to represent a macroecological approach to selecting suitable areas for conserving amphibians in drylands. Further research is needed at the local level for effective conservation policy to be enacted (Epele et al. 2021). We implemented a robust climate change analysis for the HPCA across our study area, and we did not account for non-climate-related variables that may be contributing to amphibian declines, such as biological pressures, disease, natural disasters, and human-caused habitat degradation (Lanoo 2005). Although these models are not designed to be tools for local conservation efforts due to the scale, the models represent the state of the best science available to accomplish this type of investigation to understand how suitable habitats can change under future climate scenarios. With the limitations of this study, it is imperative to understand its novelty and utility as it is the first to offer a conservation tool for amphibian conservation in the drylands of the Southwest United States and Northern Mexico.

## CONCLUSION

Zonation and RWR solutions fared far better than random solutions at selecting amphibians, while richness failed. We advocate for conservation managers to implement complementarity-based solutions, such as Zonation or RWR, rather than richness when selecting conservation areas to best protect amphibians in the drylands of the Southwest and Northern Mexico.

Results show the environmental variables have a strong relationship with the spatial configurations of the HPCA. Water and energy variables, specifically precipitation, solar radiation, and temperature, proved to be the most influential variables in determining these spatial configurations and have been linked as drivers for amphibian richness (Hawkins et al. 2003). Our results align with other studies, where high precipitation and solar radiation values were linked to high habitat suitability for amphibians (Albuquerque et al. 2024).

Our results display a substantial change in the HPCA due to climate change. Our most optimistic scenario, ssp126, representing low predicted emissions, saw a 23% change in the suitable range for amphibians. The ssp585 scenario representing high predicted emissions saw a 32% change in suitable habitat across the study area. These results portray an alarming alteration in current amphibian suitability, with the isolated dryland sites in Nevada, New Mexico, Arizona, and Utah receiving the most predicted loss of suitable habitat.

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APPENDIX I

ENVIORNMENTAL VARIABLES

| Bioclimatic | Description |
|---|---|
| Annual Mean Temperature | Average annual temperature from 1970-2000 |
| Mean Diurnal Range | (Mean of monthly (max temp - min temp)) |
| Isothermality | (BIO2/BIO7) (×100) |
| Temperature Seasonality | (standard deviation ×100) |
| Max Temperature of Warmest Month | Yearly value from 1970-2000 of the month with the highest temperature |
| Min Temperature of the Coldest Month | Yearly value from 1970-2000 of the month with the lowest temperature |
| Temperature Annual Range | (Max Temperature – Min Temperature) |
| Mean Temperature of Wettest Quarter | Average temperature from 1970-2000 for the wettest ¼ of the year |
| Mean Temperature of Driest Quarter | Average temperature from 1970-2000 for the driest ¼ of the year |
| Mean Temperature of Warmest Quarter | Average temperature from 1970-2000 for the warmest ¼ of the year |
| Mean Temperature of Coldest Quarter | Average temperature from 1970-2000 for the coldest ¼ of the year |
| Annual Precipitation | Yearly value from 1970-2000 |
| Precipitation of the Wettest Month | Rainfall value from 1970-2000 of the month with the most rainfall |

| | |
|---|---|
| Precipitation of Driest Month | Rainfall value from 1970-2000 of the month with the least rainfall |
| Precipitation Seasonality | (Coefficient of Variation) |
| Precipitation of Wettest Quarter | Rainfall value from 1970-2000 for the ¼ of the year with the most rainfall |
| Precipitation of Driest Quarter | Rainfall value from 1970-2000 for the ¼ of the year with the least rainfall |
| Precipitation of Warmest Quarter | Rainfall value from 1970-2000 for the ¼ of the year with the highest temperatures |
| Precipitation of Coldest Quarter | Rainfall value from 1970-2000 for the ¼ of the year with the lowest temperatures |
| **Solar Radiation** | **Description** |
| Solar Radiation Minimum Value | Average minimum values from 1970-200 |
| Solar Radiation Maximum Value | Average maximum values from 1970-200 |
| Solar Radiation Mean | Average values from 1970-200 |
| Solar Radiation Standard Deviation | Standard deviation of the values from 1970-2000 |
| **Topography** | **Description** |
| Elevation 5 km median | 5 km resolution of the median elevation value |

| | |
|---|---|
| Elevation 5 km standard deviation | 5 km resolution of the standard deviation of elevation values |
| Roughness median | Median roughness value |
| Roughness standard deviation | Standard deviation of roughness values |
| Slope median | Median slope values |
| Slope standard deviation | Standard deviation of slope values |
| Topographic Position index median | Median value of the difference between the elevation of each cell and the mean elevation of its neighboring cell |
| Topographic Position Index standard deviation | Standard deviation of the difference between the elevation of each cell and the mean elevation of its neighboring cell |
| Topographic Roughness Index median | Median value of the average of the elevation difference among neighboring cells |
| Topographic Roughness Index standard deviation | Standard deviation of the average of the elevation difference among neighboring cells |
| Topographic Wetness Index | (TWI, $\ln(a/\tan\beta)$) |

APPENDIX II

RESIDENT AMPHIBIAN SPECIES AND THEIR LIFE CYCLE

| | BINOMIAL | Common Name | Life Cycle |
|---|---|---|---|
| 1 | *Acris crepitans* | Northern Cricket Frog | Metamorphosis |
| 2 | *Agalychnis dacnicolor* | Mexican Leaf Frog | Metamorphosis |
| 3 | *Ambystoma californiense* | California Tiger Salamander | Metamorphosis |
| 4 | *Ambystoma gracile* | Northwestern Salamander | Metamorphosis |
| 5 | *Ambystoma granulosum* | Granular Salamander | Direct Development |
| 6 | *Ambystoma macrodactylum* | Long-Toed Salamander | Metamorphosis |
| 7 | *Ambystoma maculatum* | Spotted Salamander | Metamorphosis |
| 8 | *Ambystoma mavortium* | Barred Tiger Salamander | Metamorphosis |
| 9 | *Ambystoma opacum* | Marbled Salamander | Metamorphosis |
| 10 | *Ambystoma rosaceum* | Tarahumara Salamander | Metamorphosis |
| 11 | *Ambystoma silvense* | Durango Salamander | Metamorphosis |
| 12 | *Ambystoma talpoideum* | Mole Salamander | Paedomorphic |
| 13 | *Ambystoma texanum* | Small Mouth Salamander | Metamorphosis |
| 14 | *Ambystoma tigrinum* | Tiger Salamander | Metamorphosis |
| 15 | *Ambystoma velasci* | Mexican Tiger Salamander | Paedomorphic |
| 16 | *Amphiuma tridactylum* | Three-Toed Amphihuma | Paedomorphic |
| 17 | *Anaxyrus americanus* | American Toad | Metamorphosis |
| 18 | *Anaxyrus boreas* | Western Toad | Metamorphosis |
| 19 | *Anaxyrus californicus* | Arroyo Toad | Metamorphosis |
| 20 | *Anaxyrus canorus* | Yosemite Toad | Metamorphosis |
| 21 | *Anaxyrus cognatus* | Great Plains Toad | Metamorphosis |
| 22 | *Anaxyrus compactilis* | Plateau Toad | Metamorphosis |
| 23 | *Anaxyrus debilis* | Green Toad | Metamorphosis |
| 24 | *Anaxyrus exsul* | Black Toad | Metamorphosis |
| 25 | *Anaxyrus fowleri* | Fowler's Toad | Metamorphosis |
| 26 | *Anaxyrus houstonensis* | Houston Toad | Metamorphosis |
| 27 | *Anaxyrus kelloggi* | Little Mexican Toad | Metamorphosis |
| 28 | *Anaxyrus mexicanus* | Southwestern Toad | Metamorphosis |
| 29 | *Anaxyrus microscaphus* | Arizona Toad | Metamorphosis |
| 30 | *Anaxyrus nelsoni* | Armargosa Toad | Metamorphosis |
| 31 | *Anaxyrus punctatus* | Red-Spotted Toad | Metamorphosis |
| 32 | *Anaxyrus retiformis* | Sonoran Green Toad | Metamorphosis |
| 33 | *Anaxyrus speciosus* | Texas Toad | Metamorphosis |
| 34 | *Anaxyrus woodhousii* | Woodhouse Toad | Metamorphosis |
| 35 | *Aneides ferreus* | Clouded Salamander | Direct Development |
| 36 | *Aneides flavipunctatus* | Speckled Black Salamander | Direct Development |

| | | | |
|---|---|---|---|
| 37 | *Aneides hardii* | Sacramento Mountain Salamander | Direct Development |
| 38 | *Aneides lugubris* | Arboreal Salamander | Direct Development |
| 39 | *Aneides vagrans* | Wandering Salamander | Direct Development |
| 40 | *Aquiloeurycea cephalica* | Red-Legged False Brook Salamander | Direct Development |
| 41 | *Aquiloeurycea galeanae* | Galeana false brook salamander | Direct Development |
| 42 | *Aquiloeurycea scandens* | Tamaulipan False Brook Salamander | Direct Development |
| 43 | *Ascaphus truei* | Tailed Frog | Metamorphosis |
| 44 | *Batrachoseps attenuatus* | California Slender Salamander | Direct Development |
| 45 | *Batrachoseps campi* | Inyo Mountains Salamander | Direct Development |
| 46 | *Batrachoseps diabolicus* | Hell Hallow Salamander | Direct Development |
| 47 | *Batrachoseps gabrieli* | San Gabriel Slender Salamander | Direct Development |
| 48 | *Batrachoseps gavilanensis* | Gabilan Mountains Slender Salamander | Direct Development |
| 49 | *Batrachoseps gregarius* | Gregarious Slender Salamander | Direct Development |
| 50 | *Batrachoseps incognitus* | San Simeon Slender Salamander | Direct Development |
| 51 | *Batrachoseps kawia* | Sequoia Slender Salamander | Direct Development |
| 52 | *Batrachoseps luciae* | Santa Lucia Salamander | Direct Development |
| 53 | *Batrachoseps major* | Garden Slender Salamander | Direct Development |
| 54 | *Batrachoseps minor* | Lesser Slender Salamander | Direct Development |
| 55 | *Batrachoseps nigriventris* | Black Bellied Salamander | Direct Development |
| 56 | *Batrachoseps pacificus* | Channel Island Slender Salamander | Direct Development |
| 57 | *Batrachoseps regius* | Kings River Slender Salamander | Direct Development |
| 58 | *Batrachoseps relictus* | Relictual Slender Salamander | Direct Development |

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| 59 | *Batrachoseps robustus* | Kern Plateau Salamander | Direct Development |
| 60 | *Batrachoseps simatus* | Kern Canyon Slender Salamander | Direct Development |
| 61 | *Batrachoseps stebbinsi* | Tehachapi Slender Salamander | Direct Development |
| 62 | *Bolitoglossa platydactyla* | Brood-footed Salamander | Direct Development |
| 63 | *Chiropterotriton chondrostega* | Gristle-Headed Splayfoot Salamander | Direct Development |
| 64 | *Chiropterotriton cieloensis* | El Cielo Salamander | Direct Development |
| 65 | *Chiropterotriton cracens* | Graceful Splayfoot Salamander | Direct Development |
| 66 | *Chiropterotriton infernalis* | Purification System Salamander | Direct Development |
| 67 | *Chiropterotriton magnipes* | Bigfoot Splayfoot Salamander | Direct Development |
| 68 | *Chiropterotriton miquihuanus* | Miquihuana Splayfoot Salamander | Direct Development |
| 69 | *Chiropterotriton multidentatus* | Toothy Splayfoot Salamander | Direct Development |
| 70 | *Chiropterotriton orculus* | Cope's Flat-Footed Salamander | Direct Development |
| 71 | *Chiropterotriton priscus* | Primeval Splayfoot Salamander | Direct Development |
| 72 | *Chiropterotriton terrestris* | Terrestrial Splayfoot Salamander | Direct Development |
| 73 | *Craugastor augusti* | The Barking Frog | Metamorphosis |
| 74 | *Craugastor batrachylus* | Taumalipan Arboreal Robber Frog | Metamorphosis |
| 75 | *Craugastor berkenbuschii* | Burkenbusch's Robber Frog | Metamorphosis |
| 76 | *Craugastor decoratus* | Adorned Robber Frog | Metamorphosis |
| 77 | *Craugastor hobartsmithi* | Smith's Pigmy Robber Frog | Metamorphosis |
| 78 | *Craugastor loki* | Common Leaf Litter Frog | Metamorphosis |
| 79 | *Craugastor mexicanus* | Mexican Robber Frog | Metamorphosis |
| 80 | *Craugastor occidentalis* | Taylor's Barking Frog | Metamorphosis |
| 81 | *Craugastor pygmaeus* | Pigmy Free-Fingered Frog | Metamorphosis |
| 82 | *Craugastor rhodopis* | Polymorphic Robber Frog | Metamorphosis |
| 83 | *Craugastor tarahumaraensis* | Tarahumara Barking Frog | Metamorphosis |

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| 84 | *Craugastor vocalis* | Taylor's Stream Frog | Metamorphosis |
| 85 | *Desmognathus auriculatus* | Southern Dusky Salamander | Metamorphosis |
| 86 | *Dicamptodon ensatus* | California Giant Salamander | Metamorphosis |
| 87 | *Dicamptodon tenebrosus* | Costal Giant Salamander | Metamorphosis |
| 88 | *Dryophytes arenicolor* | Canyon Treefrog | Metamorphosis |
| 89 | *Dryophytes chrysoscelis* | Cope's Grey Treefrog | Metamorphosis |
| 90 | *Dryophytes cinereus* | North American Green Treefrog | Metamorphosis |
| 91 | *Dryophytes eximius* | Mountain Treefrog | Metamorphosis |
| 92 | *Dryophytes plicatus* | Ridged Treefrog | Metamorphosis |
| 93 | *Dryophytes squirellus* | Squirrel Treefrog | Metamorphosis |
| 94 | *Dryophytes versicolor* | Eastern Gray Treefrog | Metamorphosis |
| 95 | *Dryophytes wrightorum* | Arizona Treefrog | Metamorphosis |
| 96 | *Eleutherodactylus campi* | Rio Grande Chirping Frog | Metamorphosis |
| 97 | *Eleutherodactylus cystignathoides* | Lowland Chirping Frog | Metamorphosis |
| 98 | *Eleutherodactylus dennisi* | Long-Footed Frog | Metamorphosis |
| 99 | *Eleutherodactylus guttilatus* | Spotted Chirping Frog | Metamorphosis |
| 100 | *Eleutherodactylus interorbitalis* | Spectacled Chirping Frog | Metamorphosis |
| 101 | *Eleutherodactylus longipes* | Huasteca Chirping Frog | Metamorphosis |
| 102 | *Eleutherodactylus marnockii* | Cliff Chirping Frog | Metamorphosis |
| 103 | *Eleutherodactylus nitidus* | Shiny Peeping Frog | Metamorphosis |
| 104 | *Eleutherodactylus orarius* | Coastal Whistling Frog | Metamorphosis |
| 105 | *Eleutherodactylus pallidus* | Pale Chirping Frog | Metamorphosis |
| 106 | *Eleutherodactylus saxatilis* | Marbled Robber Frog | Metamorphosis |
| 107 | *Eleutherodactylus teretistes* | Whistling Frog | Metamorphosis |
| 108 | *Eleutherodactylus verrucipes* | Bigear Chirping Frog | Metmorphosis |
| 109 | *Eleutherodactylus wixarika* | Wixarika Chirping Frog | Metamorphosis |
| 110 | *Engystomops pustulosus* | Tungara Frog | Metamorphosis |
| 111 | *Ensatina eschscholtzii* | Ensatina Salamander | Direct Development |
| 112 | *Eurycea chisholmensis* | Salado Salamander | Paedomorphic |
| 113 | *Eurycea latitans* | Cascade Cavern Salamander | Paedomorphic |
| 114 | *Eurycea nana* | San Marcos Salamander | Paedomorphic |

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| 115 | *Eurycea naufragia* | Georgetown Salamander | Paedomorphic |
| 116 | *Eurycea neotenes* | Texas Salamander | Paedomorphic |
| 117 | *Eurycea pterophila* | Fern Bank Salamander | Paedomorphic |
| 118 | *Eurycea quadridigitata* | Dwarf Salamander | Metamorphosis |
| 119 | *Eurycea rathbuni* | Texas Blind Salamander | Paedomorphic |
| 120 | *Eurycea robusta* | Blanco Blind Salamander | Unknown |
| 121 | *Eurycea sosorum* | Barton Spring Salamander | Unknown |
| 122 | *Eurycea tonkawae* | Jollyville Plateau Salamander | Paedomorphic |
| 123 | *Eurycea tridentifera* | Comal Blind Salamander | Paedomorphic |
| 124 | *Eurycea troglodytes* | Valdina Farms Salamander | Paedomorphic |
| 125 | *Eurycea waterlooensis* | Austin Blind Salamander | Paedomorphic |
| 126 | *Exerodonta smaragdina* | Emerald Treefrog | Metamorphosis |
| 127 | *Gastrophryne carolinensis* | Eastern Narrow-Mouthed Toad | Metamorphosis |
| 128 | *Gastrophryne elegans* | Elegant Narrow-Mouthed Toad | Metamorphosis |
| 129 | *Gastrophryne olivacea* | Western Narrow-Mouthed Toad | Metamorphosis |
| 130 | *Hydromantes brunus* | Limestone Salamander | Direct Development |
| 131 | *Hydromantes platycephalus* | Mount Lyell Salamander | Direct Development |
| 132 | *Hydromantes shastae* | Shasta Salamander | Direct Development |
| 133 | *Hypopachus ustus* | Two-Spaded Narrow-Mouth Toad | Metamorphosis |
| 134 | *Hypopachus variolosus* | Sheep Frog | Metamorphosis |
| 135 | *Incilius alvarius* | Sonoran Desert Toad | Metamorphosis |
| 136 | *Incilius marmoreus* | Weigmann's Toad | Metamorphosis |
| 137 | *Incilius mazatlanensis* | Sinaloa Toad | Metamorphosis |
| 138 | *Incilius mccoyi* | McCoy's Toad | Metamorphosis |
| 139 | *Incilius nebulifer* | Gulf Coast Toad | Metamorphosis |
| 140 | *Incilius occidentalis* | Pine Toad | Metamorphosis |
| 141 | *Isthmura bellii* | Bell's Salamander | Direct Development |
| 142 | *Isthmura gigantea* | Giant False Brook Salamander | Direct Development |
| 143 | *Isthmura sierraoccidentalis* | Pine Oak Salamander | Direct Development |
| 144 | *Leptodactylus fragilis* | Mexican White Lipped Frog | Metamorphosis |

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| 145 | *Leptodactylus melanonotus* | Reddish-Brown White Lipped Frog | Metamorphosis |
| 146 | *Lithobates berlandieri* | Rio Grande Leopard Frog | Metamorphosis |
| 147 | *Lithobates blairi* | Plains Leopard Frog | Metamorphosis |
| 148 | *Lithobates catesbeianus* | American Bullfrog | Metamorphosis |
| 149 | *Lithobates chiricahuensis* | Chiricahua Leopard Frog | Metamorphosis |
| 150 | *Lithobates fisheri* | Las Vegas Valley Leopard Frog | Metamorphosis |
| 151 | *Lithobates forreri* | Forrer's Grass Frog | Metamorphosis |
| 152 | *Lithobates johni* | Moore's Frog | Metamorphosis |
| 153 | *Lithobates magnaocularis* | Northwest Mexico Leopard Frog | Metamorphosis |
| 154 | *Lithobates montezumae* | Montezuma Leopard Frog | Metamorphosis |
| 155 | *Lithobates neovolcanicus* | Transverse Volcanic Leopard Frog | Metamorphosis |
| 156 | *Lithobates onca* | Relict Leopard Frog | Metamorphosis |
| 157 | *Lithobates pipiens* | Northern Leopard Frog | Metamorphosis |
| 158 | *Lithobates pustulosus* | Mexican Cascades Frog | Metamorphosis |
| 159 | *Lithobates spectabilis* | Showy Leopard Frog | Metamorphosis |
| 160 | *Lithobates subaquavocalis* | Ramsey Canyon Leopard Frog | Metamorphosis |
| 161 | *Lithobates tarahumarae* | Tarahumara Frog | Metamorphosis |
| 162 | *Lithobates yavapaiensis* | Lowland Leopard Frog | Metamorphosis |
| 163 | *Necturus beyeri* | Gulf Coast Waterdog | Metamorphosis |
| 164 | *Notophthalmus meridionalis* | Black-Spotted Newt | Metamorphosis |
| 165 | *Notophthalmus viridescens* | Eastern Newt | Metamorphosis |
| 166 | *Plethodon albagula* | Western Slimy Salamander | Direct Development |
| 167 | *Plethodon neomexicanus* | Jemez Mountain Salamander | Direct Development |
| 168 | *Pseudacris cadaverina* | California Treefrog | Metamorphosis |
| 169 | *Pseudacris clarkii* | Spotted Chorus Frog | Metamorphosis |
| 170 | *Pseudacris crucifer* | Spring Peeper | Metamorphosis |
| 171 | *Pseudacris fouquettei* | Cajun Chorus Frog | Metamorphosis |
| 172 | *Pseudacris maculata* | Boreal Chorus Frog | Metamorphosis |
| 173 | *Pseudacris regilla* | Pacific Treefrog | Metmorphosis |
| 174 | *Pseudacris streckeri* | Stecker's Chorus Frog | Metamorphosis |
| 175 | *Pseudoeurycea gadovii* | Gadow's Salamander | Direct Development |
| 176 | *Pseudoeurycea leprosa* | Leprous False Brook Salamander | Direct Development |

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| 177 | *Rana boylii* | Foothill Yellow-Legged Frog | Metamorphosis |
| 178 | *Rana cascadae* | Cascades Car | Metamorphosis |
| 179 | *Rana draytonii* | California Red-Legged Frog | Metamorphosis |
| 180 | *Rana luteiventris* | Columbia Spotted-Frog | Metamorphosis |
| 181 | *Rana muscosa* | Southern Mountain Yellow-Legged Frog | Metamorphosis |
| 182 | *Rana pretiosa* | Oregon Spotted Frog | Metamorphosis |
| 183 | *Rana sierrae* | Sierra Nevada Yellow-Legged Frog | Metamorphosis |
| 184 | *Rheohyla miotympanum* | Small-Eared Treefrog | Metamorphosis |
| 185 | *Rhinella marina* | Cane Toad | Metamorphosis |
| 186 | *Rhinophrynus dorsalis* | Mexican Burrowing Toad | Metamorphosis |
| 187 | *Sarcohyla arborescandens* | Lesser Bromeliad Treefrog | Metamorphosis |
| 188 | *Sarcohyla charadricola* | Puebla Treefrog | Metamorphosis |
| 189 | *Sarcohyla hapsa* | Northern Streamside Treefrog | Metamorphosis |
| 190 | *Sarcohyla robertsorum* | Robert's Treefrog | Metamorphosis |
| 191 | *Scaphiopus couchii* | Couch's Spadefoot | Metamorphosis |
| 192 | *Scaphiopus hurterii* | Hurter's Spadefoot | Metamorphosis |
| 193 | *Scinax staufferi* | Middle American Snouted Treefrog | Metamorphosis |
| 194 | *Siren intermedia* | Lesser Siren | Metamorphosis |
| 195 | *Siren lacertina* | Greater Siren | Metamorphosis |
| 196 | *Smilisca baudinii* | Common Mexican Treefrog | Metamorphosis |
| 197 | *Smilisca dentata* | Upland Burrowing Treefrog | Metamorphosis |
| 198 | *Smilisca fodiens* | Northern Casque-Headed Frog | Metamorphosis |
| 199 | *Spea bombifrons* | Plains Spadefoot | Metamorphosis |
| 200 | *Spea hammondii* | Western Spadefoot | Metamorphosis |
| 201 | *Spea intermontana* | Great Basin Spadefoot | Metamorphosis |
| 202 | *Spea multiplicata* | Mexican Spadefoot | Metamorphosis |
| 203 | *Taricha granulosa* | Roughskinned Newt | Metamorphosis |
| 204 | *Taricha rivularis* | Red-Bellied Newt | Metamorphosis |
| 205 | *Taricha sierrae* | Sierra Newt | Metamorphosis |
| 206 | *Taricha torosa* | California Newt | Metamorphosis |
| 207 | *Tlalocohyla picta* | Painted Treefrog | Metamorphosis |
| 208 | *Tlalocohyla smithii* | Dwarf Mexican Treefrog | Metamorphosis |
| 209 | *Trachycephalus typhonius* | Common Milk Frog | Metamorphosis |

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| 210 | *Triprion spatulatus* | Shovel Headed Treefrog | Metamorphosis |
| 211 | *Xenopus laevis* | African Clawed Frog | Metamorphosis |