Methods and Results Outline

To test this assertion, we employed two methodological frameworks of comparing the climactic differences between arboreal and terrestrial species ranges. First, we extract the climactic variables from each species ranges to give each species a summary of climatic variables. Using these data, we conduct phylogenetic ANOVAs and model comparison to test whether and how arboreal and terrestrial species differ in the climate they experience. Second, we employ ecological niche modeling methods to define the Using these two approaches, we are able to show from several different perspectives that arboreal species inhabit a significantly different area of climate space. This has implications\_\_\_\_.

**Methods**

Phylogeny

We used a time-calibrated phylogeny from Bonett and Blair (2017) for use in our macroevolutionary analyses. This phylogeny of 516 Caudata species was estimated from three mitochondrial and four nuclear genes using Bayesian approaches under a pure-birth speciation prior on the tree topology and divergence times, an uncorrelated lognormal molecular clock, and 12 node calibrations from Shen et al. (2016: for additional details see Bonett and Blair 2017). We pruned the maximum clade credibility tree to include only new-world plethodontid species for which microhabitat and species distribution data were available (302 species; ~65% of all Plethodontidae). We similarly pruned each of the 1000 dated posterior chronograms from which the maximum clade credibility tree was derived for use in robustness analyses (see below).

Microhabitat Use

We obtained microhabitat data for 302 species of Plethodontidae from primary literature, species descriptions, field observations, and the IUCN () and AmphibiaWeb () databases. We classified each species in terms of primary and, where applicable, secondary adult microhabitat. Due to the non-discrete nature of microhabitat use in salamanders, we employed the six distinct classification schemes (6-M, 6-L, 7-M, 7-L, 6-McM, and 6-McL) that differentially combine information from the primary and secondary microhabitats into a single category (terrestrial: T, arboreal: A, aquatic: W, semi-aquatic: SW, cave-dwelling: C, fossorial: F, or saxicolous: S) following Baken and Adams (*in press*). Briefly, these six classification schemes are defined by three criteria: the data source defining arboreality, the treatment of ‘semi-aquatic’ as a category distinct from ‘terrestrial’ and ‘aquatic’, and the consideration of secondary microhabitats (majority-rule dictates that primary microhabitat is used, whereas a more lenient approach considers a species as non-terrestrial based on their secondary microhabitat; Table 1). Only two species had a secondary microhabitat where the primary microhabitat was not terrestrial. In those cases, we used the secondary microhabitat. As most results are consistent across all classification schemes, we report the 6-M results in the main text, including results from other classification schemes only when they differ from 6-M.

Table 1. Microhabitat classifications schemes. Detailed description of each classification scheme can be found in Baken and Adams (*in press*), and species’ classifications under each scheme can be found on Dryad (DOI)

|  |  |  |  |
| --- | --- | --- | --- |
| **Scheme** | **Data Source on Arboreality** | **Semi-Aquatic as a Separate Category** | **Majority Rule or Lenient** |
| 6-M | Original | No | Majority Rule |
| 6-L | Original | No | Lenient |
| 7-M | Original | Yes | Majority Rule |
| 7-L | Original | Yes | Lenient |
| 6-McM | McEntire 2016 | No | Majority Rule |
| 6-McL | McEntire 2016 | No | Lenient |

Species Distributions

To obtain species polygons from which we could extract climate variables, we downloaded the predicted geographic ranges for all New World species available on the International Union for Conservation of Nature’s (IUCN) Red List of Threatened Species database (379 species). This dataset was pruned to match all species on the Bonett and Blair phylogeny described above (293 New World species). We expanded this dataset to include 18 more species for which reliable occurrence data were available on VertNet (Constable et al 2010). To mirror the IUCN protocol in defining geographic range polygons from point data, we calculated species extent of occurrence using alpha hulls excluding marine environments defined by coastline. Although IUCN suggests using an alpha value of two, where substantial area around the external points of the distribution is included, we instead used an alpha value of one, giving a more conservative estimate of species distributions. This alpha hull parameter value was sufficient to encompass all occurrence points while minimizing overprediction that other studies have also used as criteria for geographic ranges (some papers below). This resulted in a 257 species dataset of arboreal and terrestrial species from which all climate variables were extracted for use in subsequent analyses. In order to confirm that the source of species polygon data did not skew our results, we performed all analyses with and without our point-based species distributions, finding that all results were consistent. To make a polygon of just the arboreal and terrestrial microhabitat, we aggregated all species with these arboreal and terrestrial classifications, which resulted in one arboreal polygon and one terrestrial polygon.

Alpha value papers:

Using alpha - <https://www.sciencedirect.com/science/article/pii/S0006320718308371>

Using alpha with occurrence manual - <http://singhallab.org/assets/docs/Singhal_etal_2017_gendiv_SI.pdf>

Using alpha and increasing the parameter value until all occurrence records covered - <https://www.nature.com/articles/ncomms11484#article-comments>

Using alpha value of 1.8 that resulted from the least overprediction of range extent and closely matched species range - <https://onlinelibrary.wiley.com/doi/full/10.1111/aec.12184>

Vertnet: Constable H, Guralnick R, Wieczorek J, Spencer C, Peterson AT, The VertNet Steering Committee (2010) VertNet: A New Model for Biodiversity Data Sharing. PLoS Biol 8(2): e1000309. https://doi.org/10.1371/journal.pbio.1000309

Climate Data

Using the species polygons described above, we extracted 12 climate variables from distributions of 302 new world plethodontid species. At a resolution of 2.5 arc minute, this resulted in 1,298,924 localities (range: 1-122,837 localities per species, median = 77 localities per species). Climatic variable selection followed previous studies of amphibian niche variation (Gomez-Rodriguez et al 2015, Currie 1991) and microhabitat use in plethodontids (\_,\_\_, McEntire and Maerz 2019??). These included six BioClim variables quantifying yearly averages and extremes for temperature and precipitation (BIO1, BIO5, BIO6, BIO12, BIO16, BIO17; Hijmans et al, 2005), elevation (Elev; Title and Bemmels, 2018), climatic moisture (CM; Title and Bemmels, 2018), yearly averages and extremes of potential evapotranspiration (PET.A, PET.W, PET.D; Title and Bemmels, 2018), and cloud cover (CC) following Peterson and Nakazawa (2008, IPCC 2001; Table 2) at 0.5 arc minute resolution resampled to match the resolution of other climate variables. Species level climatic data are available on Dryad (DOI).

To examine the relationship between climate and microhabitat use, we analyzed these climate data using two complementary approaches that required differently formatted data. The first phylogenetic comparative approach involved calculating summary statistics (minimum, first quartile, mean, third quartile, and maximum) for each climate variable within the extent of the species distribution. This produced a single multidimensional trait for each species, which we then tested against microhabitat using phylogenetic analyses of variance (ANOVA). The second approach utilized ecological niche modeling (ENM) to compare the climatic niches occupied by arboreal and terrestrial species. For this ENM approach, we merged all species distributions of the same microhabitat type to form a microhabitat polygon for arboreal and terrestrial species and defining pseudo-occurrence points across these microhabitat polygons from which climate data were extracted.

Phylogenetic Comparative Approach

For our phylogenetic comparative approach, we performed a series of phylogenetic ANOVAs to identify the ways in which climate varies between arboreal and terrestrial species distributions and assessed significance via randomized residual permutation procedures in the R package, RRPP (Collyer \_\_\_\_). We chose to employ the phylogenetic framework because plethodontids have been shown to display substantial niche conservatism between closely related species (CITE). For a broad scale view of whether climate differs between the microhabitat groups, we first treated all summary statistics of the 12 climate variables as a single 60-dimensional trait. As the climate variables are in a variety of incommensurate units, we used standard normal deviates to scale all variables to a mean of 0 and a standard deviation of 1. As many climatic variables can be autocorrelated, we then performed a principle components analysis (PCA) on the normalized climate variables and extracted the first five PC axes (explaining ~90% of the overall climate variation) to test against microhabitat.

For a more nuanced interpretation of which climate variables differ between arboreal and terrestrial species ranges, we then tested the raw values of each climate variable’s summary statistics separately, assessing significance using sequential Bonferroni to account for multiple comparisons. Finally, as there are many more arboreal species in the tropics than in temperate regions, we performed the same series of phylogenetic ANOVAs on a reduced dataset that includes only arboreal and terrestrial species in the tropical region to verify that these climatic patterns are not driven by regional differences alone. To test the robustness of our results with respect to microhabitat classification scheme, we repeated all analyses using each of the classification schemes described above. We also calculated confidence intervals of all Z statistics by repeating all analyses across the 1000 posterior chronograms from Bonett and Blair’s (2017) phylogenic reconstruction to account for phylogenetic uncertainty.

Ecological Niche Modeling Approach

Climate data format: For the climate data, they were all clipped to the extent of (\_\_\_) and then stacked together to be used in the Maxent model. Since the cloud cover data was at a finer resolution, I resampled the raster with a nearest neighbor method to a larger resolution to be combinable and comparable with the other variables.

To complement the analyses above, we modeled the environmental niche of arboreal and terrestrial species as defined by the conglomerated microhabitat polygons. To avoid overpredicting our models, we reduced our full dataset by gridding each polygon by a set of decreasing resolutions, selecting the values at which both terrestrial and arboreal models performed well predicting the environmental niche given our point data used. This was evaluated by comparing Area Under the Curve (AUC) scores, indicative of how well the training-model predicts the testing data subset occurrences. AUC scores range from 0 to 1, where 0.5 represents when the model has no class separation and values close to 1 represent high predictive accuracy across the two data subsets. With the goals to maximize the predictive power and minimize the points, we selected the lowest resolution at which AUC scores for arboreal and terrestrial models reached 0.80 (to classify as good) (Table 2), the winning resolution 0.360, resulting in 432 pseudo-occurrence points for the arboreal polygon, and 3,664 pseudo-occurrence points for the terrestrial polygon under the 6-M classification scheme.

***Idea*** – we use this classification scheme - The discriminative power of the AUC was defined as 0.90 ≤ AUC ≤ 1.0, excellent; 0.80 ≤ AUC < 0.90, good; 0.70 ≤ AUC < 0.80, fair; 0.60 ≤ AUC < 0.70, poor; 0.50 ≤ AUC < 0.60, failure [(Swets](https://search.proquest.com/docview/213529713?pq-origsite=gscholar)(Swets) 1988).

To model the climate between microhabitat types, we used Maxent v3.4.1 ﻿(Phillips et al. 2004, 2006) summarized across 10 replicates, as the maximum entropy algorithm generally outperforms other algorithms (Elith et al. 2006; Phillips et al. 2006; Ortega-Huerta and Peterson 2008) and is less sensitive to sample size (Wisz et al. 2007). We employed a cross-validation method with a 10-fold partition scheme repeated (N) times for each microhabitat type, reserving 10% of the distribution points for assessing model performance. Without true absence data, we evaluated each Maxent model replicate using a modified Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) using the fraction of the total area predicted present (fractional predicted area) instead of the commonly used commission rate. The ROC curve is the true positive rate (Sensitivity) plotted in function of the false positive rate (100-Specificity) for the parameters of the model. The AUC of the ROC is a measure of how well the model can distinguish between two groups (in this case, training and testing points). All model replicates with a good AUC score above 0.80 using classification scheme, were averaged to obtain a weighted consensus model for each microhabitat type. This consensus Maxent model was then projected across the geographic extent where Plethodontidae are found in North and South America (20.0° S:70.0° N; 140.0° W:11.33° W) to calculate a suitability score, ranging from 0 (non-suitable) to 1 (highly suitable) for each point on the map.

To test whether arboreal species live in habitats suitable for terrestrial life and vice versa, we calculated a reciprocal suitability score for each relationship of distributional range and suitability model with a suitability cutoff of 0.5. In order to do so, we calculated the geographic range for each microhabitat type in square kilometers, then calculated the area within that range with a suitability score of 0.5 or higher for the *other* microhabitat. This gave a percentage of the geographic range suitable for species to occupy the alternate microhabitat (e.g. how much of the terrestrial species range could support arboreal life).

Finally, we then measured the degree of niche overlap between arboreal and terrestrial species predicted suitability using two metrics: Schoener’s *D* (1968), Warren’s *I* statistic (Warren et al 2008). Schoener's D assumes that the suitability scores are proportional to species abundance, whereas Warren’s I is more conservative and measures the probability distributions of two ecological niche models (Warren et al. [2010](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4228613/" \l "b54)). Both similarity metrics range from 0 (no niche overlap) to 1 (identical niches).

Both metrics are calculated by taking the difference between microhabitat type suitability scores within each grid cell and significance was assessed using a randomization test described in Warren et al (2008, Zhu et al 2013). We then performed a niche identity test. This is used to test whether the suitability scores of the arboreal and terrestrial microhabitats generated by the ecological niche modeling have significant ecological differences (Warren et al. [2008](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4228613/" \l "b53), [2010](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4228613/" \l "b54)). We calculated the niche identity test in dismo following the methods described in Warren et al. ([2008](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4228613/" \l "b53)). This method randomly partitions the pooled occurrences of each microhabitat type, calculating a ‘null’ *I* and *D* value 100 times to construct a null distribution of *I* and *D* metrics, against which we compared the observed *I* and *D* values in a one-tailed test.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4228613/> - this is a very good paper and did a lot of similar analyses but with geckos

**All analyses were done in R**

dismo package (citation).

Alpha hull citation - Pateiro-Lo ́pez,B.&Rodrıguez-Casal,A.,2010Generalizingtheconvexhullofasample:therpackage alphahull. *Journal of Statistical Software* **34**, 1–28.

**Results**

Comparative Phylogenetic Approach

As predicted by our hypotheses, the phylogenetic ANOVA of all climate variables revealed significant differences between microhabitat types (R2 = 0.0433, F = 2.6789, Z = 2.9287, P = 0.003), as well as specific differences between arboreal and terrestrial species (Z = 5.1466, p = 0.001; Figure 1). Further, these patterns were mirrored by the phylogenetic ANOVAs of the reduced the climate dataset into five independent PC axes (89.76% of total variation; Table 2). Both PC1 and PC2 differed significantly between arboreal and terrestrial species (PC1: Z = 5.257, p < 0.001; PC2: Z = 3.1383, p = 0.004). High values on PC1 (35.29% of total variation) represent high elevation, high cloud cover, and high PET during the wettest quarter (Table 2). PC2 (19.82% of total variation) represents wet and humid versus dry and arid environments (PET of the driest quarter, annual precipitation, and climatic moisture). Although similar analyses for PC3 demonstrated significant differences between these microhabitat type under the three lenient classification schemes (6-L, 7-L, and 6-McL), these analyses were not significant under the strict classification schemes (6-M, 7-M, and 6-McM, Figure 2). All loadings for the first five PC axes can be found in Table 2.



Figure 1. PCA of climate variables

Table 2. PC loadings of first five axes. The top 10 variable loadings for each axis are bolded.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Value** | **PC1** | **PC2** | **PC3** | **PC4** | **PC5** |
| **Annual Temperature (BIO1)** | Min | 0.093 | -0.132 | -0.050 | **0.250** | -0.037 |
| Q1 | 0.073 | -0.149 | 0.036 | **0.247** | 0.133 |
| Mean | 0.067 | -0.156 | 0.070 | **0.232** | **0.193** |
| Q3 | 0.053 | -0.148 | 0.100 | **0.196** | **0.240** |
| Max | 0.033 | -0.133 | 0.132 | 0.142 | **0.283** |
| **Maximum Temperature of the Warmest Month (BIO5)** | Min | 0.010 | 0.114 | -0.169 | **0.242** | -0.067 |
| Q1 | 0.007 | 0.136 | -0.192 | **0.210** | 0.025 |
| Mean | 0.010 | 0.148 | **-0.201** | 0.176 | 0.065 |
| Q3 | 0.011 | 0.153 | **-0.202** | 0.147 | 0.095 |
| Max | 0.007 | 0.168 | -0.166 | -0.004 | **0.256** |
| **Minimum Temperature of the Coldest Month (BIO6)** | Min | 0.163 | 0.074 | 0.055 | 0.161 | -0.078 |
| Q1 | 0.173 | 0.084 | 0.075 | 0.123 | 0.029 |
| Mean | 0.174 | 0.093 | 0.075 | 0.106 | 0.071 |
| Q3 | 0.170 | 0.099 | 0.073 | 0.088 | 0.116 |
| Max | 0.157 | 0.095 | 0.078 | 0.030 | **0.200** |
| **Annual Precipitation (BIO12)** | Min | 0.099 | -0.175 | -0.085 | 0.154 | -0.176 |
| Q1 | 0.116 | **-0.205** | -0.096 | 0.062 | -0.021 |
| Mean | 0.119 | **-0.204** | -0.110 | 0.026 | 0.043 |
| Q3 | 0.116 | **-0.191** | -0.119 | -0.021 | 0.117 |
| Max | 0.093 | -0.145 | -0.122 | -0.100 | **0.256** |
| **Precipitation of the Wettest Quarter (BIO16)** | Min | 0.081 | -0.034 | **-0.221** | -0.080 | **-0.250** |
| Q1 | 0.064 | -0.018 | **-0.219** | **-0.190** | -0.172 |
| Mean | 0.049 | -0.015 | **-0.212** | **-0.240** | -0.117 |
| Q3 | 0.032 | -0.011 | -0.187 | **-0.273** | -0.057 |
| Max | -0.011 | 0.004 | -0.114 | **-0.306** | 0.075 |
| **Precipitation of the Driest Quarter (BIO17)** | Min | 0.145 | 0.095 | 0.096 | 0.100 | **-0.201** |
| Q1 | 0.158 | 0.131 | 0.118 | 0.013 | -0.103 |
| Mean | 0.156 | 0.151 | 0.111 | -0.020 | -0.049 |
| Q3 | 0.148 | 0.161 | 0.098 | -0.056 | 0.005 |
| Max | 0.109 | 0.161 | 0.106 | -0.119 | 0.154 |
| **Annual PET**  **(PET.A)** | Min | 0.011 | -0.020 | **0.236** | 0.049 | **-0.197** |
| Q1 | 0.061 | -0.008 | **0.245** | -0.034 | -0.112 |
| Mean | 0.086 | 0.012 | **0.245** | -0.066 | -0.062 |
| Q3 | 0.098 | 0.023 | **0.226** | -0.084 | -0.026 |
| Max | 0.097 | 0.037 | **0.210** | -0.116 | 0.079 |
| **PET of the Wettest Quarter**  **(PET.W)** | Min | 0.169 | -0.075 | -0.126 | 0.086 | -0.123 |
| Q1 | **0.186** | -0.067 | -0.125 | 0.021 | -0.032 |
| Mean | **0.188** | -0.062 | -0.127 | 0.004 | 0.002 |
| Q3 | **0.189** | -0.055 | -0.125 | -0.016 | 0.037 |
| Max | 0.178 | -0.038 | -0.111 | -0.061 | 0.139 |
| **PET of the Driest Quarter**  **(PET.D)** | Min | 0.006 | **-0.230** | 0.089 | 0.066 | **-0.222** |
| Q1 | 0.003 | **-0.248** | 0.133 | -0.054 | -0.078 |
| Mean | -0.004 | **-0.246** | 0.136 | -0.089 | -0.027 |
| Q3 | -0.008 | **-0.230** | 0.133 | -0.129 | 0.034 |
| Max | -0.032 | **-0.178** | 0.106 | -0.200 | 0.153 |
| **Climatic Moisture (CM)** | Min | 0.129 | -0.176 | -0.043 | 0.103 | -0.192 |
| Q1 | 0.159 | **-0.182** | -0.038 | -0.010 | -0.056 |
| Mean | 0.166 | **-0.176** | -0.041 | -0.034 | -0.003 |
| Q3 | 0.168 | -0.161 | -0.042 | -0.066 | 0.057 |
| Max | 0.151 | -0.128 | -0.043 | -0.115 | 0.193 |
| **Cloud Cover**  **(CC)** | Min | 0.178 | 0.059 | 0.070 | 0.047 | -0.166 |
| Q1 | **0.191** | 0.068 | 0.083 | -0.039 | -0.092 |
| Mean | **0.193** | 0.077 | 0.075 | -0.075 | -0.034 |
| Q3 | **0.188** | 0.079 | 0.068 | -0.101 | 0.004 |
| Max | 0.168 | 0.086 | 0.062 | -0.142 | 0.118 |
| **Elevation**  **(Elev)** | Min | **0.182** | 0.064 | -0.034 | 0.058 | -0.132 |
| Q1 | **0.195** | 0.079 | -0.032 | -0.023 | -0.061 |
| Mean | **0.195** | 0.083 | -0.038 | -0.060 | -0.006 |
| Q3 | **0.188** | 0.083 | -0.040 | -0.087 | 0.032 |
| Max | 0.165 | 0.082 | -0.042 | -0.132 | 0.138 |
| **Statistics** | *Variation* | *35.29%* | *19.82%* | *16.64%* | *11.50%* | *6.50%* |
| Overall Z | 2.1542 | 1.0465 | -0.0182 | 2.1515 | 1.9171 |
| Overall P | 0.010 | 0.142 | 0.539 | 0.007 | 0.022 |
| Pairwise Z | 5.2570 | 3.1383 | 1.0493 | 0.7391 | 0.7645 |
| Pairwise P | **0.001** | **0.004** | 0.148 | 0.225 | 0.216 |

To validate the specific nature of climatic differences between arboreal and terrestrial species, we also tested each variable separately (Figure 2). These analyses revealed significant differences between arboreal and terrestrial species distributions for all temperature variables (BIO1, BIO5, BIO6; Z > 4.079, p < 0.002), annual precipitation (BIO12; Z = 3.359, p = 0.006), precipitation of the wettest quarter (BIO16; Z = 4.336, p = 0.002), annual PET (Z = 3.462, p = 0.002), and elevation (Z = 5.645, p = 0.001; Table S1).

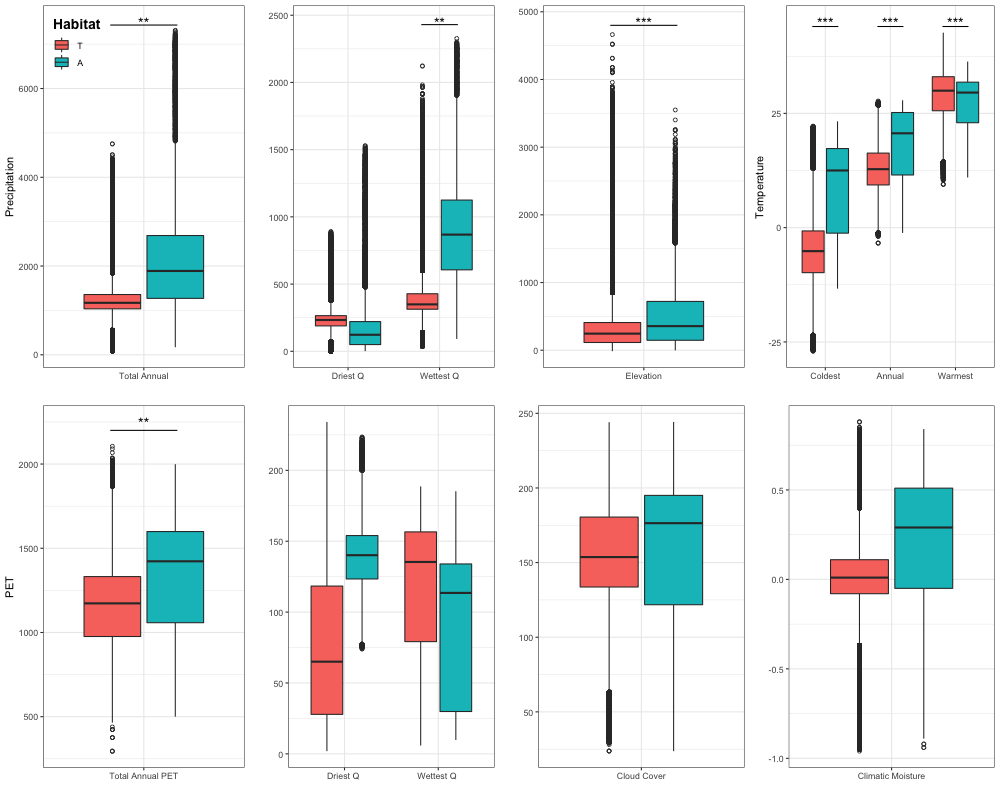


Figure 2. How arboreal and terrestrial species differ for each climate variable.

Ecological Niche Modeling

Predicted distribution

The overall geographic range for the arboreal and terrestrial microhabitat ranges from 70° to -20° longitude and from -140° to -11° latitude. Predicted suitability maps were generated from each ENM and show the overlap of distribution/suitability. Our analyses of reciprocal suitability was used with and without a cutoff of 0.5 suitability score. The predicted distribution of the arboreal microhabitat and the terrestrial microhabitat is shown in Figure X. The AUC values were 0.947 and 0.802 for the arboreal and terrestrial microhabitats, indicating robust model performance. Also, it was calculated how much the distributions were explained by the ENM, which was 72% for arboreal and 83% for terrestrial indicating good representation. (point out some interesting things about the predicted ENMs here, such as temperate/tropical or any specific regions where the arb/terr overlap is weird for example the spotty distributions that basically outline the others suitability in the tropics).

Niche identity tests

Based on the niche identity test, the observed values of D and I measuring the current niche overlap between arboreal and terrestrial microhabitats were significantly different from the null distributions (Schoener’s D = 0.348, P-value < 0.01 and Warren’s I = 0.618, P-value < 0.01).

Reciprocal suitability tests

Only 4.1% of the arboreal species distribution overlaps with the terrestrial niche model indicating a small percentage of arboreal species present where terrestrial species can live. In the opposite direction, 50.7% of the terrestrial species distribution overlaps with the arboreal niche model, indicating half of terrestrial species are also found with arboreal species.

**Discussion**

Mention how Ficetola et al 2018 says micro- and macro- scale are only weakly correlated, but this analysis fits with this argument that microhabitat selection determines the actual climate experienced by the individual. We aren’t saying that arboreal species live in hotter micro-climates, but perhaps the tendency to live arboreally is higher in climates that are hot because staying on the ground would be bad for thermoregulation …. Climate could be driving differences in microhabitat, not necessarily saying species are adapted to different temperatures. Also talk about how these were done on cave salamanders. That and fossorial and aquatic are probably most removed from outside climate.

Quote from Currie 1991: PET may be interpreted as a measure of integrated, crude, ambient energy. Operationally, it is the amount of water that evaporates from a saturated surface. It depends mainly on the amount of energy available to evaporate water and, to a lesser degree, on the relative humidity.

Fossorial (6-M) very much significantly different from all others with Annual Precip, Precip in the driest quarter, kinda for max temp of warmest month, kinda for Annual PET

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**Supplemental Material**

Table S1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Z | Pairwise P | Alpha | Variable Justification |
| BIO1 |  | 0.001 | 0.05/12 | Gomez-Rodriguez et al 2015 |
| BIO5 |  | 0.002 | 0.05/7 | Gomez-Rodriguez et al 2015 |
| BIO6 |  | 0.001 | 0.05/11 | Gomez-Rodriguez et al 2015 |
| BIO12 |  | 0.006 | 0.05/6 | Gomez-Rodriguez et al 2015 |
| BIO16 |  | 0.002 | 0.05/8 | Gomez-Rodriguez et al 2015 |
| BIO17 |  | 0.236 |  | Gomez-Rodriguez et al 2015 |
| PET Annual |  | 0.002 | 0.05/9 | Currie 1991 |
| PET of Wettest Q |  | 0.332 |  | Currie 1991 |
| PET of Driest Q |  | 0.217 |  | Currie 1991 |
| Elevation |  | 0.001 | 0.05/10 |  |
| Cloud Cover |  | 0.212 |  |  |
| Climatic Moisture |  | 0.833 |  | McEntire and Maerz 2019 ??? |

**Figures S1-S4 [Robustness for PCs1-5, Temperature, Precip, and PET values]**

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