Climbing the Mountain: Niche Modeling of Hymenopappus filifolius and Hymenopappus mexicanus using ArcGIS and Maxent

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Introduction

It is well known that organisms live in specific areas determined by many things, but especially by the local environment. Plant distributions are known to be sensitive to factors such as soil (geochronology) and climate and that the presence or absence of particular environmental factors may drive their distributions. Different factors affect different species.

One method for examining the importance of different factors in plant distributions is niche modeling. This method combines climate data and maps for different geochronology variables, with observations of where particular species have been found growing and generates models that predict the areas where environmental conditions are suitable for each species (identified where the conditions are similar and so predicts the total distribution). Niche models allow us to identify which environmental variables most strongly explain where species occur. One of these specific factors is identified, and by comparing differing niches to those of related species, we can ask questions about how adaptation to particular variables may have driven their evolutionary histories and whether adaptation to different niches was involved in driving speciation and diversification.

This project examines the distributions and environmental characters of two closely related plant species in the daisy family (Compositae: Bahieae), Hymenopappus filifolius and Hymenopappus mexicanus, that have overlapping but not identical distributions. It asks the questions: 1) Does niche modeling predict different distribution patterns for the two species? 2) Do they differ in their ecological niches? And if so 3) Are these differences potential drivers of a speciation event?

Methods

Distribution data for H. filifolius & H. mexicanus were gathered from online databases (GBIF, iDigBio, BISON) and specimens in the US National Herbarium. For H. filifolius, an original 3,200 downloaded records was cleaned down to 845 records. For H. mexicanus an original 139 downloaded records was cleaned down to 54 records. The cleaned data were then uploaded to Maxent 3.3.1e. Outputs from these analyses were then uploaded as layers into ArcMap.

Bioticnic Data were downloaded from the WorldClim database2. Using methods described in a previous study citing a coefficient of correlation of R>0.95 between variables, the variables Bio1, Bio2, Bio4, Bio5, Bio6, Bio9, Bio12, Bio15, Bio17, Bio18, and Bio19 were tested in making a niche model1. To accomplish niche modeling, the presence-only modeling software, Maxent, Version 3.3.1e3. Outputs from these analyses were then uploaded as layers into ArcMap.

Results

Bioclimatic Data Response

Table 1: Percent Contribution of Different Bioclimatic Variables

<table>
<thead>
<tr>
<th>Bioclimatic Variables</th>
<th>Hymenopappus filifolius</th>
<th>Hymenopappus mexicanus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Annual Temp.</td>
<td>23.6%</td>
<td>22.6%</td>
</tr>
<tr>
<td>Precip.</td>
<td>23.7%</td>
<td>21.4%</td>
</tr>
<tr>
<td>Temp. Seasonality</td>
<td>22.9%</td>
<td>22.9%</td>
</tr>
<tr>
<td>Annual Mean Temp.</td>
<td>16.7%</td>
<td>16.5%</td>
</tr>
<tr>
<td>Temp. Seasonality</td>
<td>22.7%</td>
<td>22.9%</td>
</tr>
<tr>
<td>Mean Annual Temp.</td>
<td>15.8%</td>
<td>11.6%</td>
</tr>
<tr>
<td>Precip.</td>
<td>22.6%</td>
<td>21.4%</td>
</tr>
</tbody>
</table>

Figure 3: Distribution of H. filifolius (blue) and H. mexicanus (orange)

Discussion

While the environmental data used in this study are only climatic (i.e. temperature and precipitation) it is surprising that two neighboring niches, apparently distributed along an altitudinal gradient, are predicted to be characterized by very different sets of these (Figure 3). Typically it would be expected that, across altitude, an increase or decrease in a variable would characterize both niches. There are three possible explanations for these results:

1. - the results we see here are accurate and that seasonality of growing conditions is of greater influence to H. mexicanus living at higher elevations than it’s sister species

2. - that the environmental variables selected for niche separation between these two species were not included in our model (e.g. soil)

3. - that modeling one widespread species against a narrowly restricted species confounds the model. Figure 6 shows H. filifolius vs H. filifolius var. nanus and H. filifolius vs. cinereus. These represent just two of the 12 subspecies of H. filifolius that occur across the western US. This figure shows that model predictions change considerably when looking at subspecies on their own. This means that when using a model for the entire distribution area of H. filifolius (Figure 3) it is likely that predictions are being made using environmental values irrelevant to the local dynamic actually responsible for differentiation between the local populations of the two species under consideration here.

Conclusions

The modeling showed that the niche occupied by H. filifolius is mostly determined by Mean diurnal range and Precipitation during the warmest month. In contrast the niche of H. mexicanus is most influenced by the Temperature seasonality (a coefficient of variability) as well as Precipitation seasonality (another coefficient of variability). So there is not as a marked difference between the two sets of variables but also in the amount of contribution from each variable and as a result we can infer that each species occupies its own niche. Even more striking is that when the projections are overlain over a map of elevation, it appears that elevation is correlated to niches of both species.

More investigation is needed to further distinguish between the niches, but this study exemplifies not only the driving forces separating the niches of this clade, but also the importance of climate in influencing species distribution and divergence. Insights provided by this study and similar studies become of increasing importance when considering themes of global warming and climate change. As the diversity of climate regions is lost and suitable habitats for plants disappear, the potential for a chain effect of species elimination grows exponentially. By understanding the variables that contribute to the niches of organisms, through more information can be supplied to help combat the growing problem of climate change.

Future Directions

- To test the predicted ranges by conducting fieldwork in areas that are predicted to have specimens but have no collections.
- To incorporate soil geology and geochemistry data (once available) into modeling to produce a better understanding of the niche parameters of the two species.
- To expand methods and information garnered from this study to learn more about if and how the endemic western North American plants in the Compositae family adapt to extreme environments.
- To investigate the subspecies of H. filifolius further to see if there are finer niche distinctions.

References


