Creating Maps of Potential Habitat for Great Basin Forbs Using Herbarium Data

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Introduction:

There is increasing interest in using native forbs for the restoration of degraded sagebrush communities that lack a native understory. Currently, there is little information available regarding the distribution and associated environmental preferences of many cold-desert forbs. This makes it challenging to design appropriate species mixes, or successfully locate and collect populations of herbaceous species for incorporation into restoration efforts.

Most range maps available for non-dominant plant species are at a course spatial scale, indicating only county or state boundaries (Figure 1). Although this provides some guidance about the boundaries of a species' range, it can overestimate the actual area they occupy and does not provide information on environmental preferences. Because forb seeds are typically more expensive than other species, it is beneficial to narrowly define suitable habitat to avoid seeding in inappropriate habitats. Creating more accurate range maps is the first step toward identifying the relative importance of different environmental variables to the success various native forbs.

Methods Overview:

We used herbarium records for ten Great Basin forbs in combination with bioclimatic variables created using PRISM data for the past 64 years (Table 1) to model the potential habitat of our focal species using Maxent modeling. Focal species include *Agoseris grandiflora*, *Blepharipappus scaber*, *Chaenactis douglasii*, *Collinsia parviflora*, *Crepis intermedia*, *Cryptantha pterocarya*, *Gilia inconspicua*, *Mentzelia albicaulis*, *Microsteris gracilis*, and *Phacelia hastata* (Figure 2).

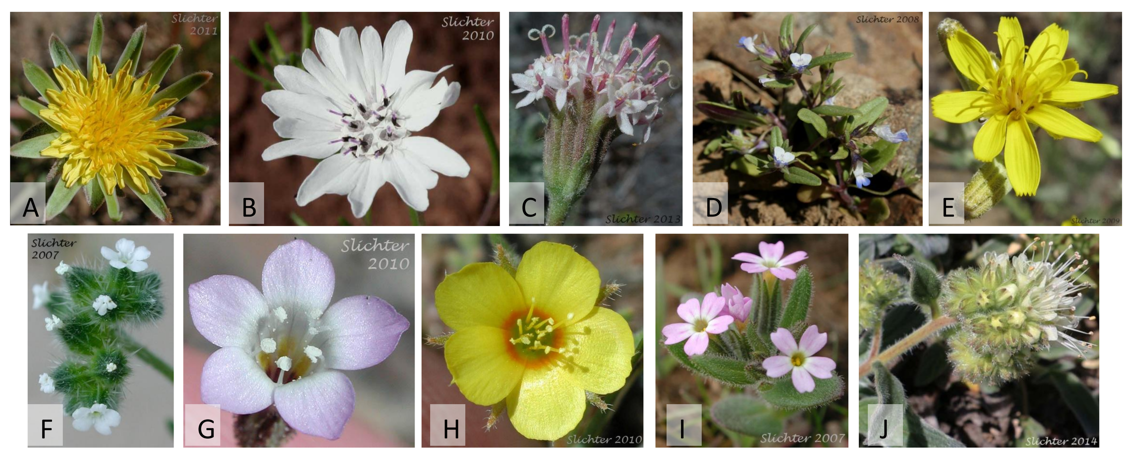

Figure 2. Pictures of our focal species, including: A. *Agoseris grandiflora*, B. *Blepharipappus scaber*, C. *Chaenactis douglasii*, D. *Collinsia parviflora*, E. *Crepis intermedia*, F. *Cryptantha pterocarya*, G. *Gilia inconspicua*, H. *Mentzelia albicaulis*, I. *Microsteris gracilis*, J. *Phacelia hastata*

Table 1. Model Variables

Variable	Biological Relevance
AET - annual actual evapo-transpiration [1, 2]	Proxy for productivity
CWD - annual climate water deficit [1, 2]	Proxy for drought stress
PET - annual potential evapo-transpiration [1, 2]	Climatic demand for water, excluding water availability
SWB - annual soil water balance [1, 2]	Quantity of water stored in the soil from one month to the next
WS - annual water supply [1, 2]	Total water supply for the year
Coefficient of variation of annual precipitation	Seasonality of precipitation
AET:CWD ratio	Relative CWD; values > 1 are more mesic, values < 1 are more xeric
PET:AET ratio	Relative drought indicator; values > 1 indicate an unmet demand for water
SWB:AET ratio	Values > 1 indicate more soil water storage than AET
WS:AET ratio	Values > 1 indicate more water for soil water storage, runoff, or deep percolation than used in AET
Positive difference between AET and SWB	Fraction of AET from month's precipitation, not from soil water
Positive difference between WS and the greater of AET or SWB	Cumulative water available for runoff or deep percolation
Spring ratio of WS and the greater of AET or SWB	Spring water available for runoff or deep percolation
Precipitation - total and seasonal [2, 4]	
Temperature range [3]	
Minimum temperature - total and seasonal [3, 4]	
Maximum temperature - total and seasonal [3, 4]	

[1] See Dilts et al. 2015 for method of calculation
[2] Summed for all months
[3] Average for all months
[4] Winter (Dec, Jan, Feb), Spring (Mar, Apr, May), Summer (Jun, Jul, Aug), Fall (Sep, Oct, Nov)

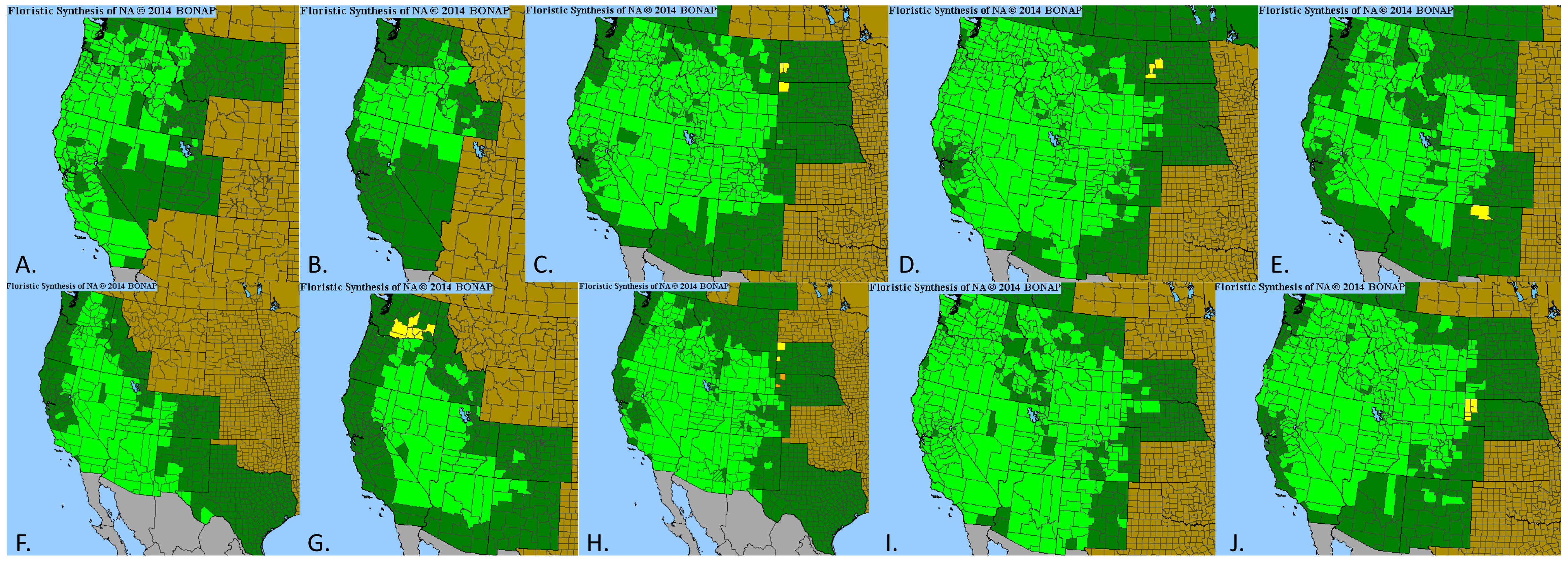

Figure 1. Range maps from the Biota of North American Plants website indicating state (dark green) and county (light green) maps for each species based on the presence of herbarium points within the relevant boundary. Yellow regions indicate that the species is rare in that location. Range maps apply to the following species: A. *Agoseris grandiflora*, B. *Blepharipappus scaber*, C. *Chaenactis douglasii*, D. *Collinsia parviflora*, E. *Crepis intermedia*, F. *Cryptantha pterocarya*, G. *Gilia inconspicua*, H. *Mentzelia albicaulis*, I. *Microsteris gracilis*, J. *Phacelia hastata*

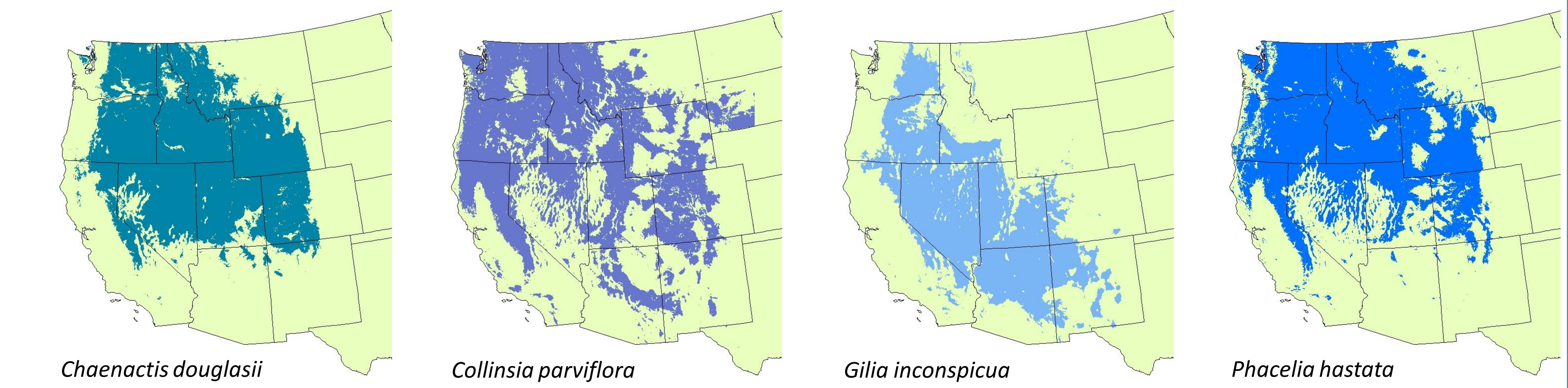

Figure 4: Maps of potential habitat for species with one top Maxent model

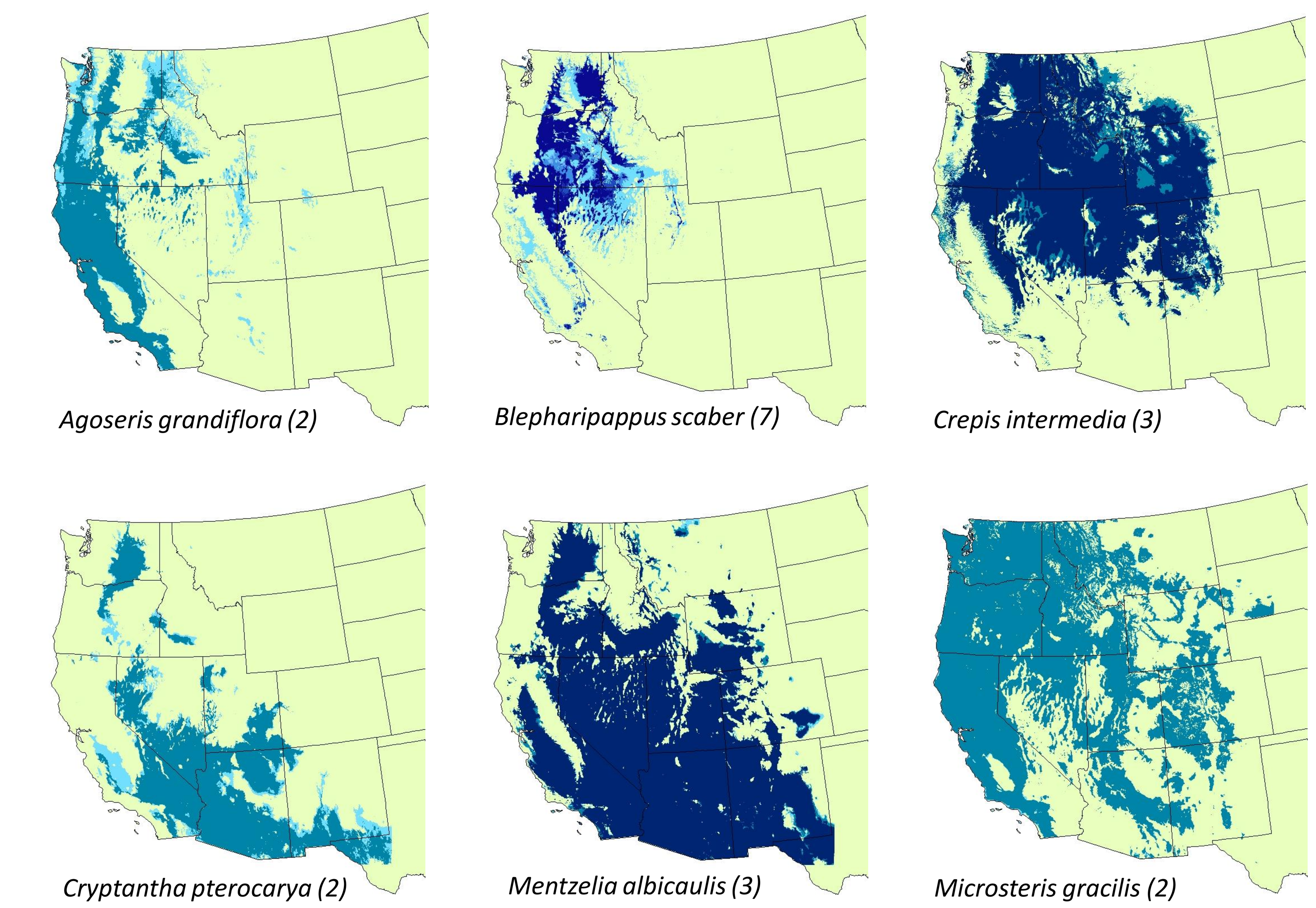

Figure 5. Maps of potential habitat for species with multiple top Maxent models. Areas of overlap for the these maps are color-coded with darker areas indicating a higher degree of overlap in the potential habitat predicted by the different models. Numbers after the species name indicate how many top models were included for each species.

Detailed Methods:

- **Step 1 –** Acquired points from the Intermountain Herbarium Network, the Jepson Herbarium in California, and the University of Washington Herbarium
- **Step 2 –** Acquired climate data from PRISM and other abiotic variables to create the bioclimatic variables for inclusion in our models (see Table 1)
- **Step 3 –** Verified point locations and removed false locations
- **Step 4 –** Eliminated points less than 20 kilometers apart (Figure 3) and created a state-related bias file to account for uneven spatial sampling
- **Step 5 –** Randomly separated thinned points into two groups with 65% in the model training group and 35% in the model testing group
- **Step 6 –** Used Maxent to run model optimization by varying the feature type(s) (linear, quadratic, product, threshold and hinge models) and the regularization parameter (1-5)
- **Step 7 –** Performed model selection using AIC values produced by the Ecological Niche Modeling Tools program (ENMTools)
- **Step 8 –** Selected a threshold value from the Maxent output for the top model or models
- **Step 9 –** Created a map of the potential range in ArcMap using the .asc file for the top model and the selected threshold value from the Maxent output
- **Step 10 –** For species with multiple top models, maps of the potential range were made by overlapping the maps for all top models. Areas of overlap for the these maps were then color-coded with darker areas indicating a higher degree of overlap in the potential habitat predicted by the models

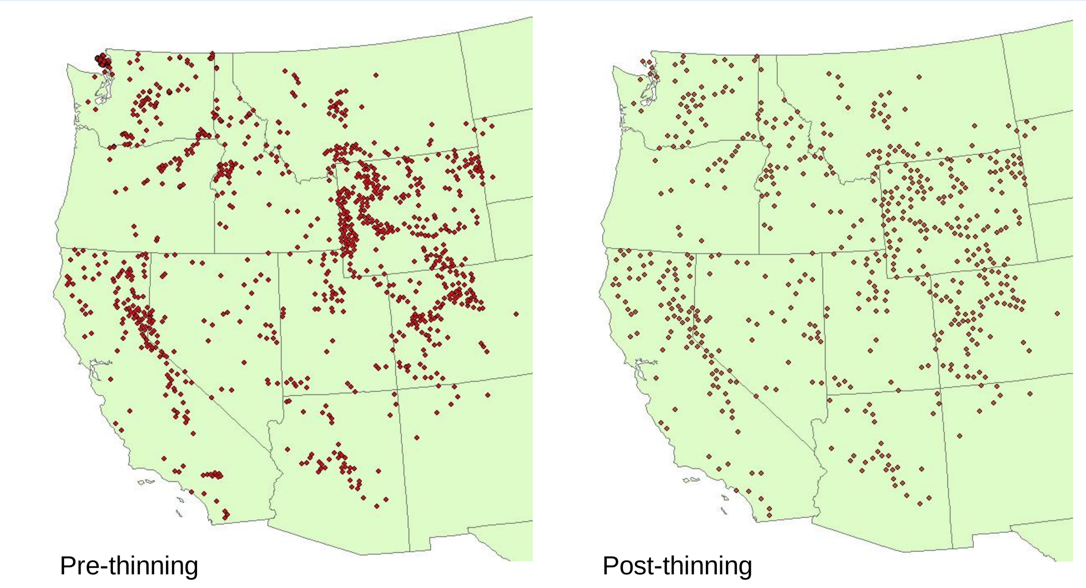

Figure 3: a depiction of the point thinning process using *Collinsia parviflora*. Points were thinned to a distance of 20 Kilometers.

Results:

Is this a possible management tool?

We found that suitable habitat estimates generally agreed with the distributions indicated by the county maps. We also found that the spatial distribution of potential habitat differed greatly among species, even though they overlap in some areas of the Great Basin (Figure 4 and Figure 5). This modeling method has been used by biogeographers to model habitat for a variety of species, and we propose that ecologists and land managers in the Great Basin may also be able to use this technique to better understand the distribution of potential restoration species. For example, they could be used to guide the selection of appropriate restoration species for a project or to find source populations for seed increase efforts. Statistical modeling includes methods to account for model uncertainty and produce multi-model ensembles that can be used to estimate climatic suitability across an area, this may be especially useful for species that are costly to procure.

Literature Cited:

Dilts, Tom E., Peter J. Weisberg, Camie M. Dencker, and Jeanne C. Chambers. 2015. Functionally relevant climate variables for arid lands: a climate water deficit approach for modeling desert shrub distributions. Journal of Biogeography 42(10): 1986-1997.

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