

**Climatic Envelope Modeling using MaxEnt:
Predicting the Affect of Near-Future Climate Change on a Threatened Species
(tutorial, no points; assigned 9 Mar 2009)**

Overview

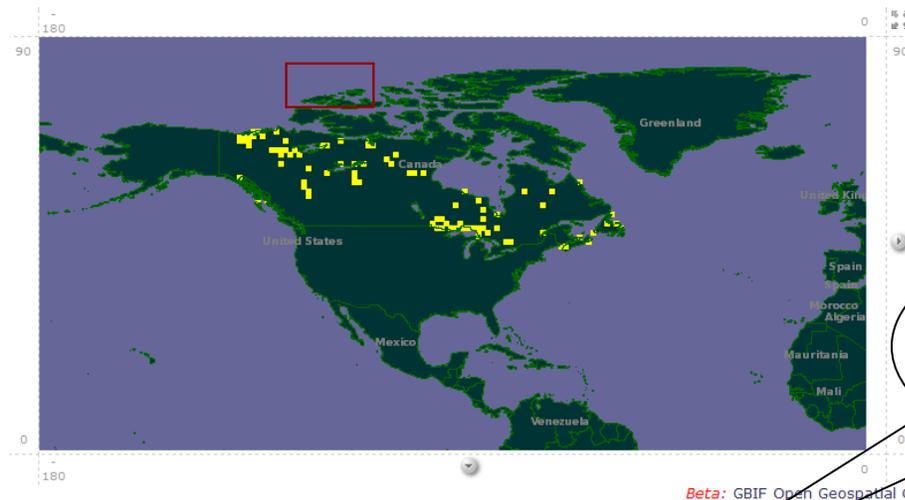
- We will obtain occurrence data of *Lycopodiella appressa* (bog clubmoss; family Lycopodiaceae), a threatened plant species in Pennsylvania, from GBIF and supplement it with PA Flora Project Data (which is not necessarily represented at GBIF).
- We will estimate a climatic envelope for *L. appressa* using occurrence data and current climate data represented in a series of grid files.
- Then we will project that climatic envelope onto climate grids that have been modeled for the year 2050 under the assumption of a doubling of atmospheric CO₂.
- We will then have generated a prediction of the potential 2050 geographic distribution of *L. appressa*.

Detailed Procedure

Obtain GBIF Occurrence Data and format for MaxEnt:

1. Go to the taxon (species) page for our species.
2. Beneath the overview map, “View all occurrences...within the viewed area.” (e.g., figure below). This will take you to page showing all mapped records (i.e., those with latitude and longitude).

Occurrence overview



This map only shows records with coordinates (143 records from a total of 282 records). This shows only records from the GBIF network and may not properly represent the total distribution of *Alnus viridis ssp. crispa*.

[View all occurrences of *Alnus viridis ssp. crispa* within the viewed area \(180°W, 0°S, 0°W, 90°N\)](#)

This link will retrieve all mapped (i.e., georeferenced) occurrences.

3. Download a spreadsheet of the occurrences (e.g., figure below). Choose a “tab delimited text format” and restrict the data to the required fields plus Latitude and Longitude.

Save this file as YOURLASTNAME-SPECIES.txt. Save also the citation information as YOURLASTNAME-SPECIES-citation.txt.

4. In Excel, modify this file to include just three columns in this order (this is the order that our modeling program MaxEnt requires): Species name, Longitude, Latitude.

Append to the end of these data the data from the PA Flora Project (included in the MaxEnt\species-input\ folder).

Save this in “comma delimited format” (aka, *comma separated values* or *.csv*) as follows:
YOURLASTNAME-SPECIES.csv

The screenshot shows a web browser window titled "Occurrence search - Download spreadsheet - Classification includes Subspecies: *Alnus viridis* ss - Windows Internet Explorer". The address bar shows a URL from data.gbif.org. The main content area is titled "Download spreadsheet of results" and includes a "Format options" section with radio buttons for "Tab-delimited" (selected), "Comma separated values", and "Excel (maximum of 65,535 records)". Below this is a "Required fields" section with checkboxes for "Data provider", "Dataset", "Scientific name", and "GBIF portal url". There are also sections for "Dataset" and "Taxonomy" with various checkboxes. The "Geospatial" section has checkboxes for "Country", "Region", "Centi cell id", "Altitude precision", "Country (interpreted)", "Provider country", "Min depth", "Max depth", "Locality", "Max depth", "County", "Continent or Ocean", "State/Province", "Latitude", "Longitude", "Coordinate precision", "Cell id", and "Max altitude". A "Download now" button is at the bottom left. A speech bubble points to the "Format options" section with the text: "Here you select the format of your download, and you can limit the meta data associated with your occurrence records."

Model Climatic Envelope in MaxEnt:

1. Open MaxEnt by double clicking on the maxent.bat file. Wait for the window below to appear.
2. Load you samples (occurrences from the .csv file).
3. Point to the directory containing the current climate grid files.
4. Select a subset of the climate variables to use (1, 5, 6, 12, 18, & 19; see Table 1 below).
5. Select the output file type to .grd (which we will later use in DIVA-GIS).
6. Point to the output directory (where you want the output files written).
7. Point to the directory containing the future climate grid files.
8. Settings to “Remove duplicate presence records” and “Random test percentage” to 25.
9. Run the analysis. This will take a while.

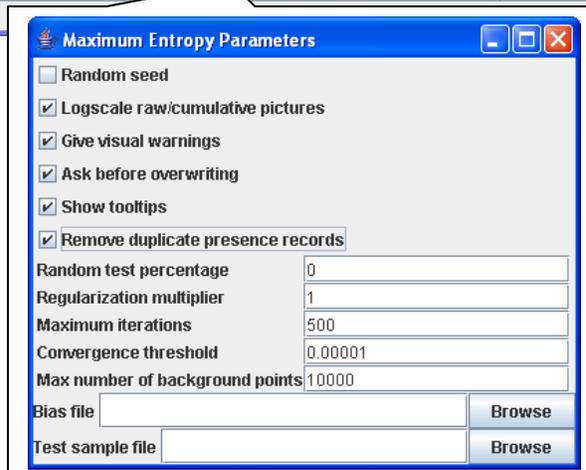
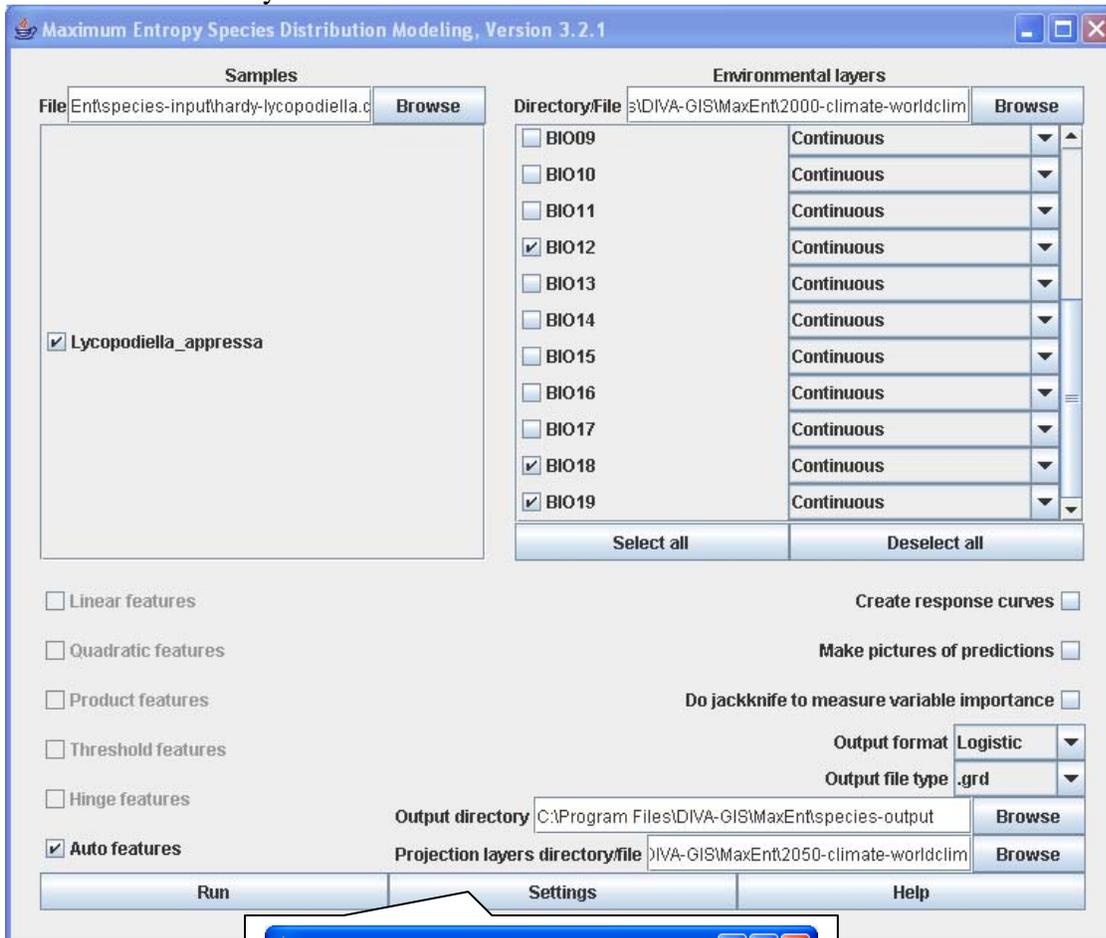


Table 1. Pool of climatic variables utilized for climatic niche modeling under the current, Worldclim 1.4 (Hijmans et al. 2005), and future, CCM3 (Govindasamy et al. 2003), climate models.

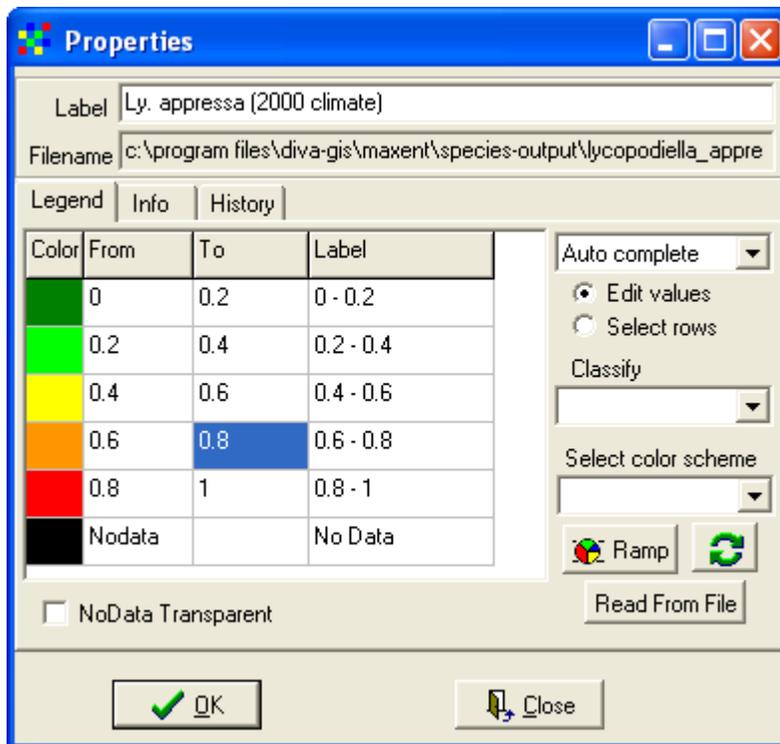
Number	Climatic Variable
01	Annual Mean Temperature
02	Mean Monthly Temperature Range
03	Isothermality
04	Temperature Seasonality
05	Maximum Temperature of Warmest Month
06	Minimum Temperature of Coldest Month
07	Temperature Annual Range
08	Mean Temperature of Wettest Quarter
09	Mean Temperature of Driest Quarter
10	Mean Temperature of Warmest Quarter
11	Mean Temperature of Coldest Quarter
12	Average Annual Precipitation
13	Average Precipitation of Wettest Month
14	Average Precipitation of Driest Month
15	Precipitation Seasonality
16	Average Precipitation of Wettest Quarter
17	Average Precipitation of Driest Quarter
18	Average Precipitation of Warmest Quarter
19	Average Precipitation of Coldest Quarter

Analysis of MaxEnt output in DIVA-GIS, Part 1:

1. From C:\Program Files\DIVA-GIS\data\ open DIVA-GIS and add layers for American countries, US states, and US counties.
2. Import your occurrence records as dots on the map.
3. Add the two climate envelope models as layers (from the MaxEnt output folder):
the present (year 2000) model will be a .grd file as follows:
Lycopodiella_appressa.grd

the future (year 2050) model will be a .grd file as follows:
Lycopodiella_appressa_2050-climate-worldclim.grd

4. Modify the title color legend for the year 2000 probability values (which are an estimate of climatic suitability or the probability of occurrence) as follows:



5. Do similarly for the year 2050 model legend.
6. Answer the following questions (next page):

For current bioclimatic model,

Name the state(s) for which there is at least a 0.8 probability of occurrence but for which there are no occurrence records.

Name the county(s) in PA for which there is at least a 0.8 probability of occurrence but for which there are no occurrence records.

*Judging from the common name and the wetland indicator for the species, what is a factor limiting the occurrence of *L. appressa* that our model has not incorporated?*

What is the best way to interpret the probability map?

For the year 2050 bioclimatic model,

Are there additional states for which there is a high probability of future occurrence?

What states are predicted to see a decline in this species?

In PA, which counties might see an increase in this species?

In PA, which counties might see a decrease in this species?

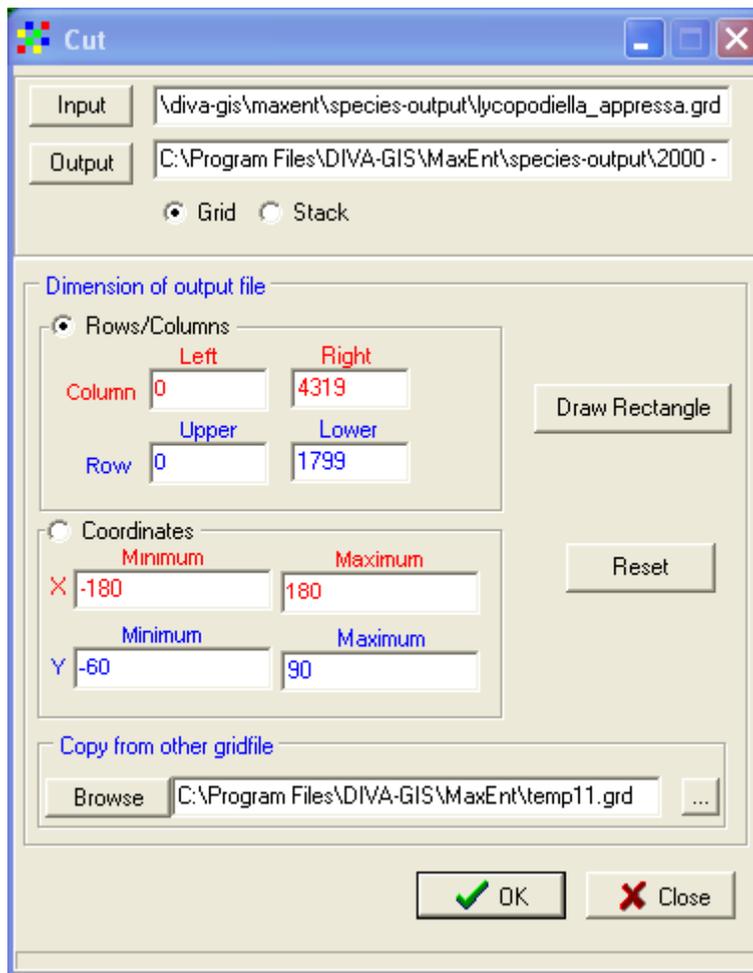
Do you think that PA will, overall, see an increase or decrease in the abundance of this species?

What are some other factors that might affect this prediction?

Continue the procedure on the next page....

Analysis of MaxEnt output in DIVA-GIS, Part 2: Quantifying the change in climatic suitability in PA for *Lycopodiella appressa*:

1. With the current bioclimatic model layer active, cut the model to include only a block that includes the state of PA (plus some surrounding area).
Copy these bounding coordinates from another grid file that I created called “temp11.grd” in the main MaxEnt directory (see below).



2. This created a new grid file. What does this grid file represent?
3. Perform “GRID > Describe” to summarize the probability of climatic suitability. Report the following:

Minimum year 2000 probability value for PA sensu lato:

Maximum year 2000 probability value for PA sensu lato:

Sum of year 2000 probability values over all 5 min² grid cells in PA sensu lato:

4. Now do the same for the year 2050 bioclimatic model and answer the following:

Minimum year 2050 probability value for PA sensu lato:

Maximum year 2050 probability value for PA sensu lato:

Sum of year 2050 probability values over all 5 min² grid cells in PA sensu lato:

*Calculate the percent increase or decrease in probability of climatic suitability in PA for *Lycopodiella appressa*. What is this value?*