

ColoradoView – Invasive Hybrid Toadflax Species Distribution Modeling Project

Final Report May 12th, 2016

1. Project Theme

Theme: Invasive species habitat suitability modeling for dalmation and yellow toadflax, and predicted habitat overlap for hybrid toadflax.

Title: Using MODIS Imagery to Predict Distribution of Invasive Hybrid Toadflax (*Linaria* hybrid) in Colorado, USA.

2. Project Team

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4. General Project Overview

Three species of toadflax are considered to be invading Colorado: yellow toadflax (*Linaria vulgaris*), dalmation toadflax (*Linaria dalmatica*) and a hybrid of the two. Much is known about yellow and dalmation toadflax; however, little is published on hybrid toadflax. All species are prolific, spreading rapidly in common conditions and across a wide range in elevation. The hybrid appears to take on characteristics beneficial for reproduction from its parents enabling it to spread to a larger distribution. The purpose of this project is to create a habitat suitability map for the hybrid toadflax species in Colorado, basing the prediction on species distribution models created for dalmation and yellow toadflax. The models will incorporate remote sensing data as well as climatic and topographic variables.

5. Research Question and Objectives

Question: What are the potential areas of niche overlap of yellow and dalmation toadflax that predict the potential for hybridization?

Objectives: (1) develop species distribution models for yellow and dalmation toadflax and habitat suitability maps for all 3 toadflax species in Colorado (2) determine if remote sensing variables improve model accuracy compared to only using climatic and topographic variables.

6. Major Products

Methodology

Species presence data points and numerous GIS layers describing environmental characteristics were acquired and processed to be suitable for our use. These layers exist in the following categories:

1. Climate
2. Topography
3. Soils
4. Vegetation indices
5. Phenology
6. Human Footprint Index (HFI)

Presence data for yellow and dalmation toadflax in Colorado were collected from the following sources:

1. <http://www.eddmaps.org/>
2. <http://www.rmh.uwyo.edu/>

In order to prepare the presence data for modeling, the following steps were performed with SDM Toolbox. The [SDM Toolbox User Guide](#) describes each of these steps; the sub-bullet is a shorthand description of what the step does.

1. Preparing Occurrence Data: Import Species Occurrence Records
 - a. Import CSV, create shapefile
2. Preparing Occurrence Data: Define projection of occurrence points shapefile
 - a. Project presence points shapefile to WGS84
3. Preparing Occurrence Data: PCA of Climate Variables to Estimate Heterogeneity
 - a. Calculate climate heterogeneity – principle component analysis
4. Preparing Occurrence Data: Measure Spatial Heterogeneity of Climate PCs
 - a. Calculate climate heterogeneity
5. Preparing Occurrence Data: Graduated Spatial Rarefying
 - a. Spatially rarefy presence points
6. Gaussian Kernel Density of Sampling Locations
 - a. Create bias file
7. Export presence data from value attribute table to CSV (species, lat, lon)
 - a. Note: not in SDM Toolbox user guide

Several groups of the environmental layers were leveraged from the previous ColoradoView invasive species project. Information on the methodology of generating those layers is found on the ColoradoView web site in the Research section, project report [Invasive Species – Wheat Stem Sawfly](#), report sections 1) Preparing NDVI/EVI for use in MaxEnt (vegetation index layers) 2) Preparing PRISM data for use in MaxEnt (climate and soils layers) and 3) Downloading and Preparing a 90m DEM for Colorado using SRTM data (topographic layers). Please refer to that report should you need to create new NDVI/EVI, climate, soils, or topographic layers instead of leveraging the existing layers created for ColoradoView (recommended, as appropriate).

The vegetation index added for this project was Vegetation Drought Response Index (VegDRI) from the eMODIS sensor. The data were found on [USGS Earth Explorer](#) and monthly data was used from 2010 – 2015. Additionally, eMODIS phenology data is new for this project and was sourced from the same

location; however, phenology data is available annually (not monthly) and at the time of use was only available for 2010 – 2014. The methodologies for processing both VegDRI and phenology data follow.

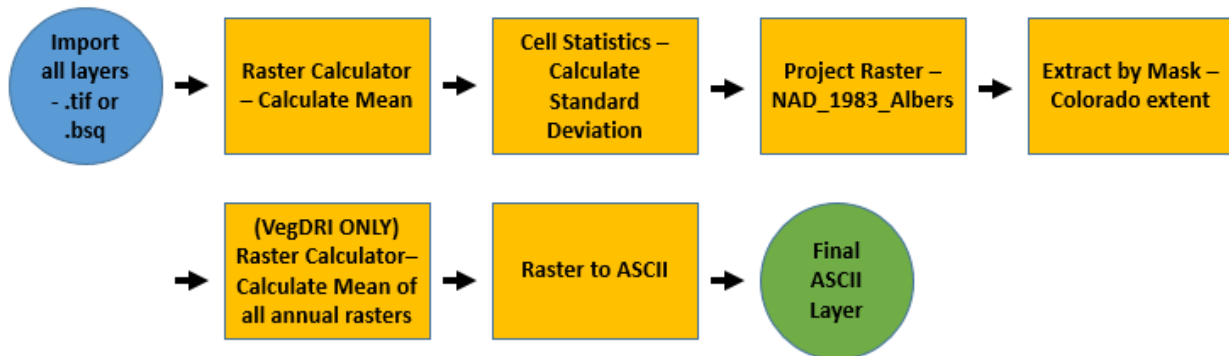


Figure 1. Workflow diagram for eMODIS layers – VegDRI and Phenology

Lastly, the HFI layer was the final introduction to this semester’s project. It was sourced from [here](#). The Wildlife Conservation Society and Columbia University Center for International Earth Science Information Network produced the Human Footprint layer at 1 km resolution. This layer was generated using nine human population related data layers such as population pressure, land use, and human access.

After processing the presence points and six different groups of layers defined above, MaxEnt modeling began. The Maximum Entropy application assumes the species will expand its range to areas with similar characteristics barring any outside influences. The data used are presence points; absence data are not required by the modeling algorithm. The objective of MaxEnt modeling is to start with the presence data and a set of environmental layers, run the model, and then reduce the layers to those that are most influential. The desired layers predict the distribution of the species and are not highly correlated with other layers. This is an iterative process based on the groups of layers used. For example, our first set modeled was climate, followed by the pertinent climate layers plus the topography layers, and so on. Determining whether a layer has significant influence requires consideration of the output statistics from MaxEnt as well as an understanding of the biology of the species. For dalmation toadflax, seven layers were kept; for yellow toadflax, five layers were most influential.

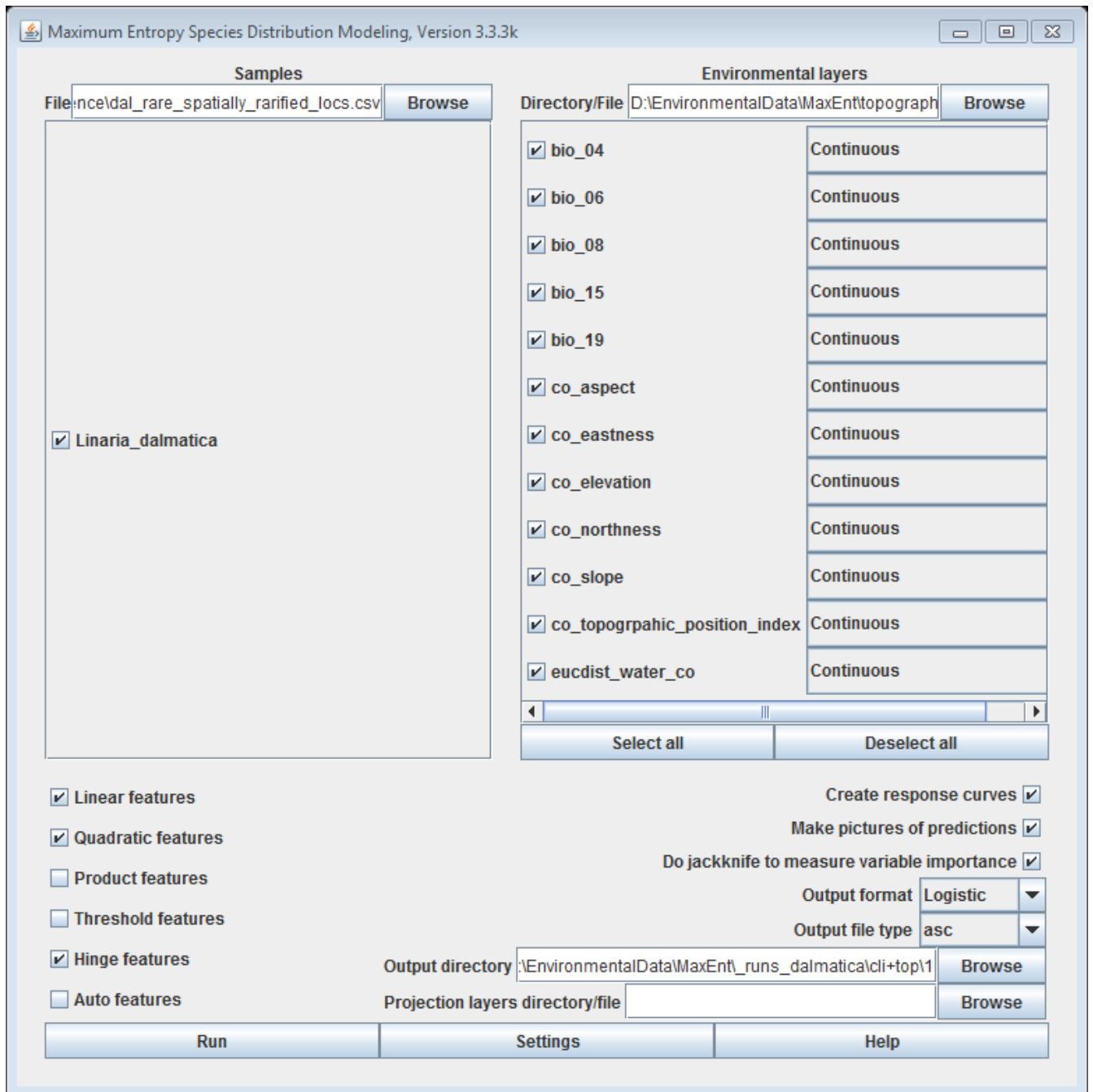


Figure 2. Example MaxEnt Screenshot

Main issues examined

To address our research question, we created a species distribution model for both dalmation and yellow toadflax, then calculated the area of overlap for potential hybridization. See maps for all three scenarios below. We also calculated Schoener's D statistic using ENMTools to be 0.66, implying a wide range of intermediately suitable habitat for both (parent) toadflax species.

Regarding the influence of remote sensing, we ran our final models with and without the selected remote sensing layers. For dalmation toadflax, the model measured better in two out of three judgement characteristics, and the same in the third characteristic with/without remote sensing layers. For yellow toadflax, the model measured better in two out of three judgement characteristics, and worse in the third characteristic.

Relevant datasets

This final project report acts as the readme file for the produced datasets.

Datasets have been stored on the Centroid L: drive in the folder
L:\Project_active\ColoradoView\2016\Invasive_Species\Toadflax_Models\Final_layers

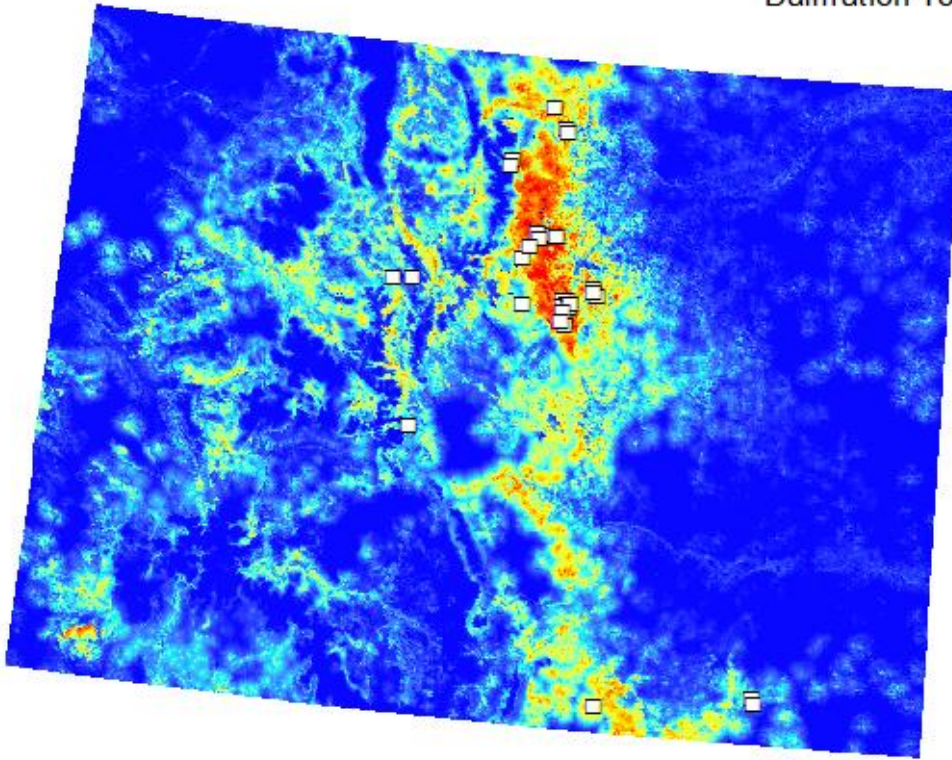
These are encapsulated in the 2016_Toadflax_Datasets.zip file that contains:

| Directory | Data layers |
|------------|---|
| climate | Bioclim 1-19 |
| hfi | Human Footprint Index 2016 |
| phenology | eMODIS phenology (9) for 2010-2014 (means and std devs across 5 years) |
| soils | ISRIC SoilsGrids (clay percent and pH at 0-5, 5-15 cm depths) |
| topography | NASA SRTM topographic data (elevation, slope, aspect, etc.) |
| vi_s | NDVI, EVI, and VegDRI for 2010-2015 (means and std devs across 6 years) |

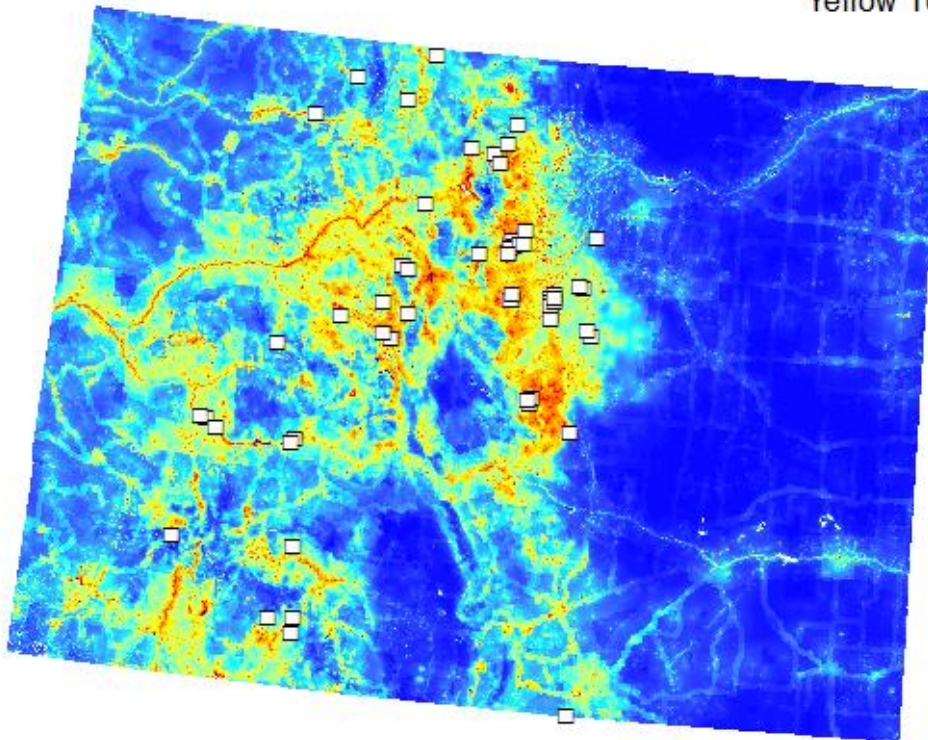
Maps

1. Species distributions; from blue to red (0 to 100% probability of occurrence); white squares are presence points used in modeling

Dalmation Toadflax







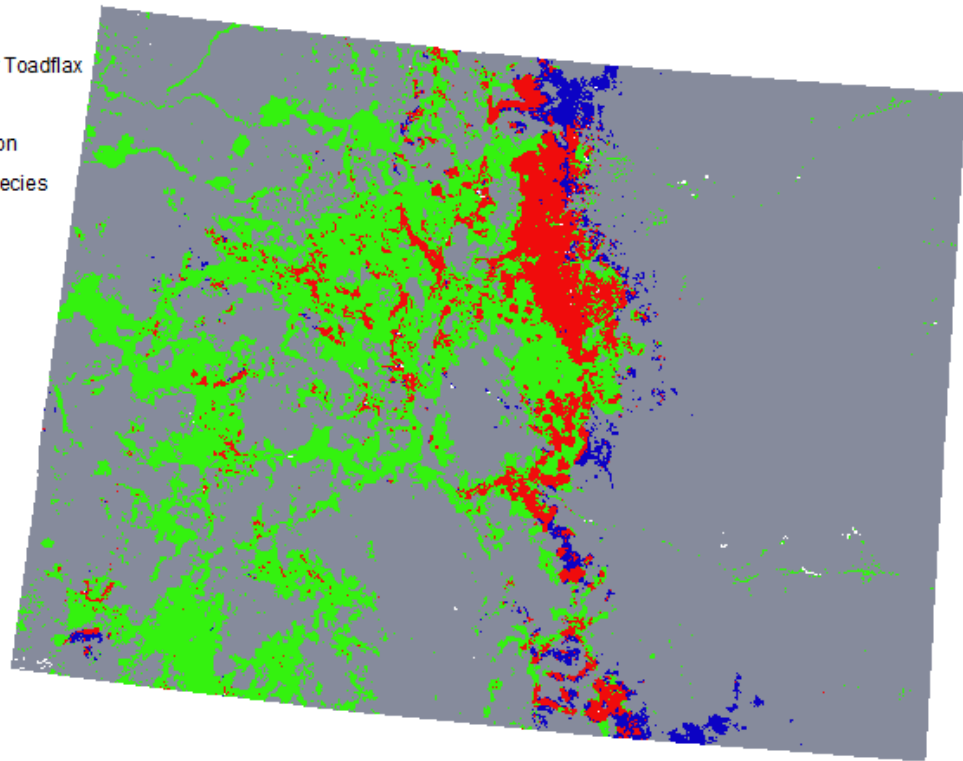
Yellow Toadflax



2. Niche overlap

Legend

-  Unsuitable for either Toadflax
-  Suitable for Yellow
-  Suitable for Dalmation
-  Suitable for Both Species



References

- Brown, J.L. 2014. SDMtoolbox: a python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses. *Methods in Ecology and Evolution*.
- Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190:231-259.
- Warren, D.L., R.E. Glor, and M. Turelli. 2010. ENMTools: a toolbox for comparative studies of environmental niche models. *Ecography* 33:607-611.

Materials on ColoradoView website

In addition to this report, an updated tutorial has been produced for the Colorado View website. It will be hosted on the [Tutorials page](#) and is titled "Identifying Niche Overlap from Maxent Model Predictions."

7. Final Reflection

Benefits to society and other researchers

The results from this research project will be evolved into a formal journal article. As such, they will be widely distributable to researchers and other members of society. The two main outcomes of our research were 1) the suitability map of Colorado for hybrid toadflax and 2) remote sensing variables improved our modeling results. These results can benefit society by raising awareness of the potential

risk of hybrid toadflax spread. An understanding of the risk may enable land managers to better plan and control the dispersal of the species. For researchers, our process demonstrates that remote sensing layers are valuable when incorporated into species distribution models similar to those performed here.

Challenges faced

We faced a notable point of confusion when trying to create the standard deviation layer for VegDRI. The process in ArcMap appeared to change the maximum value of the raster when converted from grid to ascii. However, after asking several experts for help, it was determined by dividing the grid and the ascii that they were not different i.e. the quotient was 1.

The other hurdle we faced was the creation of rarefied presence points. This was overcome by Kevin and Jordan following the identical, documented process for SDM Toolbox, thereby making the procedure repeatable and the results the same.

Recommendations, limitations, and how to use products

Our recommendations are

- Follow procedures that have already been documented; it may take asking or searching around to find these, but it will save time
- For new procedures, document them yourself so they are repeatable and can be debugged without ambiguity

The limitations that come to mind for our datasets are primarily the temporal range – ending in either 2014 or 2015, as documented above, despite the project finishing in May, 2016.

How to use the products has been discussed throughout this document. An additional recommendation is to seek support from team members as soon as you feel like you are spinning your wheels on an aspect of this work that has been done on an earlier project.