# Species distribution modeling of early-season milkweed in the Los Padres National Forest

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## Objectives

The objectives of this project are to model the distribution of four early-season milkweed species (*Asclepias spp.*) in the Los Padres National Forest, California to better inform the conservation and restoration of the threatened western monarch butterfly (*Danaus plexippus*) and to create a public-facing web dashboard to share the results of the modeling. Working with the Santa Barbara Botanic Garden (SBBG), and collaborators from Creekside Science, California Central Coast Joint Venture, UC Davis, and the California Department of Fish and Wildlife, we aim to use recently collected field survey data, public environmental data, and public remote sensing data to (a) make a species distribution map of the four milkweed species present in the Los Padres National Forest, (b) use Maximum Entropy (MaxEnt) modeling to determine the contribution of environmental variables to model predictions and predict where these species may be present that we are not currently aware of, and (c) create a web dashboard page to publicly provide information on the project and share the results for educational purposes. This project will inform the SBBG research team about where their conservation and restoration efforts will be most valuable and how accessible these sites are.

## Significance

The Los Padres National Forest contains essential egg-laying resources for recently emerged monarch butterflies (Los Padres Forest Watch 2013). During their migratory process, the monarch, having just left the safety of coastal overwintering habitats, will begin its migration towards milkweed populations present within the National Forest. These plants serve as essential breeding and egg-laying habitat for the butterflies (California Department of Fish and Wildlife n.d.). Once the eggs hatch, the larvae will eat the milkweed in preparation for crystallization. Western monarch populations have been heavily declining in the past 50 years, largely due to the loss of their over-wintering and breeding habitat (Pelton et al. 2019). These butterflies are an important cultural species and their loss may negatively impact the survival of other plant species, including food crops.

Throughout the Los Padres National Forest, there are four different species of early-season milkweed: *A. californica, A. vestita, A. eriocarpa,* and *A. erosa*. The Santa Barbara Botanic Garden staff has and will continue to perform fieldwork to identify where these milkweed species are located and the characteristics of the survey areas (Santa Barbara Botanic Garden 2023). A priority has been placed on re-visiting roughly 1000 historic populations identified through herbarium specimens, iNaturalist points, and personal communication. Since the Los Padres National Forest spans a large area of California with a diversity of terrains, an analysis of species distribution along with environmental and remote sensing data will advise on site accessibility and visitation priority. There are many known historical populations of milkweed, but there may be other populations we are not aware of. Species distribution modeling will inform the SBBG research team where undiscovered populations might be, or where milkweed could be grown for restoration purposes.

## Background

There are several factors contributing to the decline of milkweed populations. In the eastern US, it is hypothesized that commercial herbicides are largely at fault for the decline of milkweed, and this same hypothesis is now being extended to the western populations as well (Los Padres Forest Watch 2013, Pleasants and Oberhauser 2013). The decline of milkweed and monarch

populations began roughly around the same time as the U.S. agricultural revolution, which also resulted in a significant loss of natural lands (Boyle et al. 2019). Additionally, the droughts that California has been facing may be putting additional stress on milkweed, inhibiting disease resistance, growth, and seed germination (Bahmani et al. 2018). To mitigate the decline of western monarchs, a petition was submitted to classify the monarch as a "threatened" species, though it is slated to be officially listed under the federal Endangered Species Act in 2024 (California Department of Fish and Wildlife n.d.). This classification will allow for stricter protection of the species and its habitat, including milkweed. The Santa Barbara Botanic Garden has conducted one year of field surveys in the forest with a second year of surveys set to begin during the late spring and summer of 2024.

**Equity**

While the primary emphasis of this project does not have a specific environmental justice or equity focus, part of the group's responsibility will be to incorporate principles of accessibility in the deliverables. Scientific research and its discussion frequently appear shrouded within the confines of academia, and the Santa Barbara Botanic Garden as an educational non-profit organization hopes to alleviate any sense of opacity surrounding this project. Other specific additions to the web dashboard will include informative captions in plain language, alt-text, easy-to-read font, and colorblind-friendly color palettes.

**Data**

Listed are the data point summaries and polygon data from the SBBG surveys, as well as public sources of environmental data. SBBG's complete data files with associated geodata have yet to be transferred to Google Drive due to their substantial size but will be uploaded and shared upon the start of the project.

| **Variable** | **Source** |
|---|---|
| Milkweed presence, SBBG survey data, and milkweed polygon data | Santa Barbara Botanic Garden |
| Vegetation coverage | USDA Forest Service |
| Topography | USGS National Map Lidar |
| Slope | USGS SRTM digital elevation model |
| Historic climate | NOAA National Centers for Env. Information |
| Forest soil carbon | USFS Geospatial Data Discovery |
| Forest management planning | USDA Forest Service regional data |

**Computational Tools and Needs**

The computational tools needed for this project are R to organize the data, write scripts, and run the species distribution modeling scripts and MaxEnt for the distribution modeling. MaxEnt is

open-source software and can be used via the dismo package in R (Hijmans et al. 2023). The SBBG team has expressed their support of hosting the web dashboard on their website as long as it is accompanied by a description, known as an "Insight".

**Possible Approaches**

The client has suggested one possible approach of delegating the work between group members. This involves dividing the students to work on (a) the distribution mapping, (b) gathering, organizing, and incorporating the remote sensing data into the model, and (c) beginning on the framework of the web dashboard. This is just one possible approach and can be discussed at the beginning based on group preference and will naturally develop as the project unfolds. Regarding the steps of the project, the following will need to be completed:

1) *Workflow*: Collaborate on the project using two different GitHub repositories and the Bren server, Taylor. One will be for the mapping and MaxEnt modeling and the second will be through a GitHub organization to construct the web dashboard.
2) *Data selection & cleaning:* Examine remote sensing and occurrence data sets and select appropriate variables for climate, vegetation, and topography. Perform any cleaning and organization of the data needed to run the modeling analyses.
3) *Analysis*: Create a species distribution map, use MaxEnt to find the significant contributing factors to milkweed presence, and analyze the modeling outputs.
4) *Model visualization*: Further develop the modeling output visualizations to assist SBBG scientists in analyzing trends for future directions and communications of the results.
5) *Web dashboard development*: Use the results from the modeling as well as the distribution data and background information to create a public web dashboard.

**Deliverables**

In addition to the design plan, technical documentation, and oral presentation, the client will receive:

1) A species distribution map of the four milkweed species.
2) Raw MaxEnt outputs from the species distribution modeling.
3) Polished spatial outputs of the MaxEnt species distribution modeling.
4) Information on the accessibility of sites of interest.
5) A public, presentable web dashboard with project details and results.

**Audience**

The raw MaxEnt outputs, spatial results, and accessibility assessments are intended for the SBBG team involved in the broader milkweed restoration project. The web dashboard will be specifically designed for the public to learn about the importance of milkweed in the Los Padres National Forest for the reproduction of the monarch butterfly. It will also include background on the scope of the restoration project, the results of the modeling, and why this analysis is helpful for the larger project. Visitors of the web dashboard will be able to use an interactive map showing the location of milkweed populations and geographical features of the area.

## Supporting Materials

### References


Bahmani, M., R. Naghdi, and D. Kartoolinejad. 2018. Milkweed seedlings tolerance against water stress: Comparison of inoculations with Rhizophagus irregularis and Pseudomonas putida. Environmental Technology & Innovation 10:111–121.

Boyle, J. H., H. J. Dalgleish, and J. R. Puzey. 2019. Monarch butterfly and milkweed declines substantially predate the use of genetically modified crops. Proceedings of the National Academy of Sciences 116:3006–3011.

California Department of Fish and Wildlife. (n.d.). Monarch Butterfly.

Hijmans, R. J., S. Phillips, and J. L. and J. Elith. 2023, May 21. dismo: Species Distribution Modeling.

Los Padres Forest Watch. 2013. Monarch Butterfly.

Pelton, E. M., C. B. Schultz, S. J. Jepsen, S. H. Black, and E. E. Crone. 2019. Western Monarch Population Plummets: Status, Probable Causes, and Recommended Conservation Actions. Frontiers in Ecology and Evolution 7.

Pleasants, J. M., and K. S. Oberhauser. 2013. Milkweed loss in agricultural fields because of herbicide use: effect on the monarch butterfly population: *Herbicide use and monarch butterflies*. Insect Conservation and Diversity 6:135–144.

Santa Barbara Botanic Garden. 2023. SOW Early Season Milkweed Surveys.


### Budget/Justification

This project is not anticipated to have any budgetary needs beyond the standard support for MEDS capstone projects.

### Client Letter of Support

See attached.

Santa Barbara Botanic Garden

Bren School of Environmental Science & Management
Master of Environmental Data Science (MEDS) degree program
Bren Hall 2400 University of California, Santa Barbara, CA 93117

To Whom It May Concern,

In an effort to improve the critically low population numbers of the western monarch (*Danaus plexippus*), we propose to model the distribution of resources most limiting to their migratory cycle. Specifically, we propose to model the distribution of early-season milkweed species which serve as their breeding habitat. To better understand the distribution and abundance of these plants, in the summer of 2023, staff at the Santa Barbara Botanic Garden (SBBG) conducted extensive field surveys within the Los Padres National Forest (LPNF) to identify patches where *Asclepias californica*, *A. vestita*, *A. eriocarpa*, and *A. erosa* are growing. During surveys, we collected spatially explicit data on the presence, status, and use of milkweed by monarchs across the Los Padres National Forest. In addition, we collected data about the slope, aspect, vegetation community and phenology of each patch. With over 250 polygons mapped the dataset is ideal for modeling.

Students of the Bren School of Environmental Science & Management within the Master of Environmental Data Science (MEDS) degree program will take the abundance of data collected in 2023, along with the abundance of publicly accessible geodata, to model the distribution of milkweed across the Los Padres National Forest. The specifics of the modeling efforts are up to the group involved, but we envision some type of Species Distribution modeling (i.e., MAXENT or related program). Results of the modeling effort will be immediately employed to design our 2024 survey efforts, providing an opportunity to evaluate model output. Beyond informing immediate action, results will be of great value to monarch conservation and restoration projects across the west, informing restoration expectations and providing the raw materials for restoration efforts. The results will also be highly publishable.

Students will also be encouraged to design an interactive tool, to be hosted on the Gardens website, where the model can be explored. The garden pledges a willingness and ability to provide long-term support post-project completion, including application troubleshooting, deployment, and maintenance of the application post-graduation.

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