

The Friends of Nachusa Grasslands
2024 Scientific Research Project Grant Report
Due June 30, 2025

Please answer the following questions with clearly written summaries to give Nachusa Friends' science committee members, officers, and board members a good idea of what you accomplished using your grant money. Unless you object to the Friends doing so, your report will be uploaded into the science section of the Friends' website: nachusagrasslands.org.

1. Please save this form to your desktop with a unique file name that includes "Friends 2023 Science Grant Report" and your last name.
2. Complete the form using the headings in **bold** as your guide.
3. Save the file as a Word document or a PDF.
4. Attach the file to an e-mail, and send it to: nachusafriendsscience@gmail.com no later than June 30, 2025.
5. The subject of the e-mail should be "2024 Scientific Research Grant Report" and your last name.
6. If you have not completed your work, please submit this form anyway by the June 30 deadline and plan to contact Friends after your project is complete so that we may learn from and publicize the outcomes as appropriate.

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2024 grant amount: \$2239

Research Project Topic: Testing the conservation value of range-edge populations: local adaptation, genetic load, and inbreeding in Sundial lupine

Research Project Purpose: In many countries and states, many locally at-risk species are found in the jurisdiction only at the edge of their geographical distribution and it is often unclear how important and amenable these range-edge populations are to conservation. Northern range edge populations may be particularly valuable for conservation because they may carry genetic adaptations that contribute to a species' overall genetic diversity, including important adaptations for range extension under climate change. Despite their potentially high conservation value, edge populations of most rare or threatened plants lack genetic studies that may guide their conservation. I'm testing two theoretical predictions about edge populations that can directly inform their conservation value: edge populations may be adapted to their local conditions or suffer from poor genetic quality (i.e inbreeding and hidden deleterious mutations, also known as genetic load). In particular, I'm testing these predictions in the rare and at-risk plant Sundial lupine (*Lupinus perennis*), a plant that occupies rare oak savannah, pine barren, and prairie habitats.

Research Project Outcomes to date: In 2022 and 2023, I reciprocally transplanted lupine seed from 6 populations spanning Michigan, Ontario, and Ohio. In 2025, some plants finally matured and flowered, allowing me to quantify their reproductive performance. Preliminary results show that there is no pattern of local adaptation in edge populations, but a potential advantage by core populations at all sites. Nevertheless, the quality of a site more strongly determines the performance of lupine. Further analysis is currently underway.

In February 2025, I successfully extracted, sequenced, and aligned DNA from a total of 18 remnant lupine populations including Nachusa Grasslands. Please note the delay in completing this project as I was worried about the quality of sequencing outputs. Preliminary results from this data show that all populations exhibit similar levels of individual inbreeding coefficients (F_{IS}) and genetic diversity (π), with greater variance in genetic diversity among edge populations. For instance, lupine populations from Albany, New York and Concord, New Hampshire, exhibited the highest levels of genetic diversity. Other populations, both core and edge, had similar levels of genetic diversity.

As expected, lupine populations were genetically distinct from one another, with exception to populations that were more closely clustered by geography and at found at higher density (i.e many Wisconsin populations found within 100KM distance). The populations closest in 'genetic distance' to Nachusa Grasslands include lupines at the University of Wisconsin-Madison Arboretum, Fort McCoy, and Indiana Dunes National Park.

Please note that numerous analyses will soon be underway, including:

- (1) Effective population size (N_e) to determine any population size risks
- (2) Demographic models to identify any past bottlenecks or expansion events
- (3) Genotype-environment associations (GEAs) to determine any signals of local adaptation along the genome, as expression of local adaptation may depend on 'extreme' years.
- (4) Genetic load to determine the presence of hidden deleterious mutations lingering among populations

As a preliminary take-home, the results combined from both my field experiment and the genomic analyses show that populations are genetically differentiated but exhibit little difference in performance in the field. Core populations may hold an advantage over edge populations at all sites (statistical analyses pending), yet such an advantage has a smaller contribution to performance than the quality of lupine habitat. Of course, these results require confirmation and any insights should be held until a final peer-reviewed publication is in place.

Describe how the grant funds you have received from the Friends of Nachusa Grasslands have been used in regard to the above topic, purpose, and/or outcomes:

The awarded grant funds were used to pay for DNA extraction and sequencing for 27 individual plants sampled from Nachusa Grasslands at Stonebarn Savanna. In detail, I completed whole-genome sequencing at Génome Québec at low coverage (average ~10x coverage). The lupines at Nachusa Grasslands were not involved in the field experiment.

Describe how your project has benefited the work and goals of Nachusa Grasslands:

This project studies the charismatic plant Sundial lupine which is considered rare in Illinois. The plant is also a food source to other at-risk butterfly species, including the Karner blue butterfly, the Frosted elfin, and the Mottled duskywing. Understanding the potential genetic risks of this plant not only enhances Nachusa Grasslands' goals of preserving and protecting rare plants, but also other rare species that depend on it. Promoting the persistence of Sundial lupine at Nachusa Grasslands, and at other localities, is thus important to the long-term survival of populations, species, and overall biodiversity.

Describe how your findings can be applied to challenges in management practices for restoration effectiveness and species of concern:

While my results still require additional confirmation and analyses, a preliminary take-home message is that Nachusa Grasslands could source seed for restoration from any population as performance is largely tied to the site/habitat quality rather than genetics. On the other hand, preserving local genetic identity may still be a priority as the particular adaptations leading to similar performance across the range is unknown. For instance, there may be particular molecular pathways, physiological or morphological traits unique to Nachusa that allows the population to express similar performance to other populations. My further analyses will attempt to answer this question.

Please list presentations/posters you have given on your research:

Have you submitted manuscripts to scientific journals? If so, which ones? If not, do you anticipate doing so? (Please send digital copies of published articles to the Friends so that we can learn from your work.)

I will follow up when they are published.

What follow-up research work related to this project do you anticipate (if any)?

As mentioned above, there are additional analyses to be completed, and I anticipate future results to be shared. In addition, I also surveyed population size, density, and

habitat area for 32 populations spanning Minnesota to New Hampshire in 2025. In the future, I hope to write a paper summarizing the differences between these populations, which may arise to differences in climate, conservation actions, and more.

Optional: Suggestions for improving the application and award process for future Friends of Nachusa Grasslands Scientific Research Grants:

I would only suggest outlining Nachusa Grasslands' goals somewhere on the application, unless it is already so.

Thanks for supporting my research!!!!