

Final Abstract

Final Report Approved on November 6, 2024

M.L. 2021 Project Abstract

For the Period Ending June 30, 2024

Project Title: Creating Cost-Effective Forage and Management Actions for Pollinators

Project Manager: Daniel Cariveau

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Funding Source:

Fiscal Year:

Legal Citation: M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08n

Appropriation Amount: \$198,000

Amount Spent: \$198,000

Amount Remaining: -

Sound bite of Project Outcomes and Results

We examined how seed mix design and land management influenced floral resources for native bees. Our findings will help reduce the cost of pollinator seed mixes. We also developed a seed mix tool enabling land managers in Minnesota to input seed mixes to maximize forage for native bees.

Overall Project Outcome and Results

We planted over 400 3x3 meter plots with a diverse array of seed mixes for prairie restoration. We varied the density and diversity of forb seeds as well as the ratio of forb-to-seed. We found that the forb-to-grass ratio was the most important factor for overall floral abundance while the forb-to-grass ratio and seed diversity positively influenced phenological coverage of floral bloom. Seed density had little effect on any floral resource measure. This suggests that land managers in Minnesota can use lower seed density mixes and thus reduce the overall cost of ecological restoration. Further, we mimicked the common land management strategies of burning and mowing and found that these management techniques had little effect on overall floral resource production. We also measured nectar and pollen rewards and how those rewards were influenced by seed mix design. We found little effect of any of these factors on pollen or nectar rewards. Finally, we developed a seed mix tool that enables land managers to build seed mixes to

support native bees. Land managers can use this tool to see which native bee species are supported by which plants and provides suggestions as to which plant species could be added to support additional native bees. This tool is freely available for anyone to use on our website.

Project Results Use and Dissemination

We presented this research in numerous talks for the general public as well as researchers. We have published two peer-reviewed manuscripts (see attached). The pollinator seed mix tool we developed is available online for anyone to use.



Environment and Natural Resources Trust Fund

M.L. 2021 Approved Final Report

General Information

Date: November 27, 2024

ID Number: 2021-308

Staff Lead: Noah Fribley

Project Title: Creating Cost-Effective Forage and Management Actions for Pollinators

Project Budget: \$198,000

Project Manager Information

Name: Daniel Cariveau

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Project Reporting

Final Report Approved: November 6, 2024

Reporting Status: Project Completed

Date of Last Action: November 6, 2024

Project Completion: June 30, 2024

Legal Information

Legal Citation: M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 08n

Appropriation Language: \$198,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to evaluate pollinator forage across time and in response to burning and mowing and to design an open-access web-based tool to share these data for land managers across Minnesota to inform restoration seed mix selection.

Appropriation End Date: June 30, 2024

Narrative

Project Summary: We will collect long-term, species-specific plant data on pollinator forage quality and quantity. These data will be used to design an open-access web-based tool for land managers in Minnesota.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Planting flowers is the most effective method to conserve pollinators. For example, the first goal in the 2019 Minnesota State Agency Pollinator Report is that “lands throughout Minnesota support healthy, diverse, and abundant pollinator populations”. The key output of this goal is to provide “More food sources for pollinators”. However, pollinator habitat is incredibly expensive with seed mixes alone often costing over \$1,000 per acre. Further, to ensure that habitats provide forage for multiple years, land managers often carry out costly management actions. The high cost of seeds and management limits the ability of public and private landowners to increase and maintain healthy pollinator landscapes.

A critical next step in creating habitat is to determine how to maximize benefits for pollinators while minimizing costs. There are three main knowledge gaps. First, there is a lack of information on the forage (nectar and pollen) quality and quantity of different plants used in pollinator seed mixes. Second, we lack detailed information on how forage resources change across years. Third, we do not understand how different management regimes influence forage quality and quantity. Finally, it is critical that this information is easily accessible to land managers.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

To fill these knowledge gaps, we will measure the forage (nectar and pollen) quantity and quality of 30 different flowering plant species. We will also collect data on the amount of flowers blooming and the number and species of bees visiting these plants. Second, we will use this information to help design and disseminate a web-based seed mix optimization tool. Third, we will conduct a study in which we randomly assign burning, mowing, or no treatment (control) to the experimental plots.

To accomplish this, we will leverage an ongoing study. We established a large-scale seed mix experiment in 2018. In total, we installed 288 - 9x9' plots that vary in the types and number of flowering plant species. In 2019 and (hopefully) 2020 we collected flower abundance and bee data on these plots. In addition, the seed mix tool is currently in development. Both the field study and the seed mix tool are funded by the Foundation for Food and Agriculture Research.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state’s natural resources?

We will generate species-specific plant data that will enable land managers to create seed mixes that maximize the benefit to pollinators while minimizing the costs. Habitat is critical for native pollinators - including the over 400 species of bees native to Minnesota. This proposal will directly benefit the state's natural resources by increasing the quantity of pollinator habitat by reducing the cost per acre while also increasing habitat quality. For example, results from the project will help meet the output of the first goal of the Minnesota State Agency Pollinator Report: to provide "more food resources for pollinators".

Project Location

What is the best scale for describing where your work will take place?

Region(s): SE

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Measure the quantity and quality of pollinator forage (nectar and pollen) over time.

Activity Budget: \$121,795

Activity Description:

In the late fall of 2018, we planted a large-scale experimental study to determine how to maximize benefits to pollinators while minimizing costs. In particular, we planted 288 - 9x9' plots. Each plot contains a plant community in which we varied the number and type of plant species as well as the density of seeds. Prior to this current ENRTF proposal, we will have collected 2 full years of data on floral abundance and bee use. We will use ENRTF funds to complete 2 additional field seasons. This is critical as prairie plants take 3-4 years to establish. In particular, we will measure how floral abundance changes through time. Further, we will collect data on the nectar and pollen produced by the plants in this experiment. This will include sugar content of nectar, amount of nectar and pollen produced, and protein content of pollen. This information is critical as it will allow us to quantify the value of different plant species in regards to forage resources for pollinators. We can then link this forage value with the seed costs (see Activity 2) and will disseminate this information to land managers in Minnesota (see Activity 4).

Activity Milestones:

Description	Approximate Completion Date
First field season data collection	October 31, 2021
Collect data on bee diversity and abundance	September 30, 2022
Summarize results in outreach materials for land managers in Minnesota	April 30, 2023

Activity 2: Evaluate the effects of burning and mowing on pollinator forage quality and quantity

Activity Budget: \$26,831

Activity Description:

Land management actions, specifically mowing and prescribed fire, are costly methods used to promote growth of native plant species and reduce growth of invasive plants. Despite the large effects that mowing and burning have on plant communities, we do not know how these management actions impact the quantity and quality of pollinator forage. With our existing experimental setup of 288 seed mix plots, we are in a perfect position to test this. We will mow one-third of our plots, burn one-third using an experienced tallgrass prairie restoration management company, and designate the remaining one-third as control (unmanaged) plots. We will then quantify floral abundance, bee use, and forage quantity and quality in these different treatments.

Activity Milestones:

Description	Approximate Completion Date
Mow one-third of the experimental plots	September 30, 2021
Burn one-third of the experimental plots	February 28, 2022
Incorporate results into outreach materials	March 31, 2023

Activity 3: Design and implement online, publicly accessible seed mix tool

Activity Budget: \$35,154

Activity Description:

We are collaborating with researchers at the UMN Institute on the Environment (Ione) to create an online seed mix tool.

This tool will allow a user to input their site characteristics (e.g. soil moisture, sun/shade), county, and pollinator conservation program generate a seed mix that is optimized to support the greatest number of pollinators for a given budget. Currently, the model underlying the web-based interface uses basic data on a limited suite of plant species. We will use the results from Activity 1 to provide more detailed data and include more plant species. Further, we will incorporate seed costs data into the model. Our experimental results will enable land managers to create highly effective seed mixes at minimal costs. We will deliver our data to the primary model developer, Peter Hawthorne (IonE), and assist with model trouble-shooting and stakeholder engagement. We will organize stakeholder meetings to test and refine the tool with land managers in government agencies and conservation groups. We had already held a preliminary stakeholder meeting to get initial feedback on this tool that included participants from BWSR, DNR, and Minnesota offices of The Nature Conservancy, Xerces Society, and United States Fish and Wildlife Service.

Activity Milestones:

Description	Approximate Completion Date
Delivery of field season 1 data to IonE collaborator	January 31, 2022
First virtual stakeholder meeting to test version of the tool with experimental data	May 31, 2022
Delivery of field season 2 data to IonE collaborator	January 31, 2023
Second virtual stakeholder meeting to test version of the tool with experimental data	May 31, 2023
Seed mix tool place online with publicly available data collected from Activity 1	June 30, 2023

Activity 4: Communicating experimental results and introducing the seed mix tool to land managers

Activity Budget: \$14,220

Activity Description:

In addition to the virtual stakeholder meetings with MN land managers described in Activity 2, we will hold an in-person outreach event to communicate our results with MN land managers and introduce a larger audience to our seed mix tool. We propose a 1-day workshop at the Rosemount Extension and Outreach Center consisting of the following activities: 1) Overview of the experimental design and main results, 2) Guided tour of our experimental plots, 3) Walk-through of the seed mix tool by the software developer, and 4) Working session for attendees to work with the software developer to create seed mixes for their own project needs. This workshop will be free to all attendees. In addition, we will create instructions that will enable new users to access the web-based tool.

Activity Milestones:

Description	Approximate Completion Date
Create outreach materials - online and in print	February 28, 2023
Hold workshop to disseminate results to land managers	April 30, 2023

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Peter Hawthorne	Institute on the Environment	Develop web-based tool	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.

One of the main objectives of this project is to develop a free, open-access, easy to use tool that land managers and seed suppliers can use to build seed mixes (Activity 3). This tool will be built and data will be populated by Peter Hawthorne. We will hold stakeholder meetings with MN land managers to develop the tool. We will hold an in-person outreach event in May 2023 to communicate our results with MN land managers and introduce a larger audience to our seed mix tool. We propose a 1-day workshop at the Rosemount Extension and Outreach Center (location of experiment) consisting of the following activities: 1) Overview of the experimental design and main results, 2) Guided tour of our experimental plots, 3) Walk-through of the seed mix tool by the software developer, and 4) Working session for attendees to work with the software developer to create seed mixes for their own project needs. This workshop will be free to all attendees. In addition, we will create instructions and an online tool that will enable users to access the web-based tool.

We will include the ENRTF logo in all signs, outreach materials, and the tool website. As we have in the past, we will also include the ENRTF logo on all talks and state this explicitly during acknowledgements. For peer-reviewed papers, we will acknowledge the ENRTF and include the grant identification number.

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

The web-based tool will be available in the middle of the project and we will continue to update as results become available. The website will be run by the Institute on the Environment at the University of Minnesota. We will continue to seek funding to maintain and update this website into the future. We predict that once this seed mix tool is adopted by land managers, we will be able to generate funding for this tool into the future.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Data-Driven Pollinator Conservation Strategies	M.L. 2016, Chp. 186, Sec. 2, Subd. 03a	\$520,000
Pollinator Research and Outreach	M.L. 2017, Chp. 96, Sec. 2, Subd. 03n	\$500,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount	\$ Amount Spent	\$ Amount Remaining
Personnel										
Field Technician		Data collection, entry, and management			7%	0.52		-	-	-
Field Technician		Data collection, entry, and management			7%	0.26		\$10,520	-	-
Principle Investigator		Oversee Projects, Financial Management, and Supervise Postdocs and PhD Student			37%	0.08		\$13,535	-	-
PhD Student - Summer and two semesters at 1-credit status		Data Analysis, Field Work, Supervising Field Technicians			20%	0.1		\$23,991	-	-
Postdoctoral Research Associate		Project Management, Report Writing, Data Management, Hiring and Supervising Field Technicians			25.4%	1.4		\$123,067	-	-
							Sub Total	\$171,113	\$171,113	-
Contracts and Services										
Landbridge Ecological Incorporated	Professional or Technical Service Contract	The contractor will burn half of the 3 x 3 yard treatment plots.				0.25		\$850	\$850	-
Rosemount Research and Outreach Center (UMN)	Professional or Technical Service Contract	This is for renting the plots at the Rosemount Research and Outreach Center (part of University of Minnesota).				0		\$1,375	\$1,375	-
Hawthorne Spatial	Professional or Technical Service Contract	Peter Hawthorne is a specialist who is working on our project. He has since moved from the university to his own practice. This is simply moving funding that was originally approved for him in personnel to here.				0.16		\$24,186	\$24,186	-

							Sub Total	\$26,411	\$26,411	-
Equipment, Tools, and Supplies										
	Tools and Supplies	Collecting nets (4), plot markers (1000), collection vials (2000), pin flags	Collecting bees, marking plots before and after burn					\$327	\$327	-
							Sub Total	\$327	\$327	-
Capital Expenditures										
							Sub Total	-	-	-
Acquisitions and Stewardship										
							Sub Total	-	-	-
Travel In Minnesota										
	Miles/ Meals/ Lodging	Travel to field sites approximately 3 times per week during the 2022 field season. We will be able to fit 2-3 people in a vehicle. This is based on \$0.56 per mile federal rates ~ 3 times per week for 16 weeks. (55 miles round trip from saint paul campus x approximately 3 trips per week x 16 weeks = \$1,543	This will pay for rental car to visit field site. Field site is at UMN Rosemount Research and Outreach Center					\$149	\$149	-
							Sub Total	\$149	\$149	-
Travel Outside Minnesota										
							Sub Total	-	-	-
Printing and Publication										
	Publication	Publication Costs	Cost of publishing peer reviewed research					-	-	-
	Printing	Outreach materials for land managers.	Printing of outreach materials for land managers					-	-	-

			to highlight the seed mix tool.							
							Sub Total	-	-	-
Other Expenses										
		The budget will include the following: printing materials specifically for event (\$500), tent and chair set up and rental for 32 attendees (\$500), travel to site for set-up (\$100), 2 outdoor toilet rentals (\$240), Refreshments (\$160).	This will be a field day for land managers. We will show them how to use the seed mix tool.	X				-	-	-
							Sub Total	-	-	-
							Grand Total	\$198,000	\$198,000	-

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Other Expenses		The budget will include the following: printing materials specifically for event (\$500), tent and chair set up and rental for 32 attendees (\$500), travel to site for set-up (\$100), 2 outdoor toilet rentals (\$240), Refreshments (\$160).	While refreshments are generally ineligible, this event would be a multi-hour event and would take place in the summer. Refreshments are needed to make attendees comfortable and attentive during the workshop.

Non ENRTF Funds

Category	Specific Source	Use	Status	\$ Amount	\$ Amount Spent	\$ Amount Remaining
State						
			State Sub Total	-	-	-
Non-State						
			Non State Sub Total	-	-	-
			Funds Total	-	-	-

Attachments

Required Attachments

Visual Component

File: [3d75fe13-aaa.pdf](#)

Alternate Text for Visual Component

Visual showing a schematic of the project....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Hawthorne_SupportLetter	8c62cd93-359.pdf
UMN Proposal Letter	c8d4e0f8-f4f.pdf
Research Addendum	76303831-340.docx
Background Check	f12480f8-ae.pdf
Mueller et al. 2024	ae910964-d64.pdf
Muller et al. 2024 Restoration Ecology	15d94142-bb4.pdf
Restoration Ecology In Prep	71a9ad4d-f74.docx

Media Links

Title	Link
Seed mix tool	https://umnseedmixtool.streamlit.app/

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

For some reason, the activities were out of order. I changed it to the correct order. They should be as follows: Activity 1: Measure the quantity and quality of pollinator forage (nectar and pollen) over time, Activity 2: Evaluate the effects of burning and mowing on pollinator forage quality and quantity, Activity 3: Design and implement online, publicly accessible seed mix tool, Activity 4: Communicating experimental results and introducing the seed mix tool to land managers. Please note, no wording or budgets were changed.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the Commissioner's Plan applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request	<ul style="list-style-type: none"> • Budget - Personnel • Budget - Professional / Technical Contracts 	Peter Hawthorne is a software developer whom we co-wrote and developed this grant. He now has his own practice and we are still working with him. Therefore, we moved him to professional services. The work getting done is the same.	February 11, 2023	Yes	February 17, 2023
2	Amendment Request	<ul style="list-style-type: none"> • Budget - Professional / Technical Contracts 	We added information on the contractor. The company Landbridge Ecological Services completed this burn in May 2022. The burn took place on half of plots and we are sampling these plots currently.	June 29, 2023	Yes	June 29, 2023
3	Amendment Request	<ul style="list-style-type: none"> • Budget • Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences • Budget - Printing and Publication • Budget - Other 	Increase funds for postdoc and seed mix model development (Hawthorne). Burning costs from contractors were much less than anticipated. Reduced cost of techs and travel as this was covered through other funds from Cariveau lab. Reduced materials costs as we emphasize the development and dissemination of the seed mix model that will be online and paper publishing costs are not as necessary. Some publishing costs (see attached peer reviewed manuscript) covered by Cariveau lab.	March 24, 2024	Yes	April 12, 2024

Status Update Reporting

Final Status Update August 14, 2024

Date Submitted: October 11, 2024

Date Approved: October 30, 2024

Overall Update

We have completed six years of sampling with much of this from the funding of LCCMR. We found that overall, a low grass to forb ratio was the most important factor driving floral resources while forb plant diversity was important for providing floral resources throughout the summer. Seed density has little effect on floral resource abundance. This suggests that land managers can save cost by planting less seed while still seeing benefits to pollinators. Further, we found that floral resource quantity was robust seed mix design as well as burning. (See attached in preparation manuscript.) We carried out data collection through June 2024 on this LCCMR funding and used other internal funds to complete sampling in July and August of 2024. We are currently checking those data for peer-reviewed manuscripts. We have disseminated our results in talks and presentations and have two peer-reviewed publications with another to be submitted soon. We completed a seed mix application tool (<https://umseedmixtool.streamlit.app/>). We have to make a few minor edits and then will post We created seed mix application with Peter Hawthorne. We are working on a few minor edits and then will post for open access onto our lab's website.

Activity 1

We attempted to sample all plant species for pollen and nectar. Five species provided enough pollen or nectar to conduct statistical analysis (*Ratibida pinnata*, *Heliopsis helianthoides*, *Chamaecrista fasciculata*, *Penstemon grandiflorus*, *Penstemon digitalis*). We did not find that plant diversity, seed density or to forb:grass ratio influenced the production of pollen or nectar in any of these species. This suggests that floral resources are robust to seed mix design. Seed mixes that minimize grass to forb ratios will ensure that production of floral resources are abundant for pollinators. We are currently in the final stages and will be submitting a manuscript on these results for peer review to the journal *Restoration Ecology* (see attached manuscript in preparation).

(This activity marked as complete as of this status update)

Activity 2

We burned half of the plots and mowed the other half. As five species provided enough pollen or nectar to conduct statistical analysis (*Ratibida pinnata*, *Heliopsis helianthoides*, *Chamaecrista fasciculata*, *Penstemon grandiflorus*, *Penstemon digitalis*) we were able to investigate how this burning influenced the per-flower resource production. We did not find an effect of burning on any of these metrics this suggests that the production of floral resources is robust to prescribed fire. We will be submitting a manuscript on these results for peer review to the journal *Restoration Ecology* (see attached manuscript in preparation).

(This activity marked as complete as of this status update)

Activity 3

We have developed the tool it can be found here: <https://umseedmixtool.streamlit.app/>. We use the Minnesota Board of Water and Soil Resources as a template to generate mixes. This will be useful for land managers as they will be able to download BWSR mixes but also see how to format a csv file to analyze their own seed mixes. By loading the csv file into the "Analyze Seed Mix" section, land managers will be able to determine 1) which pollinator species their mix will likely support, 2) which plants they could add to support more species of pollinators. This analysis also includes a list of potential pollinators that it would support with the new plant species, and 3) whether it is meeting CP42 guidelines. CP42 is a commonly used seed mix for pollinator conservation on private lands that have Conservation Reserve Program contracts.

(This activity marked as complete as of this status update)

Activity 4

We will be putting the seed mix app on the Cariveau Native Bee Lab website. We have a few small technical changes that need to be made. We are also working on a manuscript for peer review. Finally, we will continue to highlight this in talks with D. Cariveau using it in a presentation to the United States Fish and Wildlife Service in September 2024.
(This activity marked as complete as of this status update)

Dissemination

We have already published two peer-reviewed publications based on this research. We have a third manuscript that is close to being submitted. Further, Julia Brokaw has finished her PhD thesis. She successfully defended and her dissertation was submitted to the University of Minnesota library. We have highlighted this work in multiple talks. D. Cariveau will be highlighting the seed mix app to practitioners at the United States Fish and Wildlife Service in late September 2024.

Status Update Reporting

Status Update June 1, 2024

Date Submitted: October 11, 2024

Date Approved: October 30, 2024

Overall Update

We are continuing to work on the seed mix application model with Peter Hawthorne. We are continuing to collect data on our experimental plots at the Rosemount Research and Outreach.

Activity 1

This activity was previously marked complete.

(This activity marked as complete as of this status update)

Activity 2

We are finalizing the seed mix application with Peter Hawthorne.

Activity 3

This activity was previously marked complete.

(This activity marked as complete as of this status update)

Activity 4

We are finalizing the seed mix application with Peter Hawthorne.

(This activity marked as complete as of this status update)

Dissemination

We have continued to present this research in outreach talks. A postdoc in the lab (Uta Muller) submitted an article to the peer-reviewed journal Restoration Ecology.

Status Update Reporting

Status Update December 1, 2023

Date Submitted: March 24, 2024

Date Approved: April 12, 2024

Overall Update

We completed another field season collecting data on floral resources including pollen and nectar concentrations. Plots have been either burned or mowed. We have had one manuscript published in a top-tier ecology journal. Two of the authors were funded by this project while writing (Brokaw and Bruninga-Socolar). The first author (Müeller) was hired after publication. We have another publication in peer review and expect to submit a third before the end date of this project. See the attachment for publication We are finalizing the seed mix selection mode with Peter Hawthorne (activities 2 and 4). We will continue to collect data this summer. The Cariveau lab will use other funds to complete data collection as there is great interest in this project and we are excited to extend this work.

Activity 1

We have collected pollen and nectar data from a number of plants. We have focused on *Penstemon digitalis* and *Penstemon grandiflorus* and measured pollen availability in *Ratibida pinnata*, *Heliopsis helianthoides*, and *Chamaecrista fasciculata*. We did find that floral resources have increased over time. From the discussions of this project, we published a perspectives piece in *Frontiers in Ecology and the Environment* (See attached). Of the approximately 150 ecology peer-reviewed journals, this is ranked 6th. We have another manuscript that is currently in review in *Restoration Ecology*. We are hopeful that this will be published as it was accepted pending major revisions. We have a third paper that is in progress that uses these data.

(This activity marked as complete as of this status update)

Activity 2

We are still working on this objective with Peter Hawthorne.

Activity 3

We have now burned or mowed all plots per the treatments outlined in the proposal. We did not find an effect of burning on the floral resources overall. We measured both floral area (a common metric for assessing floral resources) as well as nectar and pollen for species where this was methodologically possible. We have a manuscript that is in progress for submission to a peer-reviewed journal and expect to submit for peer review in 2024. We will conduct one more field season measuring floral area in 2024.

(This activity marked as complete as of this status update)

Activity 4

We are still working on this objective with Peter Hawthorne.

Dissemination

Activities 2 and 4 are focused on dissemination. We are finalizing the seed mix model with Peter Hawthorne.

Status Update Reporting

Status Update June 1, 2023

Date Submitted: June 29, 2023

Date Approved: June 29, 2023

Overall Update

We continue to analyze data for nectar availability, nectar quality, pollen availability, floral area, and plant establishment. We have used the findings or ideas generated from the research to publish a manuscript with another being submitted in mid-June 2023. Further, these data are being used for Julia Brokaw's dissertation which will be presented publicly in late July 2023. We are continuing to refine the seed mix tool with Dr. Peter Hawthorne and will present this to practitioners in spring 2024.

Activity 1

We sampled a number of flowers for pollen and nectar. We found that *Penstemon grandiflorus* nectar volume was reduced in 2022 compared to 2021. However, the sugar concentration was higher in 2022 than in 2021. We also found that *P. grandiflorus* nectar sugar concentration was higher in lower richness plots. This might be due to less competition with other plants. We assessed pollen availability in three plant species: *Ratibida pinnata*, *Heliopsis helianthoides* and *Chamaecrista fasciculata*. We did not find any effect of any of the treatments on pollen availability.

Activity 2

We sampled 288 plots for floral area. Part of this data was used in a paper that will be submitted for peer review in mid-June 2023. In this paper, we found low forb to grass ratio had the largest impact on floral resources for pollinators while seed density did not have a large impact. This is useful for land managers as they can use less expensive lower seeding density mixes while maintaining floral rewards for pollinators. We have also completed surveys on plant establishment. These data are being analyzed for Julia Brokaw's dissertation and will be presented to the public on July 30, 2023.

Activity 3

We have been working on the online tool with Peter Hawthorne. We have implemented the ability of the tool to incorporate seed mixes to match prairie restoration programs such as those outlined by the Minnesota Board of Water and Soil Resources. We are continuing to add data from our other projects (some of which are funded by ENRTF) to provide higher-resolution plant-by-pollinator interaction data. We will be giving a seminar on this tool in spring 2024.

Activity 4

See the dissemination notes below. We have highlighted this work in four outreach talks. We also published one manuscript focused on ideas in this experiment. The journal: *Frontiers in Ecology and the Environment*. This journal is among the five most impactful journals in the field of ecology. One of the foci of this journal is making articles accessible and of interest to land managers and practitioners.

Dissemination

We used this information in the four outreach talks. We have used data from this study for a manuscript that we will be submitting on June 20, 2023. This funding also supported research on a perspectives manuscript that has been accepted for publication in *Frontiers in Ecology and the Environment*. This is among the top five highest-impact journals in the field of ecology.

Status Update Reporting

Status Update December 1, 2022

Date Submitted: December 16, 2022

Date Approved: December 20, 2022

Overall Update

We sampled 288 plots for floral area across four different rounds for nearly 1200 plot samples. Overall, the number of plots with blooming flowers has increased each year with 2022 having the most plots with blooming flowers. Of the 40 flowering plants, 11 plants have not yet bloomed at all in the past four years while 29 species have bloomed. We collected pollen from three plant species and nectar from five plant species. There was a number of logistical challenges with getting nectar and pollen data. We have begun to develop a seed mix tool.

Activity 1

We collected pollen from three species: prairie coneflower (*Ratibida pinnata*), false sunflower (*Heliopsis helianthoides*), and partridge pea (*Chamaecrista fasciculata*). We sonicated anthers for 5 minutes and then vortexed for 15 minutes. Pollen was then placed on slides and counted. We collected nectar from five plant species large beardtongue (*Penstemon grandiflora*), foxglove beardtongue (*P. digitalis*), bee balm (*Monarda fistulosa*), prairie coneflower (*Ratibida pinnata*), and partridge pea (*Chamaecrista fasciculata*). Nectar measurements included nectar volume as well as sugar content. We found that for *Penstemon digitalis*, sugar concentration declined as seed density increased. We used these results for a manuscript that is currently in review at a peer-reviewer. We are currently analyzing the pollen and nectar data from the remaining species.

Activity 2

We sampled 288 plots across four rounds for floral area. This resulted in nearly 1200 samples across the season. This sampling involved collecting floral area data on blooming forb species. We found that the number of blooming plants was highest in 2022. One of our overarching findings was that as the number of sown grass seeds increased, total floral area declined. There was a positive relationship between sown plant diversity and total floral area. Interestingly, we did not find a strong effect on the amount of forb seed planted. This suggests that seed densities can be a bit reduced and this might reduce to total costs of seed mixes. We currently have a manuscript in review that focuses on these issues and this funding supports the salaries of some of the co-authors. We also have a manuscript we are hoping to submit in early 2023 that uses data from this research.

Activity 3

We are working with Peter Hawthorne to develop the seed mix tool. We have met with members of MN BWSR and plan on releasing this tool in the spring 2023.

Activity 4

We are working on a creating a field day for land managers to highlight results of our project and demonstrate the seed mix tool.

Dissemination

Julia Brokaw, a graduate student working on this project presented the results of her research. One was at the MN Horticultural Society and another at the American Entomological Society. Dan Cariveau highlighted this study at a large lecture for senior citizens at Alexandria Technical and Community College in Alexandria, MN. We have one manuscript in revision for a peer reviewed journal and two others in review.

Status Update Reporting

Status Update June 1, 2022

Date Submitted: June 1, 2022

Date Approved: July 1, 2022

Overall Update

We completed a successful field season in summer of 2021 and are working towards a publication for a peer-reviewed journal. We contracted a burn and it was completed just prior to this report (May 27, 2022). We are have just begun our 2022 summer field season.

Activity 1

In July and August of 2021, we trialed nectar measurements on four species: *Penstemon digitalis*, *Ratibida pinnata*, *Mondarda fistulosa*, and *Solidago* spp. We continued to collect data on plant floral resource abundance throughout the summer of 2021. The data are cleaned and will be uploaded on to the Cariveau Lab MySQL database in summer 2022. We found that in 2021, plots with highest ratio of forb to grass seed produced this highest and most consistent amount of bloom and resources for bees. While diversity and overall seeding rate did not have an effect. This is promising as it suggests that lower cost plots (fewer overall seeds and lower diversity) may provide abundant and consistent resources for native bees. We are combining these data with previous work on these plots and are nearly finished writing a manuscript for a peer-reviewed journal. We have hired a field technician and have maintained the plots this fall and this spring.

Activity 2

We have contracted and completed a burn on May 27, 2022. We burned a total of 147 plots and the burn went well. (As it was just a few days prior to this report, we have not yet been invoiced for this service.) We are just starting sampling of plots the first week of June.

Activity 3

The person we are contracting with at the UMN is changing jobs and this has somewhat delayed our ability to develop the seed mix tool. However, we have a solution to move forward and will begin this process summer of 2022.

Activity 4

Outreach will take place in 2023.

Dissemination

Dissemination of this project will be focused at the end of 2022 and first part of 2023. We have scheduled at least two presentations to stakeholders in the 2022.