2016 Project Abstract
For the Period Ending June 30, 2020

PROJECT TITLE: Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity
PROJECT MANAGER: Lauren Sullivan
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2016, Chp. 186, Sec. 2, Subd. 08b as extended by M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 19

APPROPRIATION AMOUNT: $ 556,000
AMOUNT SPENT: $ 556,000
AMOUNT REMAINING: $ 0

Sound bite of Project Outcomes and Results
This project determined habitat connectivity between prairie fragments by measuring plant movement of 6 species by dispersal of pollen and seeds to improve prairie restoration implementation. New modeling approaches indicated that spillover from established/remanent prairies is a more complicated process than previous thought and requires different land management.

Overall Project Outcome and Results
Outcomes and results are broken down by the papers completed.

Papers Accepted

1. Sperry, K. P., Hilfer, H., Lane, I., Petersen, J., Dixon, P. M., & Sullivan, L. L. (2019). Species diversity and dispersal traits alter biodiversity spillover in reconstructed grasslands. *Journal of Applied Ecology*, *56*, 2216–2224.
    - When restored prairies are adjacent to remnant prairies, rare species will move into and establish in these remnant prairies. This is a process we call spillover
    - Species that move into remnants tend to be dispersed by wind or animals.
    - Over 1200 ha of restored prairies benefit from spillover from remnant prairies in Minnesota.
2. Sperry, K. P., Shaw, A. K., & Sullivan, L. L. (2019). Apps can help bridge restoration science and restoration practice. *Restoration Ecology*, 3–6.
    - We created an interactive map for managers in Minnesota to use to determine how landscape connectivity would change when they either 1) removed a remnant prairie, or 2) added a prairie to a location via restoration.
3. Sullivan, L. L., Michalska-Smith, M. J., Sperry, K. P., Moeller, D. A., & Shaw, A. K. (2021). Consequences of ignoring dispersal variation in network models for landscape connectivity. *Conservation Biology*, *35*(3), 944–954.
    - We learned that in Minnesota grasslands, if we model connectivity of our existing habitat fragments by incorporating an actual dispersal kernel, we get very different estimates of connectivity than when we use traditional approaches.
    - This work demonstrates the importance of using dispersal kernels for measuring connectivity.

Papers in Revision

4. Sullivan, L. L., Portlas, Z., Hamilton, J. (In Revision for American Naturalist). Local climate and habitat continuity interact to alter contemporary dispersal potential.
    - *Geum triflorum* dispersal depends on the type of habitat it lives in, as well as the climate in that growing year. As the number of growing degree days increases in prairie habitat, *G. triflorum* disperses farther. However on isolated alvar habitat, as the number of growing degree days increases, *G. triflorum* disperses less distance.

Papers in Prep

5. Radford, Z., Sullivan, L. L., and Moeller, D. (In Prep). Fine-scale maintenance of adaptive genetic variation despite gene flow in a remnant tallgrass prairie.
    - We see evidence of small scale gene flow in *Ratibida columnifera* at Bluestem Prairie, MN.
6. Sullivan, L.L, Radford, Z., Sperry, K., Shaw, A. and Moeller, D. (In prep.) Pollen dispersal of 6 prairie plant species in Northwest Minnesota.
    - We are working to determine the dispersal ability of 6 grassland species.

Project Results Use and Dissemination

This project has been presented at the Ecological Society of America conference in 2018 to an invited session on the role of space for coexistence as well as in 2019. Additionally, our team presented findings at the Botany Society meetings in 2019, 2020, and 2021 and various intuitional research talks in 2019 and 2020. The list of published papers associated with this project can be found in our Overall Project Outcomes.

One of the main outreach foci of this project was to provide conservation agencies and the MPCP with tools that they can use to determine the degree of habitat connectivity and the necessary size of corridors, to promote the spread of desirable species. To that end, we created and an app to the Nature Conservancy, and the MN DNR in March 2019. This app can be found at MN Connectivity.

Date of Report: September 21, 2021

Date of Next Status Update Report: NA

Date of Work Plan Approval: June 7, 2016

Project Completion Date: June 30, 2020

PROJECT TITLE: Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity

Project Manager: Lauren Sullivan

Organization: University of Minnesota

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Location: Clay County, Minnesota

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$556,000**
	Amount Spent:	**$556,000**
	Balance:	**$0**

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 08b as extended by M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 19

Appropriation Language:

$556,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to determine habitat connectivity between prairie fragments by measuring plant movement by dispersal of pollen and seeds to improve prairie restoration implementation. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

Carryforward; Extension (a) The availability of the appropriations for the following projects is extended to June 30, 2020: (12) Laws 2016, chapter 186, section 2, subdivision 8, paragraph (b), Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity;

I. PROJECT TITLE: Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity

II. PROJECT STATEMENT:

WHY: Connections among habitat fragments are changing across Minnesota. These changes help some plant species while impairing others. Unfortunately, it is not always desirable species that benefit and undesirable species that are harmed. The **GOALS** of this project are to measure prairie plant connectivity to 1) promote the movement of desirable (e.g.: native) species by natural processes, or proper corridor creation, by 2) providing essential information about movement to the Minnesota Prairie Conservation Plan (MPCP).

This project will achieve the following **OUTCOMES:**

1. Measure the pollen and seed dispersal distances for 8 representative native Minnesota prairie species.
2. Determine connectivity of prairie fragments, which informs:
    a. Restoration practices for Minnesota conservation agencies.
    b. Decisions about the appropriate distances for sources of local-ecotype seed.
3. Provide conservation agencies and the MPCP with tools that they can use to determine the degree of habitat connectivity and the necessary size of corridors, to promote the spread of desirable species.

HOW: By measuring plant pollen and seed movement among habitat fragments, we can quantify habitat connectivity. This project will increase the success of the MPCP and other Minnesota restoration projects by understanding how well habitat corridors, and prairie fragments function to move species.

Background: Since 1908, Minnesota has lost 99% of its 18 million acres of remnant prairie. In addition to the overall loss in area, the prairie habitat has also become fragmented into increasingly smaller pieces. Prairie habitat can only persist as long as prairie plant and animal species are able to move among fragments, ensuring their connectivity. Having sufficient connectivity is important for maintaining important ecological and human services including habitat for pollinators and other wildlife, soil stability, water quality, and high quality land for hunting and other recreational activities. It is necessary to know how far plant species move by pollen or seeds, in order to critically evaluate how well Minnesota conservation projects connect prairie habitats.

Minnesota is currently investing large amounts of money and effort into prairie restorations and corridor creation, through the MPCP. However, this project was created by making assumptions of how far plants and animals move down corridors and between fragments. Since it is unknown how far plants move between restored areas, it is difficult to determine how successful these restoration projects will be. Our project will supply the MPCP and other conservation agencies with crucial movement information that can be immediately implemented by the MPCP to improve the quality of prairie corridors and other restorations across the state.

Premises and Hypothesis

I. **Maintaining plant connectivity between prairie fragments depends on how far species can disperse, and is essential for increasing both species and genetic diversity in fragments. Connectivity can in turn have a positive effect on other members of the prairie ecosystem, including pollinators and other wildlife.**

II. **Determining how far plants disperse has been difficult in the past due to the difficulty tracking tiny pollen grains and seeds. However, with advances in sequencing techniques, it is now possible to use genetics to determine how far species are moving on a large subset of species. Dispersal distances must be measured in order to understand prairie fragment connectivity.**

III. **Plants have different dispersal syndromes, or ways their pollen and seeds disperse (e.g.: pollen and seeds disperse by wind, pollen disperses by animals and seeds disperse by wind, pollen disperses by**

wind and seeds disperse by animals, and both pollen and seed disperse by animals). We believe these syndromes will differ in how far their pollen and seeds disperse. The literature does not provide a comprehensive test of how these syndromes differ in their pollen and seed dispersal distances, and this must be measured.

IV. Landscape connectivity will depend on the dispersal ability of plant species. Animal pollinated species will disperse farther and therefore be more connected than wind pollinated species. Animal dispersed seeds are more connected than wind dispersed seeds. Finally, within the wind-dispersed seeds, traits such as height, terminal velocity, morphology are important drivers of connectivity.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of *July 22, 2016:*

Amendment Request (07/22/2016):

I would like to purchase a GPS system because all rental options were not accurate enough. The GPS system I would like to purchase costs $4500, and includes the Trimble R2 sub-foot Rover GPS unit (which can provide up to centimeter accuracy in open grasslands), the Terraflex software necessary for collecting and processing data, and the mounting equipment for the GPS unit. I propose to move $4500 from the travel budget (per diem is no longer needed this year) to the equipment/tools/supplies budget.

Amendment Approved (07/22/2016)

Project Status as of *January 1, 2017:*

We began work on this grant by establishing our field sites and collecting field data on three of our target species (Activity 1), as well as collecting connectivity data at many adjacent prairie sites (Activity 2). We are currently working to extract DNA from these species and germinate the offspring necessary to estimate pollen dispersal distance (Activity 1). Over the last reporting period we have worked with three recently graduated biology technicians, and collaborated with many people, including: 4 faculty from MSUM, 1 faculty from NDSU, 1 person from the SNA program, 2 people from TNC, and 1 person from FWS. We have presented at one local scientific meeting (for the Nature Conservancy – approx. 35 people in attendance), and volunteered to lead two outreach activities: one for Scientific and Natural Areas (SNA) stewards in the Clay County area (through the SNA program – 6 people) and one for the MSUM undergraduate summer interns (through MSUM – 15 students).

Amendment Request (12/20/2016):

I am requesting that some of our travel funds be allocated for costs associated with attending the National Native Seed Conference in Washington DC in February 2017 and presenting on this work. This conference is a great opportunity to get new ideas about how to perform this project better, and also to inform scientists, land managers and policy makers from around the country about the work that we are doing in Minnesota to understand prairie connectivity and movement. The costs associated with the conference include $400 registration, $350 flight, $900 hotel ($1650 total) – I propose to re-allocate some travel funds for the conference.

Amendment Approved (12/28/2016)

Project Status as of *July 1, 2017:*

Over the last reporting period, we extracted DNA from both the parental generation and offspring generation of one of our target species. We have also decided to use the sequencing facility at the University of Minnesota to sequence our samples. We are currently running pilot studies for our three collected target species to determine how easily we can sequence our samples, and for what cost. The 2017 field season has also begun and we have begun collecting data from three new target species, for a total of 6 out of the proposed 8 target

prairie species. We have hired two new field techs, one recently graduated biology student, and anther who will begin her senior year this coming fall. We have also presented our work at one national conference (the National Native Seed Conference – 330 people in attendance, including scientists, land managers and the native seed industry), and one for the MSUM undergraduate summer interns (through MSUM – 7 students).

Project Status as of *January 1, 2018:*

We accomplished a lot on this project over the last reporting period. We finished tissue and data collection for our full set of 8 species as promised under our work plan. We have now collected tissue from over 2000 individuals of our 8 target species and collected seeds to germinate from all 8 species. Over the summer we trained two highly accomplished field technicians who have now moved on to full-year science technician positions. In collaboration with these two technicians, we developed a scientific study to look at which species are moving on the landscape, and if remnant prairies can act as sources of rare species for reconstructed prairies. We found that when low-diversity reconstructed prairies are adjacent to remnant prairies, there is evidence of rare species spilling over into these reconstructions up to 50m (Supplemental Figure 2). We are currently working on publishing our findings. Additionally, we are still working with the University of Minnesota genetics group to help us sequence the DNA of our species. There has been a lot of trial and error due to the difficulty of working with non-model plant species. However, we continue to work closely with them, and should have results from our first species in a month or two; after which we can begin building our dispersal kernels.

Amendment Request (02/06/2018):
First, we did not end up purchasing our own GPS unit because we found one we could rent from the University for much less money. So I would like to move $800 of the money for purchasing the "subfoot accuracy GPS unit" to a new category within "Equipment/Tools/Supplies" called GPS rental. Then, I request that we move the rest of the $3700 for the GPS purchase to the "Equipment/Tools/Supplies" – Field and Lab Supplies to cover the cost of extra supplies we will need for extracting DNA and for sampling plants in the field. Finally, due to unexpected slowness in the sequencing facility, I need to change a few of my completion date deadlines within Activity 1 and Activity 2 (see below).
Amendment Approved (02/15/2018)

Project Status as of *July 1, 2018:*

During the past reporting period we have focused on continuing to grow seedlings and extract DNA from plant tissue. We have now extracted DNA from all individuals of 3 of the 8 target species, and are partially finished with 2 more. Due to the strict nature of requirements by the sequencing facility, and the time it takes to extract DNA to that standard, we are asking for an amendment to move some of our money to pay for the facility to also extract DNA for us for a few of the species that remain (see amendment request below). After a lot of back and forth and needing to re-do sequencing, we have a full set of sequence data for one of our target species from the sequencing facility and we plan to begin creating dispersal kernels within the next month.

Amendment Request (07/03/2018):
We need to move a few budget items around to make sure we have enough money for supplies and field travel, and to adjust for a few budget items that cost less than anticipated. Sequencing is costing ~$5000 less than anticipated, and we did not need to rent the GPS again, so we have another $246 surplus. I would like to add ~$3000 for field and lab supplies, ~$2700 for travel to field sites. In doing this, we have moved money for supplies from activity 2 to activity 1 to make budgeting simpler and because activity 1 requires more supplies. Finally, we need to update the timeline for creating the dispersal kernels for our 8 target species. Working to get the DNA sequenced has proven to be a difficult task as our sequencing facility (UMGC) is doing a lot of troubleshooting with our data and thus running into road blocks. This means it is just taking longer to get the work completed. We are doing our best to get remainder of our samples sequenced as soon as possible.
Amendment Approved (Amendment Approved by LCCMR 8/28/2018)

Project Status as of *January 1, 2019:*

In the last reporting period, for Activity 1 we finished sequencing the DNA from two species, and a third should be finished in the next month or two. We have also run pilot projects on the final four species with the sequencing facility to make it easier to sequence the DNA from all individuals once the offspring have finished germinating and have enough tissue to extract from (which should be done within the next month). For Activity 2 we have completed general connectivity models and have written up a manuscript that will be submitted for publication within the upcoming reporting period. These models can be modified to fit our dispersal kernels that we create once we have all of our sequencing completed. For Activity 3 we have made a lot of progress within the last reporting period. We have developed a web-based application for managers where they can select the county they are in within Minnesota, and determine which prairies in the county are connected based on various dispersal distances. We are planning multiple events where we demonstrate this application to land managers, in order to present it to them for Activity 3. Finally, our side project that was developed by the technicians on the project to look at native species spillover from remnant prairies to restored prairies is under review in the Journal of Applied Ecology. See Supplemental Figure 3 for a one-page summary of our research findings that can be shared freely.

Amendment Request (12/28/2018):

We are requesting a Legislative Extension for our project to move the end date to October 31, 2019. Due to issues outside our control, we have been unable to complete the sequencing for Activity 1 as quickly as we originally planned. In short, the sequencing facility we originally planned to use shut down operation and so we had to develop a completely new system with the University of Minnesota Genomics Center (UMGC). It has taken quite a while to trouble shoot our methods with our non-model native prairie plant species and so we are not yet finished with all of the sequencing for Activity 1. Should we not receive the extension, the results we can provide on plant species connectivity from our project are very general. If we receive a Legislative Extension, we will be able to provide much more targeted connectivity information about specific rare species in the state of Minnesota. This information will be passed on to land managers throughout the state (we already have made these connections), and will be able to provide information to the Minnesota Prairie Conservation Plan as to the dispersal and connectivity abilities of plant species, which is currently missing.

Amendment Request signed into law 5/31/19

Project Status as of *July 1, 2019:*

We have made incredible progress in the last reporting period. First, we cleaned up all tags from plants at Bluestem Prairie for Activity 1. Additionally, we are extremely close on finishing all of the sequencing for our target species, and have just two more species to sequence. Which means we have finished the sequencing for 5 of our total 7 target species. Additionally, we have submitted our first research paper from Activity 2 for publication and we just received positive reviews at Conservation Biology. Once this project is accepted for publication we will create a 1 page summary that can be shared freely. Our side project on species spillover is now accepted for publication at the Journal of Applied Ecology and can be found at this website (https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2664.13469) Finally we have made fantastic progress on Activity 3. We developed the web-based application for how managers in Minnesota can implement connectivity analyses on the grasslands in their county (https://grassland-connectivity.shinyapps.io/MNConnectivity/). We held several meetings to beta-test the app, including a meeting with the MN, ND, SD TNC chapter. A web-based tutorial is now available here (https://www.youtube.com/watch?v=bS93mnMyAW8), and we will be presenting this app to other Minnesota land managers in the fall. We also published a paper on the usefulness of apps for conservation management in Restoration Ecology and can be found here (https://onlinelibrary.wiley.com/doi/10.1111/rec.12999).

Amendment Request (08/02/2019):

I am requesting a few changes to the budget to help us use up the rest of the money. It turns out we need a bit more money for hiring people to help us process our samples and analyze our data, and we need a bit more money for lab supplies to make this happen. Fortunately, we do not need quite as much money as we anticipated for sequencing, and the rest of our Activity 3 work is completely virtual so it requires no money to conduct.
Amendment Approved (08/20/2019)

Project Status as of *January 1, 2020:*

Over the last 6 months we have been working on analyzing our genetic data to perform paternity analysis and extract dispersal kernel information from the data. We are making progress and are starting to feel comfortable with the pipelines to do the work, however we keep finding issues with the genetic data that we need to deal with. I believe this will be worked out soon. All sequencing for the project has been completed!

Project Status as of *July 1, 2020:*

We have completed the sequence analysis of our genetic data and have finished our models as well. We have published 3 scientific papers from this work (from the modelling, the fieldwork and the interactive app), and are working on two more papers on the genetic data.

Overall Project Outcomes and Results:

Outcomes and results are broken down by the papers completed.

Papers Accepted

1. Sperry, K. P., Hilfer, H., Lane, I., Petersen, J., Dixon, P. M., & Sullivan, L. L. (2019). Species diversity and dispersal traits alter biodiversity spillover in reconstructed grasslands. *Journal of Applied Ecology*, *56*, 2216–2224.
    - When restored prairies are adjacent to remnant prairies, rare species will move into and establish in these remnant prairies. This is a process we call spillover
    - Species that move into remnants tend to be dispersed by wind or animals.
    - Over 1200 ha of restored prairies benefit from spillover from remnant prairies in Minnesota.
    - We presented on this work at the Ecological Society of America conference in 2018 to an invited session on the role of space for coexistence.
2. Sperry, K. P., Shaw, A. K., & Sullivan, L. L. (2019). Apps can help bridge restoration science and restoration practice. *Restoration Ecology*, 3–6.
    - We created an interactive map for managers in Minnesota to use to determine how landscape connectivity would change when they either 1) removed a remnant prairie, or 2) added a prairie to a location via restoration.
    - You can find this interactive app here: https://grassland-connectivity.shinyapps.io/MNConnectivity/
    - We presented on this app to the Nature Conservancy, and the MN DNR in March 2019
3. Sullivan, L. L., Michalska-Smith, M. J., Sperry, K. P., Moeller, D. A., & Shaw, A. K. (2021). Consequences of ignoring dispersal variation in network models for landscape connectivity. *Conservation Biology*, *35*(3), 944–954.
    - We learned that in Minnesota grasslands, if we model connectivity of our existing habitat fragments by incorporating an actual dispersal kernel, we get very different estimates of connectivity than when we use traditional approaches.
    - This work demonstrates the importance of using dispersal kernels for measuring connectivity.
    - We presented on this work at the Ecological Society of America conference in 2019.

Papers in Revision

4. Sullivan, L. L., Portlas, Z., Hamilton, J. (In Revision for American Naturalist). Local climate and habitat continuity interact to alter contemporary dispersal potential.
    - *Geum triflorum* dispersal depends on the type of habitat it lives in, as well as the climate in that growing year. As the number of growing degree days increases in prairie habitat, *G. triflorum* disperses farther. However on isolated alvar habitat, as the number of growing degree days increases, *G. triflorum* disperses less distance.
    - We presented on this work at the Botany Society meeting in 2019, and at various institutional research talks in 2019 and 2020.

Papers in Prep

5. Radford, Z., Sullivan, L. L., and Moeller, D. (In Prep). Fine-scale maintenance of adaptive genetic variation despite gene flow in a remnant tallgrass prairie.
    - We see evidence of small scale gene flow in *Ratibida columnifera* at Bluestem Prairie, MN.
    - We presented on this work at the Botany Society meeting in 2021.
6. Sullivan, L.L, Radford, Z., Sperry, K., Shaw, A. and Moeller, D. (In prep.) Pollen dispersal of 6 prairie plant species in Northwest Minnesota.
    - We are working to determine the dispersal ability of 6 grassland species.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Measure pollen and seed dispersal distances for native prairie species
Description: We propose to determine how far plants are moving by pollen and seed using a combination of DNA paternity analysis and GPS location data (See attached Figure). In this way, we can know how far related individuals are from each other. By aggregating all measured movement distances from each species, we can create both pollen and seed dispersal kernels for all of our target species. These kernels can be compared across dispersal syndromes to determine which types of species will move farther than others. For example, we can determine if species with animal pollination and animal-dispersed seeds move farther than animal pollination and wind-dispersed seeds.

Our work for Activity 1 takes place in Clay County, Minnesota. We chose this location as it contains large swaths of remnant prairie that have never been plowed. When determining the dispersal kernel of these species, we must be able to match parents and offspring. Thus, it is important to work in a prairie without human-caused seed additions because during a restoration many seeds from unknown parental sources are seeded randomly at one time, making movement and paternity determination difficult. We are proposing to work within Bluestem Prairie, a remnant tallgrass prairie on the Lake Agassiz Beach Ridge (See attached Figure with map). We visited the site in early November 2015 to determine the likelihood of project success at the site, and determined it would be an ideal site.

The primary goal of Activity 1 is to create dispersal kernels for our 8 target species (Table 1) within a large, continuous remnant prairie in order to maximize our ability to detect long distance dispersal. In the first year (summer 2016) we will focus on four of our eight target species in order to refine our methodology, and finish collecting data from our remaining target species in the second year (summer 2017). Then, time and money permitting, we will sample near-by smaller remnant habitat fragments in order to detect connectivity between distant habitat patches, and to see if species' dispersal kernels are similar between large, continuous prairies and smaller, more fragmented prairies.

Species	Latin name	Dispersal syndrome
Prairie dropseed	*Sporobolus heterolepis*	**syndrome I** pollen: wind; seed: wind
Big bluestem	*Andropogon gerardii*	**syndrome I** pollen: wind; seed: wind
Blazing star	*Liatris aspera*	**syndrome III** pollen: animal; seed: wind
Sawtooth sunflower	*Helianthus grosseserratus*	**syndrome III** pollen: animal; seed: wind
Showy milkweed	*Asclepias speciosa*	**syndrome III** pollen: animal; seed: wind
Coneflower	*Echinacea angustifolia*	**syndrome III** pollen: animal; seed: wind
American licorice	*Glycyrrhiza lepidota*	**syndrome IV** pollen: animal; seed: animal
Prairie rose	*Rosa arkansana*	**syndrome IV** pollen: animal: seed: animal

Table 1: List of proposed target species we will focus on for this project and their dispersal syndromes.

In order to create our proposed dispersal kernels, we will be collecting leaf and pollen tissue and GPS location data from all individuals of our 8 target species within our sampling area at Bluestem Prairie. We will then run genetic paternity analysis on all of our samples to determine which individuals are most closely related to which other individuals. We then calculate the distance between each parent and offspring in a pair, to determine the distance that the offspring's seed must have traveled (seed dispersal distance), and combine all the seed dispersal distances for all individuals within each target species and calculate the probability of dispersing all possible dispersal distances for this species. This is the seed dispersal kernel. We use a similar method to calculate the pollen dispersal kernel. We match pollen that has landed on a mother plant to a father plant (the pollen's origin) using DNA parentage analysis. We calculate the distance between the father plant and the mother plant, to determine the distance that the father's pollen must have traveled (pollen dispersal distance). Again, we combine all the pollen dispersal distances for all individuals within each target species and calculate the probability of dispersing all possible dispersal distances, or the pollen dispersal kernel.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 417,575
Amount Spent: $ 417,575
Balance: $ 0

Outcome	Completion Date
select sites and receive permits to sample	*July 2016*
collect tissue samples for first 4 target species	*November 2016*
extract DNA from first 4 target species	*June 2017*
send samples out for sequencing and receive genetic data	*November 2017*
run paternity analysis on first set of target species	*June 2018*
create dispersal kernels for first set of target species	*February 2019*
collect tissue samples for remaining 4 target species	*November 2017*
extract DNA from remaining 4 target species	*December 2018*
send samples out for sequencing and receive genetic data	*August 2019*
run paternity analysis on remaining set of target species	*September 2019*
create dispersal kernels for remaining set of target species	*September 2019*

Activity Status as of *January 1, 2017:*

We successfully selected sites for Activity 1 work in Clay County and received the appropriate permit for our study. We are working at Bluestem Prairie, which is primarily managed by The Nature Conservancy. From July to the end of September, we worked to collect tissue samples from 3 of our target species including *Ratibida*

columnifera, *Echinacea angustifolia*, and *Solidago rigida*. These three species are slightly different from our proposed species in Table 1, and will replace a few species in Dispersal Syndrome III: pollen dispersed by animals and seeds dispersed by wind. These species were chosen because they were the species that were in the appropriate densities at the site to sample (i.e., not too many, not too few). We had hoped to collect from 4 target species this year, but due to the late start in the season many species were past flowering/seed set. We could not start collecting until around August 1 because it took some time to get the sites selected and our equipment ordered after July 1. We did manage to successfully survey 3.5 hectares of Bluestem prairie for: 408 individuals of *R. columnifera*, 591 individuals of *S. rigida*, and 322 individuals of *E. angustifolia*. We collected location data and tissue samples from all of these individuals, which represent ~95% of all flowering individuals in the study area - we likely missed a few, but this varied by species. We are currently beginning the work of extracting the DNA from our collected target species. This include growing up offspring from select moms to collect tissue from and sequences in order to determine pollen dispersal distance. We should be on track to finish these three species by June of 2017 as we proposed above.

Activity Status as of *July 1, 2017:*

We are continuing to stay on track for Activity 1. We have successfully extracted DNA from all parents of one species (*R. columnifera*), and grown up over 450 offspring from each of two of the target species (*R. columnifera* and *S. rigida*). While we promised to have all of the DNA extracted from our first three target species by June 2017, we have not quite finished this yet. We decided to take a more conservative approach, where we submit DNA samples from our three target species to be sequenced by the facility at the University of Minnesota to determine how likely our project is to work before we spend too much time and money extracting the DNA from all of our samples from our currently collected 3 target species. This pilot study is under way, and once it is complete and we get the go-ahead, we will be able to extract and sequence all of our target species quickly. While we are waiting for the results we have perfected the DNA extraction technique for each species, so as to be prepared when we get the "ok".

Over the winter, we created a map of our sampled target species, so we could see spatial patterns of where our individual target species were found within the sampled 3.5 ha (Supplemental Figure 1). This spring, we begun a second field season, and have collected tissue from 3 more target species at our site, including *Geum triflorum* (in order to partner our work with that of Dr. Jill Hamilton at North Dakota State University), *Penstemon grandifloras*, and *Oxytropus lambertii*. These species vary in flowering phenology and dispersal mode in order to sample a wide range of rare prairie plant species. The field sampling process is going smoothly this year, and we expect to finish our 8 target species on schedule this season.

Activity Status as of *January 1, 2018:*

The field work portion of this project is on track for Activity 1. As proposed, we have collected tissue from all 8 of our proposed target species. It was difficult to find species that fit nicely into the dispersal syndrome categories (Table 1) that were in the appropriate abundances in the field, and were also diploid (which makes the paternity analysis possible). Thus, we focused our efforts on collecting from a range of insect pollinated, wind or animal dispersed species (syndrome III and IV), although we were able to collect from one wind pollinated, wind dispersed species (syndrome I). This new subset of species will give us a richer idea about how pollen is moving in prairies, and how plant species are serving as resources for pollinators.

In working with my two summer technicians, Jessica Peterson from the MN DNR, and Ian Lane from University of Minnesota, we developed an observational study to determine if we are seeing species move on the landscape. If we see evidence for this, it would give credence to the importance of understanding how species move more fully (the rest of the project). The movement of target species from one habitat to another is often called spillover. We examined if spillover was occurring from high quality remnants into adjacent reconstructed prairies (seeded with both high and low diversity). We found that spillover of rare prairie species does in fact occur from remnant prairie sources, but we only see evidence of it in low diversity reconstructed prairies. The spillover effects occurred up to 50m away from the remnant prairie (Supplemental Figure 2). We are currently working to publish this information in a peer reviewed journal.

The last piece of Activity 1 is the genetic sequencing component. We are a bit behind schedule here, but this is unfortunately unavoidable. There has been a lot of difficulty in developing the methods for extracting and sequencing the DNA from these non-model plant species. However our team has been doing a fantastic job of facing these challenges and continuing to move forward despite many delays. We have extracted DNA from two full sets of target species (~300 *Ratibida columnifera* and 500 *Solidago rigida* individuals). In addition, we have grown up offspring for these two species (~450 offspring for each species). Our lab technician is also beginning to explore the population-level trait variation in these offspring. We had a lot of difficulty germinating offspring from *Echinacea angustifolia*, one of our target species collected in 2016. However we recently began to see germination so we hopefully have that protocol down now. We should be hearing back from the sequencing facility in the next month or two on our first complete species (*R. columnifera*), and should be able to begin data analysis soon. The first attempt to sequence this species was not fully successful, so much of the work had to be repeated. The sequencing facility seems confident everything should work out this time around.

Activity Status as of *July 1, 2018:*

We are generally still on track to meet our deadlines for Activity 1 above. We have received our first set of full sequences from the sequencing facility for one species (*Ratibida columnifera)*, and so can begin to create pollen dispersal kernels. We have submitted a full set of extracted DNA from our second species, *Solidago rigida* and they are going through the sequencing process currently. This will hopefully be faster than for *R. columnifera* because of the base work we have put in already. We had difficulty extracting DNA from our third species, *Echinacea angustifolia,* but we are getting close here, and should have that submitted soon. We are now beginning to extract DNA from our fourth and fifth species, *Penstemon grandiflourus* and *Geum triflorum*.

We are also making good progress on the observational study in collaboration with Ian Lane (University of Minnesota grad student) and Jessica Peterson (Scientist at MN DNR). The manuscript is complete and has gone through several rounds of peer-editing. We are planning to submit the paper for publication in August, 2018.

Activity Status as of *January 1, 2019:*

We have completed the sequencing process for two species (*Ratibida columnifera* and *Solidago rigida*) and should be finished with the sequencing of the third species (*Echinacea angustifolia*) within the next few months. We are in the process of running the paternity analysis and creating the dispersal kernels for these first two species, and it will be relatively straightforward to complete this process for the rest of the species once we have completed the process once. The final four target species (*Penstemon grandiflorus, Geum triflorum, Delphinium carolinianum,* and *Artemisia frigida*) have had their pilot testing run with the sequencing facility and thus are ready to be sequenced fully when the offspring tissue is grown. This should be finished within the next month, and we will submit the tissue samples for these last four species at that time. Finally, we have decided to drop our eighth species (*Oxytropus lambertii*) because we could not get a complete enough sample of its population in the field, and we worry we would not get good sequencing results. Thus we feel we have acted in the spirit of the grant by trying as hard and collected tissue from 8 target species, but only the collections for 7 of these are adequate for sequencing.

Our observational study with Ian Lane and Jessica Peterson is now under review at the Journal of Ecology. Supplemental Figure 3 provides a 1 page summary of the project and our results and can be shared freely.

Activity Status as of *July 1, 2019:*

We have completed the sequencing for 5 of our 7 target species, including *Ratibida columnifera*, *Echinacea angustifolia*, *Solidago rigida*, *Artemisia frigida*, and *Geum triflorum*. Our last two target species, *Penstemon* grandiflorus and *Delphinium carolinianum* are both halfway through the process of DNA extraction and sequencing and should be completed soon. We have cleaned up all tags and flags from Bluestem Prairie in order to eliminate eco-waste, and thus we are completely done in the field. We are currently in the process of calculating dispersal kernels for our species.

Activity Status as of *January 1, 2020:*

We have completed sequencing for 6 of our 7 target species: *Ratibida columnifera*, *Echinacea angustifolia*, *Solidago rigida*, *Artemisia frigida*, *Geum triflorum*, and *Penstemon grandiflorus*. We unfortunately ran out of funds halfway through sequencing *Delphinium carolinianum*, and thus will not be able to finish this species unless we can find another ~$12,000. So we will move on without this species and see if we can round up the funds. We are working through how to determine paternity using computer-based pipelines but it is a process that takes a lot of tweaking. We believe that we are getting close, and as soon as we are able to feel confident in our paternity assignments, then we will be able to calculate our dispersal abilities and dispersal kernels.

Final Report Summary:

We have finished the paternity analysis for our 6 species, and are working to determine the dispersal ability for all of these species. See Table 1 for the species we have finished.

Table 1: Mean and Max pollen dispersal distances for the species we have finished analyzing/

Species	Mean Pollen Dispersal Distance	Max Pollen Dispersal Distance
Ratibida columnifera	118m	351m
Artemisia frigida	23m	228m
Penstemon grandifloras	112m	368m

ACTIVITY 2: Determine connectivity of prairie fragments in NW Minnesota

Description: Once we know the dispersal kernels of our target species, we can determine the connectivity of the prairie fragments in Clay County for those species using connectivity network analysis. This connectivity work will span across remnant and restored prairies. We can then test our hypotheses that connectivity networks vary by dispersal syndrome and dispersal traits. We also have the ability to make estimates of dispersal kernels of non-target species that are similar to the targets, and determine connectivity of those species as well, to better characterize the community.

We will use the dispersal kernels measured in Activity 1 to parameterize network models that can inform Clay County of the connectivity of its grasslands. Within a defined region of Clay County, we will sample all of the grassland fragments for species richness. We will likely choose the area surrounding Bluestem Prairie where we are measuring the dispersal kernels, but the decision will ultimately depend on where we can utilize previously conducted fragment richness surveys. If previous sampling methods match our methods, we will use existing data instead of collecting the data ourselves.

During the 2016 and 2017 summer field seasons, we will survey the plant species richness of the prairie fragments in Clay County. We will also use GIS to spatially locate each of the prairie fragments. Then, combining these two datasets, we will create connectivity networks where we estimate how connected the prairie fragments are based on the species richness, the pollen and seed dispersal distance of each target species, and the distance of each fragment to each other. This information is useful for planning precision prairie restorations as we can determine locations where new restorations would greatly increase connectivity on the landscape.

We may also be able to generalize our connectivity results to a broader range of prairie plant species than just the 8 target species that we measure. If, in Activity 1, we find that species with different dispersal syndromes consistently have different dispersal kernels, we can infer that non-target prairie species with the same dispersal syndromes are likely to have similar dispersal kernels as the species we measured. Thus, we will potentially be able to infer connectivity for any prairie plant species, as long as we know how its seeds and pollen are dispersed.

Summary Budget Information for Activity 2:	**ENRTF Budget:**	**$ 138,412**
	Amount Spent:	**$ 138,412**
	Balance:	**$ 0**

Outcome	Completion Date
determine which prairie fragments to survey in Clay Co.	*August 2016*
get permission to survey selected prairies	*September 2016*
begin richness surveys in downtime from sampling tissue	*November 2016*
complete richness surveys in downtime from sampling tissue	*November 2017*
Create general connectivity models	*December 2018*
determine connectivity for all target species	*October 2019*

Activity Status as of *January 1, 2017:*

We are on schedule for Activity 2 within the last reporting period. We were able to determine which sites we wanted to sample and received permission in June 2016. We sampled many of the remnant and restored prairies that were adjacent to Bluestem prairie this field season for richness and abundance. We sampled 7 restored prairie sites, and 7 remnant prairie sites with 15 vegetation plots at each site. We will continue this work in prairies that are more distant from our main study site at Bluestem Prairie in the upcoming year. We have those sites selected and know how to obtain the collecting permits before the upcoming field season. We are currently in the process of cleaning up the data and beginning to get the models together that can look at connectivity between prairies. While we will not know the exact dispersal distances of our target species for a while, we will be able to get our models set up so it is simple to plug that information in once we have it (proposed approx. February 2018).

Activity Status as of *July 1, 2017:*

We have begun analysis to compare the plant communities between restored and remnant prairies sampled last year. We are in the process of beginning to create connectivity models of our prairie sites, and will also continue to sample the plant community at many sites throughout the region. The plants have just greened up enough for us to begin community sampling, which we will do over the next few months in our down time from sampling the individual target species.

Activity Status as of *January 1, 2018:*

We continue to be on target for this project. We are likely to need to sample more communities next summer. This will be determined by the connectivity models we create over the next reporting period.

Activity Status as of *July 1, 2018:*

Again, we continue to be on target for this Activity, although we need to extend the exact deadline for the species connectivity out because of the speed of sequencing. We are currently working on the general models that will help predict landscape-level connectivity of all the species. This way, when we have the actual dispersal distance information after the sequencing occurs, we can easily plug the new information to our general models and create the connectivity maps.

Activity Status as of *January 1, 2019:*

Our Activity 2 goals are right on track. We have created general connectivity models that predict the landscape-level connectivity of species across all grasslands in Minnesota. We worked with Rich Johnson at The Nature Conservancy to get the most accurate GIS layers of all possible grassland types within the state (e.g. native prairies, hay fields, restored prairies, etc). We then used these habitat fragments to make predictions about the connectivity of these fragments using network models for a series of reasonable dispersal distances. This manuscript is currently going around for peer-editing and will be submitted for publication within the next reporting period.

If we receive a Legislative Extension we can update these general models with the dispersal information for our target species and can then provide species specific network-based information on how to conserve these grassland species in Minnesota by understanding their connectivity.

Activity Status as of *July 1, 2019:*

Our general connectivity models for the state of Minnesota are now complete. We have written up a publication of the work which we submitted to Conservation Biology and recently received positive reviews. We are in the process of completing this publication. Once accepted, we will create a 1-page summary to share freely to help managers understand state-wide connectivity. In addition, this work is the basis for our web-based app that we built for Activity 3 (below), which will be available in full for managers this fall.

Activity Status as of *January 1, 2020:*

Activity 2 is complete. Our publication is still in review at Conservation Biology, and we hope that our analysis of the connectivity of grassland fragments of Minnesota will be accepted soon. As mentioned previously, once accepted, we will create a 1-page summary to share freely to help managers understand state-wide connectivity.

Final Report Summary:

Activity 2 is complete. We do still need to create our 1-page summary, but we have published our paper and presented on the connectivity work we created to local land managers.

ACTIVITY 3: Directly inform the MPCP and create conservation connectivity tools

Description: In order to make this project as broadly useful as possible, we will create open-source, user-friendly models that federal and state agency members can use to determine habitat connectivity of many species. We will do this by extrapolating dispersal distance measured in Activity 1 to species that are similar (in terms of dispersal syndrome) to the target species. This information will then be shared specifically with the Minnesota Prairie Conservation Plan in order to provide plant movement information for future re-evaluations of the plan. This information will help determine how big corridors need to be, and how close fragments need to be, in order to maintain plant connectivity. We will make our models available to anyone in a conservation agency that has prairie plant survey data from multiple prairie fragments, and is interested in learning how to prioritize locations for prairie restorations. We will hold virtual workshops to help agency members learn how to use these tools to analyze the connectivity of their landscape. Private land owners interested in restoring prairie can also benefit from this tool and participate in workshops.

Summary Budget Information for Activity 3:	**ENRTF Budget:**	**$ 13**
	Amount Spent:	**$ 13**
	Balance:	**$ 0**

Outcome	**Completion Date**
inform Minnesota Prairie Conservation Plan of dispersal distance information	*February 2019*
develop online tools for measuring habitat connectivity	*December 2018*
hold virtual workshops to train agency members, citizens, scholars, etc on how to use the virtual tools to determine connectivity of their own prairie fragments	*May & June 2019*

Activity Status as of *January 1, 2017:*

This activity has not yet begun.

Activity Status as of *July 1, 2017:*

This activity has not yet begun.

Activity Status as of *January 1, 2018:*

This activity has not yet begun.

Activity Status as of *July 1, 2018:*

This activity has not yet begun. However we have hired someone to work on this, and she starts August 1, 2018.

Activity Status as of *January 1, 2019:*

This activity is in full swing and we are meeting our goals. We have developed an online tool for measuring habitat connectivity for all of Minnesota. This is a web-based, interactive app that anyone can use. You select your county, and this brings up all of the grasslands within that county. Then, you have a slider bar to select the dispersal distance you think is appropriate and the application shows you (with connected lines) which prairies are connected to each other based on that dispersal distance and provides a series of connectivity metrics (e.g. the number of connected prairies in your county, the number of isolated prairies, etc). Also, this app allows you to select a location that you think you might want to locate a prairie restoration, and it updates the connectivity metrics to determine if this new prairie will promote connectivity or not given the existing prairies. We have set up meetings in early 2019 to work with the folks from the Minnesota Prairie Conservation Plan to workshop the app to find out what they are interested in and how they think it should be improved to be more useful to managers. After this, we will hold workshops to show anyone who is interested how to use the application.

Activity Status as of *July 1, 2019:*

We have now nearly completed this activity. We have created the web-based app (https://grassland-connectivity.shinyapps.io/MNConnectivity/) that allows managers in Minnesota to examine the grasslands in their county and calculate the connectivity of these grasslands based on given dispersal distances. A web-based tutorial is available to help people understand how to use the the app, and can be found here (https://www.youtube.com/watch?v=bS93mnMyAW8). We will be hosting a web-based seminar for how to use the app this coming fall for managers including the MN DNR, BWSR and others, once field season comes to an end. Additionally, we published a summary paper about the importance of using web-based applications for helping solve conservation management problems in Restoration Ecology, which can be found here (https://onlinelibrary.wiley.com/doi/10.1111/rec.12999).

Activity Status as of *January 1, 2020:*

Due to scheduling conflicts with field work and moving, we have not yet set up our web-based seminar for how to use our app. We are currently working to schedule this workshop.

Final Report Summary:

Activity 3 is complete. Our paper is published and so is the app. We have presented on this work to local land managers.

V. DISSEMINATION:

Description:

Findings from Activities 1 and 2 will be published in peer-reviewed journals. Important findings from these Activities will be shared with parties involved in the project and land managers in Clay County. These bodies include but are not limited to: The Nature Conservancy, The Department of Natural Resources, Fish and Wildlife Services, and Minnesota State University Moorehead. The Minnesota Prairie Conservation Plan will be specifically targeted and all results will be shared and discussed with the founders of this plan.

The online tutorials and connectivity tools created in Activity 3 will be made publicly available to any private citizen, state or federal agency, non-profit, or scientific body interested in the results and methods. Online workshops will be open to any interested party. Contact information will be provided in case users run into snags when using the tools.

Work from Activity 1 and 2 will be presented at the National Native Seed Conference in February 2016 for land managers, policy makers and scientists all interested in promoting the use and production of native seed in the United States.

Status as of *January 1, 2017:*

We have disseminated this research in several ways this reporting period. We presented at the Science Slam for The Nature Conservancy (~ 35 attendees – scientists, TNC staff, and land managers using TNC lands) where we discussed our work to date. We also discussed our project with Minnesota State University Moorhead undergraduate student interns during intern development day (15 students). Here we brought students out to the field site and discussed the project and the conservation-related ideas behind it. Finally, we presented at a monthly meeting for the SNA land stewards run by the Minnesota DNR (6 land stewards). Again, we brought the stewards out to Bluestem Prairie SNA to introduce them to the research that was happening on one of the SNA's.

Status as of *July 1, 2017:*

We have disseminated this research in several ways this reporting period. First, we attended the National Native Seed Conference (~330 attendees – scientists, restoration specialists, policy makers, land managers, native seed producers), where we presented a poster on our work. We received a lot of interest in the project, and made several connections that have helped improve the work of this project. We look forward to sharing our work more as it progresses and we have solid results! We also presented at the MSUM intern development day (7 students) where we talked to students about our research, and our path to become a scientist. We then took the students and other MSUM faculty into the field, showed them our study plots, and had them participate in helping us find individuals of our target species.

Status as of *January 1, 2018:*

Over the past reporting period we have participated in two dissemination events through the Minnesota DNR. First, we contributed to the MN DNR Science Sunday section on their Facebook page. We provided a description of our project, which they published on facebook to inform others about the work occurring in conjunction with the DNR. Also, in September we participated in the MN DNR Little Lunch on the Prairie series, where we presented our project and the results so far via the web to MN DNR land managers across the state. 14 people were in attendance.

Status as of *July 1, 2018:*

During this reporting period Lauren gave a talk at the University of Missouri where she discussed this project and our results thus far. There were approximately 80 people in attendance, including students, faculty and staff. Additionally, Allison gave a talk at the University of Colorado, Boulder where she also discussed the project and its preliminary results. There were approximately 60 people in attendance including students, faculty and staff.

Status as of *January 1, 2019:*

Work from this project has been presented at two University seminars within the last reporting period – one by Lauren at Washington University in St Louis, and one by Allison at St. Olaf. There were approximately 40 ad 30 people in attendance (respectively), and these audiences included faculty and undergraduate students, as well as graduate students at Washington University. This work was also presented at the Ecological Society of America conference in New Orleans in August by both Lauren and technicians Hayley and Katie. Here there were approximately 80 people in attendance – which included ecologists from all around the world.

Status as of *July 1, 2019:*

We beta-tested our web-based app with faculty and students at the University of Minnesota Friday Noon Seminar (~15 people), and with the MN, ND, SD TNC chapter (~10 people). This helped us improve the quality of the app to address questions of interest to managers. Lauren also presented on work from this project (Activities 1 and 2) at the Iowa State University Ecology and Evolution seminar that had approximately 75 people in attendance.

Status as of *January 1, 2020:*

Lauren presented on the general connectivity model at the Ecological Society of America conference in August, 2019. There were approximately 60 people in attendance, all ecologists interested in the concept of connectivity.

Project Results Use and Dissemination

This project has been presented at the Ecological Society of America conference in 2018 to an invited session on the role of space for coexistence as well as in 2019. Additionally, our team presented findings at the Botany Society meetings in 2019, 2020, and 2021 and various intuitional research talks in 2019 and 2020. The list of published papers associated with this project can be found in our Overall Project Outcomes.

One of the main outreach foci of this project was to provide conservation agencies and the MPCP with tools that they can use to determine the degree of habitat connectivity and the necessary size of corridors, to promote the spread of desirable species. To that end, we created and an app to the Nature Conservancy, and the MN DNR in March 2019. This app can be found at MN Connectivity.

VI. PROJECT BUDGET SUMMARY:
A. ENRTF Budget Overview:
See Attached Budget

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 7.25

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota	$ 289,120	$289,120	In-kind support: non-summer salaries of Shaw and Moeller, office space, lab space
Shaw startup	$1,428	$1428	Two weeks of field work to set up the field sight and begin collecting data before July 1. The flowering season will begin before this date, so it will be necessary to begin before July 1 to get all the appropriate data. Funds include hotel room, per diem and car rental. Details are the same as above.
State			
None			
TOTAL OTHER FUNDS:	**$**	**$**	

VII. PROJECT STRATEGY:
A. Project Partners:

Funded Partners

Lauren Sullivan (Postdoctoral Researcher - UMN) will oversee project and conduct all research, Allison Shaw (Assistant Professor – UMN) will assist with modeling and determining connectivity, and David Moeller (Assistant Professor – UMN) will assist with genetic analysis.

Non-funded Partners

Greg Hoch (MN DNR) and Steve Chaplin (The Nature Conservancy (TNC)) will assist with site selection, promote workshops, and incorporate information gathered into the Minnesota Prairie Conservation Plan to make real change for Minnesota prairies.

We will have many non-funded partners in the Clay County area to broaden the scope of this project. We are working with Brian Wisenden and Tony Bormann at Minnesota State Moorehead (2015 LCCMR grant recipients) to discuss site selection, and outreach opportunities. We will work with them to hire undergraduate field assistants and provide these assistants with research opportunities through the University of Minnesota as well as Minnesota State. We will also provide reciprocal outreach by presenting our work through their outreach program funded by their LCCMR grant. We are working with Brian Winter at the Nature Conservancy, and Cindy Leuth at the Minnesota DNR to get the appropriate permissions to perform our work at the proposed site.

B. Project Impact and Long-term Strategy:

First, this project will provide important data that is now only possible because of cutting edge genetic sequencing technology. This will be the first set of information on the dispersal ability of a suite of species that vary in their dispersal syndromes. This project will provide important conservation information that multiple federal agencies can incorporate into their prairie restoration programs. The connectivity information and ability to measure it will be useful, widely across the state. We have contacted the Minnesota DNR, the Board of Water and Soil Resources, and the Nature Conservancy, and they have indicated that they would be very interested in attending the trainings and that this project would provide important information that would be immediately useful to existing programs. This project is extremely timely because it will increase the success of the Minnesota Prairie Conservation Plan, and will be immediately implemented into its upcoming re-evaluation. This project complements an LCCMR proposal by Daniel Cariveau (UMN) titled “Data driven pollinator conservation” that also seeks to understand habitat connectivity and its importance for native pollinators. We will work with both Cariveau and Crystal Boyd to combine the outreach efforts of our LCCMR projects to bring information about plant movement and their insect pollinators to the general public.

This work will be long-lasting as information will be incorporated into the Minnesota Prairie Conservation Plan. It will also be pivotal for creating precision prairie conservation plans across the state that allow managers to target specific areas for restorations that will help increase prairie habitat connectivity across the state. We anticipate that the data collected in this project could provide the basis for future studies on the dispersal and connectivity of Minnesota prairie species. Where possible, we will seek out collaborations and apply for further funding sources to support this work into the future.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
none		$

VIII. RESEARCH ADDENDUM:

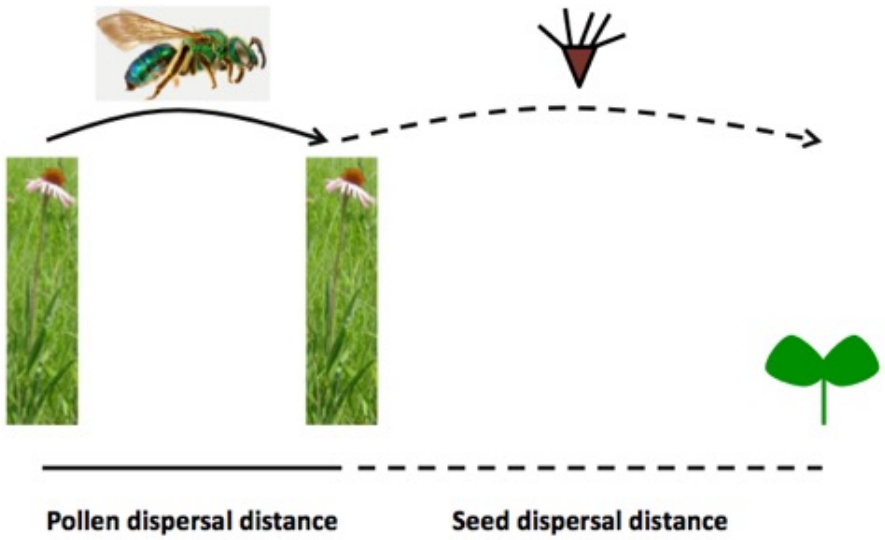
See attached at the end. All published papers are also included.

IX. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 1 2017, July 1 2017, January 1 2018, July 1 2018, and January 1 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

X. VISUAL COMPONENT or MAP(S):

How to measure pollen and seed dispersal distance



Research Area

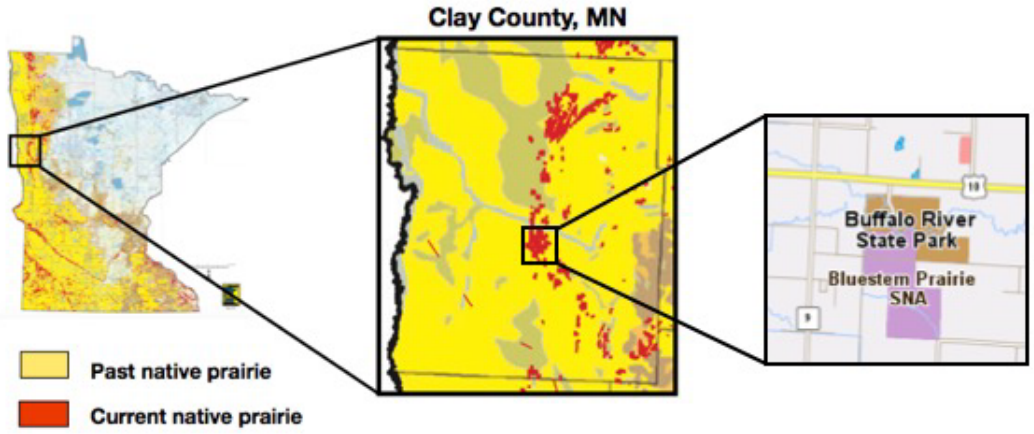
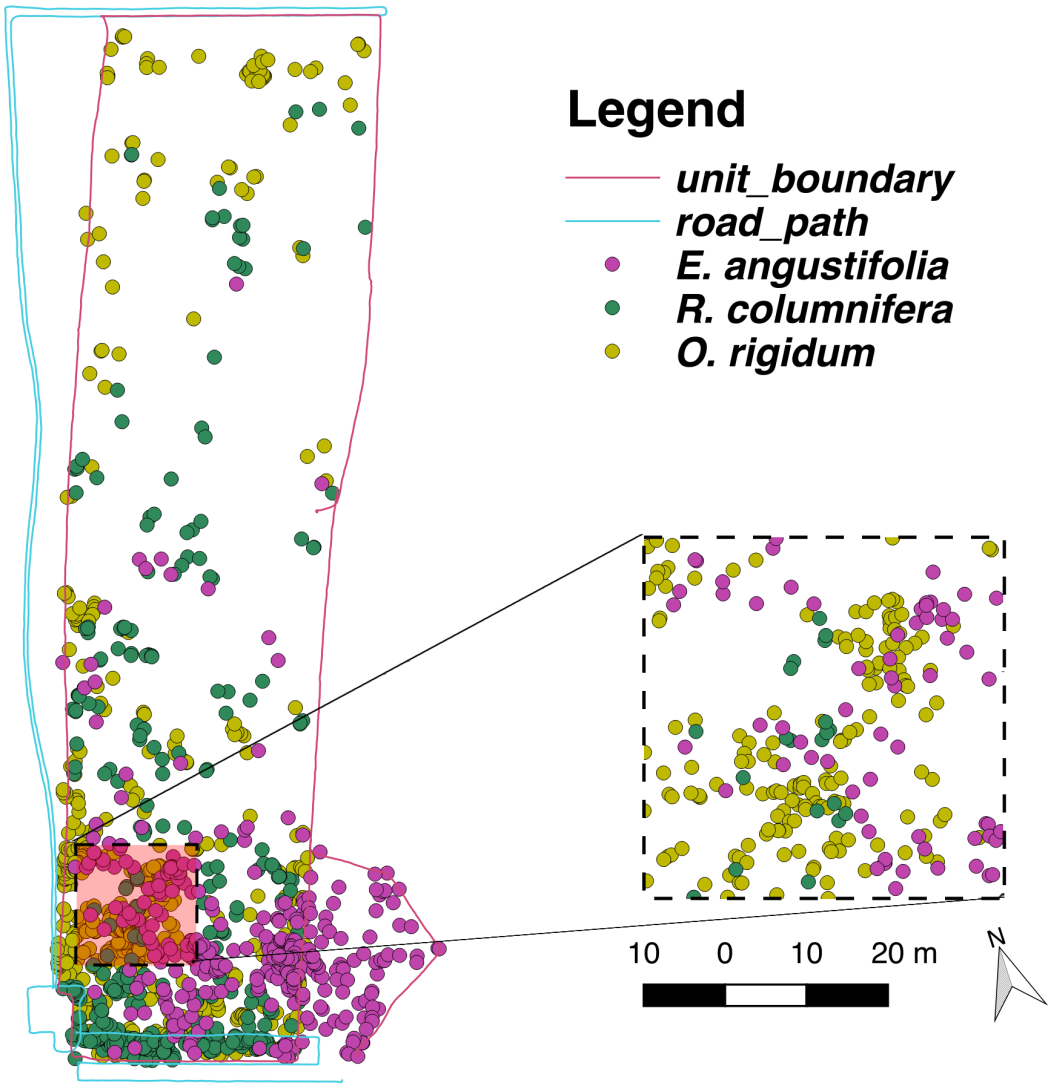


*Image from the Minnesota Prairie Conservation Plan

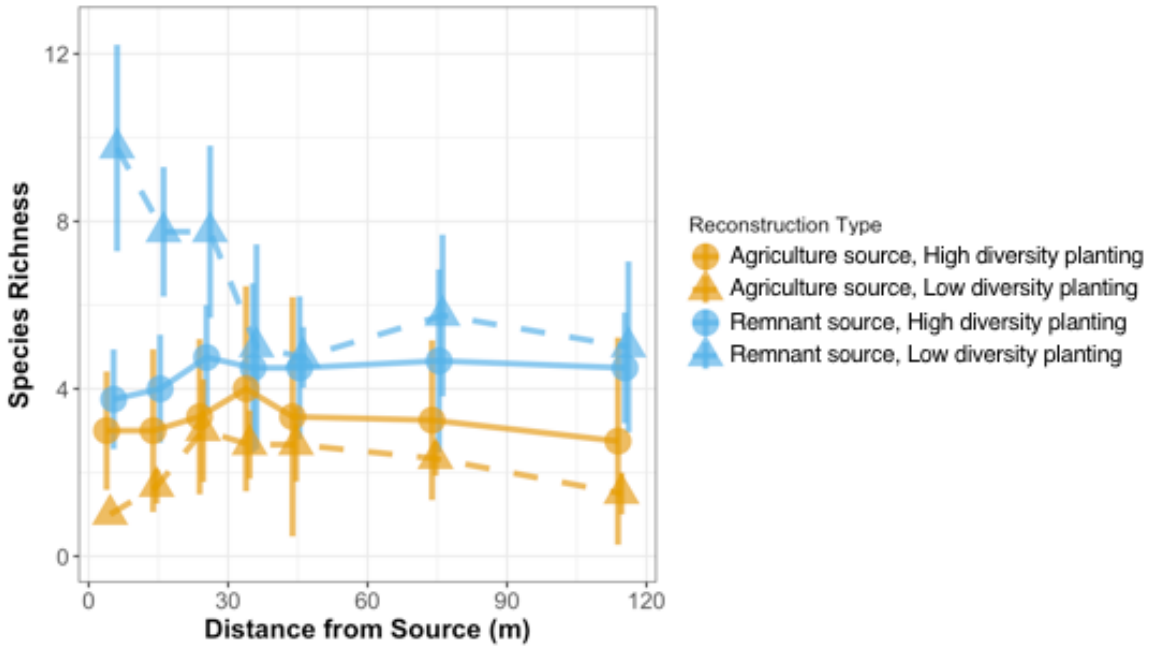
*image from the MN DNR website

Supplemental Figure 1



Supplemental Figure 1: Map of our study area and all individuals of our three target species from 2016. We collected tissue from all individuals of Purple coneflower (*Echinacea angustifolia* – purple circles), Yellow coneflower (*Ratibida columnifera* – green circles), and Stiff goldenrod (*Solidago rigida* – yellow circles) within 3.5 ha at Bluestem Prairie in Clay County, MN.

Supplemental Figure 2



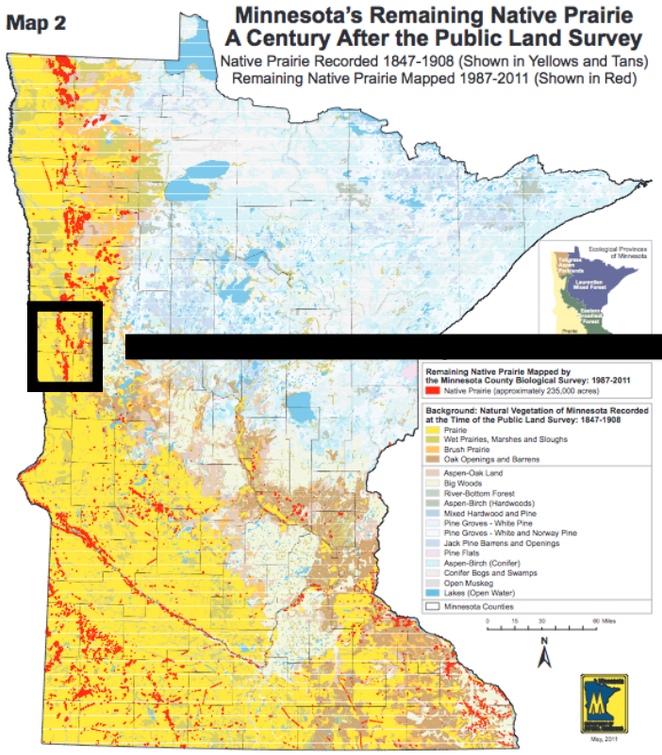
Supplemental Figure 2: Spillover of target species occurred, but only in low diversity reconstructions adjacent to remnant prairies (blue triangles) for the first 50m. There was no significant distance effect for low diversity sites adjacent to agricultural fields (yellow triangles), or high diversity sites adjacent to remnants (blue circles) or agricultural fields (yellow circles).

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget

Project Title: Measuring Pollen and Seed Dispersal for Prairie Fragment Connectivity
Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 08b
Project Manager: *Lauren Sullivan*
Organization: University of Minnesota
M.L. 2016 ENRTF Appropriation: $ *556,000*
Project Length and Completion Date: 4 *Years, June 30, 2020*
Date of Report: November 18, 2021

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM											
Personnel (Wages and Benefits)	$261,059	$261,059	$0	$138,326	$138,326	$0		$0	$0	$399,385	$0
Lauren Sullivan *UMN postdoc - supervise and participate in the research project full time. 82% salary, 18% benefits. 100% FTE for 3 years ($159,000)*											
Allison Shaw *UMN assistant professor - participate in sampling and develop connectivity models. 75% salary, 25% benefits. 8.333% FTE for 3 years ($36,800)*											
Dave Moeller *UMN assistant professor - participate in sampling and parentage analysis 75% salary, 25% benefits. 8.333% FTE for 3 years ($40,500)*											
*Student field assistants (3 total). 100% salary. 25% FTE for 3 years ($13/hour * 40hr/week * 12 weeks * 3 years = $18,720)*											
Civil Service Tech 1 lab assistant, civil service employee - help with lab work and extractions. 78% salary, 22% benefits.100% FTE for 2 years ($81,580)											
Civil service employee Bioinformatician - assist in data analysis of parentage analysis. 78% salary, 22% benefits. 100% FTE for 1 year ($46,400)											
Equipment/Tools/Supplies											
Field and Lab Supplies (flags, coin envelopes, bar code reader, 96 well plates, chemicals, vials, etc)	$12,000	$12,000	$0	$86	$86	$0				$12,086	$0
GPS Rental	$554	$554	$0							$554	$0
Supplies to conduct workshops (food, name tags, etc)							$0	$0	$0	$0	$0
Printing											
printing materials for workshops							$13	$13	$0	$13	$0
Travel expenses in Minnesota											
Travel for field work *lodging, car rental, per diem.*	$23,788	$23,788	$0	$0	$0	$0				$23,788	$0
Out of state travel for conference to present work from project *(flight: $360 + hotel $900 + registration $400 = $1660)*	$1,660	$1,660	$0							$1,660	$0
Other											

*Lab services for genotyping plant samples to determine paternity (8 species * 250 samples/species the first year, and 4 species * 200 samples/species the second year = 2800 samples @ $50/sample = $140,000*	$118,514	$118,514	$0							$118,514	$0

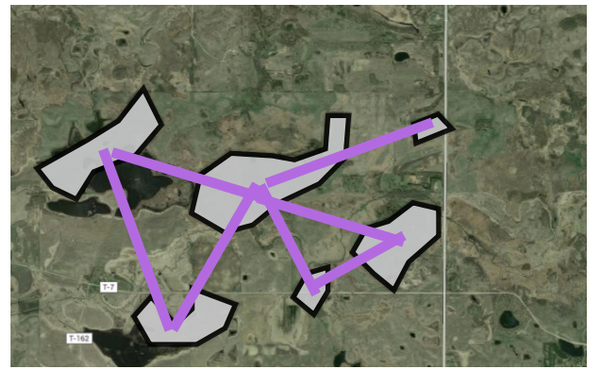


Measuring pollen and seed dispersal distance

seed dispersal distance

pollen dispersal distance

to determine prairie habitat connectivity and proper corridor size



From: the Minnesota Prairie Conservation Plan