M.L. 2014 **Project Abstract**
For the Period Ending June 30, 2019

PROJECT TITLE: Enhancing Pollinator Landscapes
PROJECT MANAGER: Marla Spivak
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2014, Chp. 226, Sec. 2, Subd. 06a and M.L. 2015, Chapter 76, Section 2, Subdivision 19

APPROPRIATION AMOUNT: $864,000
AMOUNT SPENT: $863,766.25
AMOUNT REMAINING: $ 233.75

Sound bite of Project Outcomes and Results

There is a large knowledge gap regarding the distribution, floral preferences, and nesting ecology of the more than 400 native bee species in Minnesota. This projected led to an extensive, collaborative network and research team that has generated critical data on the distribution, abundance, floral use, and nesting of native bees.

Overall Project Outcome and Results

There is a large knowledge gap regarding the distribution, floral preferences, habitat use, and nesting ecology of the more than 400 native bee species in Minnesota. This funding provided the first important and comprehensive step to fill this gap. For Activity 1, the University of Minnesota hired Dr. Daniel Cariveau in September 2015. Since starting as an Assistant Professor, Dr. Cariveau has built a large, highly productive lab group focusing on native bee ecology and conservation. This includes five graduate students, three postdoctoral research associates, four full-time research staff and over 20 undergraduate research technicians. He has raised over $3 million in state and federal funds and has published seven manuscripts in that time. He has also helped organize projects throughout the state and has built relationships with MNNDR, Pheasants Forever, MNDOT, USFWS, and The Nature Conservancy. For the second activity we collected over 10,000 specimens of 268 species and verified the identity of over 13,000 specimens and nearly 350 species from historic collections. We have thus documented the current and past distribution and abundance of Minnesota's native bees. This provides critical baseline data that will inform native bee conservation. For the third activity, we compiled data on over 45,000 native bee by plant interactions. We sampled bees in urban and prairie ecosystems. We have used these collections to develop lists of plants for habitat and these data have generated research into minimizing restoration costs. In the fourth activity, we documented how plant species and management activities influence nesting of stem-nesting bees. This work is a critical step as most research addresses only floral use by bees. The results of this work can be used by homeowners to better manage nesting habitat. We are in the process of publishing results in peer-reviewed journals. Data will be open access upon publication.

Project Results Use and Dissemination

Using this funding we were able to reach a wide array of audiences. For one, we held a total of four organizational symposia that focused on ongoing pollinator work being funded by the Environmental and Natural Resources Trust Fund. At these symposia, individuals with projects funded through ENRTF discussed the scope, results and importance of their findings. A major goal of these symposia was to prevent overlap and encourage collaboration. Therefore, we also held break-out sessions at these meetings and discussed new

project ideas along with how to share results from current research. These symposia typically involved 15 – 20 presentations with 30-50 participants. Staff and LCCMR members attended a number of these symposia. In addition, we presented nearly 30 outreach talks and 3 scientific presentations that focused on the research being conducted from this proposal. Some of these talks included large audiences and were broadcast widely, such as interviews with the Minnesota Public Radio. In addition, we also spent the summer of 2017 managing a novel, multi-tiered mentorship program. Drs. Cariveau and Rodgers mentored two University of Minnesota undergraduate students. These students received their own funding through the Undergraduate Research Opportunity Program at the University of Minnesota. In addition, the City of Minneapolis recruited two Urban Scholars to participate in sampling. The Urban Scholars program provides mentorship and funding to undergraduate students from diverse backgrounds to conduct scholarly work with the City of Minneapolis. Drs. Cariveau and Rodgers also recruited a Step-Up student. The Step-Up program is aimed at providing internships to high school students that experience barriers to employment. Finally, we created an outreach document titled Nesting Habitat for Stem Nesting Bees. All of the content of this document is compiled and the design is being finalized.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: October 28, 2019

Date of Next Status Update Report: Final Report

Date of Work Plan Approval: June 4, 2014

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

PROJECT TITLE: Enhancing Pollinator Landscapes

Project Manager: Marla Spivak

Organization: University of Minnesota

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Location: Ramsey Co and Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$864,000**
	Amount Spent:	**$863,766.25**
.25	**Balance:**	**$ 233.75**

Legal Citation: **M.L. 2014, Chp. 226, Sec. 2, Subd. 06a and M.L. 2015, Chapter 76, Section 2, Subdivision 19**

Appropriation Language:
$864,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to identify sources of nectar and pollen for native pollinators and honey bees and coordinate ongoing and future efforts to enhance pollinator habitat and opportunities for pollinator nesting and foraging. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

Carry forward; Extension: (c) The availability of the appropriations for the following project is extended to June 30, 2019: Laws 2014, chapter 226, section 2, subdivision 6, paragraph (a), Enhancing Pollinator Landscapes

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

I. PROJECT TITLE: Enhancing Pollinator Landscapes

II. PROJECT STATEMENT:

Why? Pollinators help our crops so much that we tend to forget it is a two-way street—we must also help our pollinators. The current, widespread decline of pollinators has become critical and threatens their well-being and even their very existence. Neither native wild bees nor managed honey bees are secure. The causes of decline are not completely known, but many known causes can be combated. Loss of nesting sites, fewer flowers, increased disease, more insecticides, and other causes all combine. Fortunately, the present crisis for pollinators comes at a time when society recognizes the severity of the problem and is motivated to act to improve pollinator resources and environment. Improving conditions for pollinators will also improve conditions for birds and other wildlife, reduce soil erosion, improve water quality, and further beautify the landscape of our state.

Goals. The goal of this project is to provide new and reliable supplies of nectar and pollen for wild bees and honey bees, across the entire growing season in key beekeeping regions of Minnesota. Specific aims are to 1) coordinate and help conduct statewide surveys and identification of Minnesota's existing native bee populations, estimated between 300-400 species; 2) identify and document forbs, and other plants that contribute the most to nectar and pollen resources for all bees, and specifically that contribute to continuous honey production for managed honey bees; and 3) begin to identify and document plants and plant communities that provide nesting and overwintering sites for Minnesota's native bees.

How? Supplies of food and habitat for pollinators must be enhanced by strategic changes in land-use. This project will help create a new and critically needed interdisciplinary faculty position to lead and coordinate the research proposed here, and to help consolidate and accelerate the many other pollinator efforts that are ongoing and planned, including: i) research, extension and public programs on honey bee health and best beekeeping practices, (UMN and Beekeeping Associations); ii) surveying and compiling of the state's first database of wild pollinators (UMN and MNDNR); iii) documenting the impact of grazing on native plants and pollinators (USGS); iv) reconstructing habitats and corridors for pollinator nesting and foraging (DNR, BWSR, NRCS, USFWS, Pheasants Forever, and The Nature Conservancy); v) developing community educational projects on pollinators and habitat (UMN, Pheasants Forever, DNR); vi) prairie butterfly conservation and breeding (MN Zoo); vii) Monarchs in the Classroom (UMN); and viii) understanding systemic pesticide impacts on bees (UMN, MDA).

Outcomes include a statewide working group on pollinator habitat and ecosystem services, led by a new faculty member, landscape maps and assessments, demonstration sites, best management practices, peer-reviewed scientific papers, and long-term plans for sustaining pollinators and helping Minnesota beekeepers. Results will help private land owners and public land managers. The project will provide examples for other states in our region to adapt and expand.

III. PROJECT STATUS UPDATES:

Project Status as of December 15, 2014

Activity 1: A new tenure track, Assistant Professor position in Pollinator Ecology at the University of Minnesota was advertised nationally in October, and applicants will be reviewed and interviewed in Spring 2015. We are coordinating efforts and establishing collaborations among researchers and other statewide agencies on pollinator and habitat projects by hosting meetings, reading groups, and a week long course that includes two public events. Activity 2: Joel Gardner (Masters degree in Entomology) is verifying identifications of Minnesota bees in the University of Minnesota Insect Museum and databasing the bees in collaboration with DNR. Elaine Evans (PhD candidate in Entomology) has identified potential areas for surveys of wild bee pollinators in prairie-

grassland habitats, to begin in 2015. Activity 3: Colleen Satyshur (Masters degree in Biology) is gathering background literature, compiling lists of flowers recommended for pollinator grassland plantings, and researching methods of quantifying bee floral use beginning in 2015. With in-kind funds from General Mills, we are constructing the first pollen reference library for Minnesota by collecting flowers and making slides of pollen for identification by microscopy. We are using the pollen library to identify pollen honey bees are collecting to determine the extent that honey bees forage on native flowers. Activity 4. C. Satyshur and J. Gardner are identifying plants and plant communities that provide nesting and overwintering sites for Minnesota's cavity-nesting native bees.

Amendment Request December 22, 2014

We are requesting a two-year extension of this project. For Activity 1, we expect the new faculty member to be hired by September 2015, at which time we will begin using the three-year's worth of funds allocated for salary and associated fringe benefits for this person. The University is committed to supporting this new faculty position over the long term beyond this initial ENRTF investment. In determining the best financial structure to ensure this commitment can occur, it was decided that the best strategy for the University was to begin providing some financial support in the form of a partial match at the start of the position. The tenure college of the new faculty member will contribute 10% salary for the first three years, with 90% covered by ENRTF. These matching support funds will offset some of the originally planned funding needs and related timeline for the position. The matching funds will allow for the ENRTF investment to be expended over a longer period of time and allow support of additional efforts and accomplishments by the position beyond what was originally proposed. The extension also will provide flexibility in the case the new faculty member is not able to begin employment at the University of Minnesota until later in 2015 or early 2016 (e.g., if the person needs additional time to complete projects with former employer).

Amendment Approved: 5/29/15

Project Status as of August 15, 2015

Activity 1: Dr. Dan Cariveau, an expert in native bee and pollination ecology, was hired as an Assistant Professor in the Department of Entomology. He has begun a research program, is developing courses and is coordinating native bee survey and research efforts at the UMN and other entities. Activity 2: Verification, identification and database entry of native bees from the UMN Entomology museum is ongoing. Approximately 140 new species have been databases since the last update. We are finishing collecting bees from two regions in MN: Anoka Sand Plain and the Saint Paul-Baldwin Plains. Specimens will be pinned, identified, and entered into the database over the fall and winter. Activity 3: To determine floral choice of honey bees, we analyzed pollen loads from honey bees whose hives were near prairie habitats. To determine floral choice of native bees, we constructed floral arrays using specialized shipping pallets as planters. We have been collecting bees visiting the flowers in these planters and will assess which flower species are most preferred by native bees. Activity 4: We have been surveying vegetation for bee nests. Using the results of these surveys, we created choice arrays of stems for native bees. These stems will be reared in the lab and newly emerged adults will be identified to species.

Project Status as of February 15, 2016

Activity 1: Dan Cariveau has written an LCCMR proposal that has been recommended for funding through ENTRF. He will recruit 3 new graduate students this summer to study habitat ecology of native bees. Activity 2: Nearly 8500 bee specimens have been checked and databased from the University of Minnesota Insect Collection. Joel Gardner has identified a total of 264 species. Over 5000 specimens were collected in

surveys in 2015 and these specimens are currently being identified and databased. Preparations for summer 2016 are in progress. Activity 3: To determine flower use by honey bees in prairies, we have been identifying pollen from using light microscopy. In addition, we have started collaborations with other scientists in the hopes of using Next Generation sequencing to increase the taxonomic resolution of pollens. Data are continuing to be analyzed for the bee preference study. We have found a number of plants that are most preferred by native bees. In addition, we found that honey bees do not use plants in palettes however they were common on native plants in a field setting. Dan Cariveau will continue this study in the summer of 2016. Activity 4: We are continuing to rear bees from stem nests that were collected in summer 2015. As bees emerge they are collected, pinned and identified. We are close to finishing the rearing process. We have begun site selection for a study in the summer of 2016 to better assess plant use by nesting bees as well as stem height. Information on stem height will inform management practices such as mowing.

Project Status as of September 15, 2016

Activity 1: Dan Cariveau began research on Minnesota prairies. He will be teaching 3 courses this year including *Pollinator Protection in Managed Landscapes*. Two new graduate students in his lab are studying wild bees, habitat and pollination. He has also spoke at numerous public events. Activity 2: Nearly 12,000 bees have been databased from the University of Minnesota Insect Collection. Joel Garder has identified a 276 species. Specimens from 2015 surveys have been pinned. Specimens from 2016 are being processed. Over 4,000 have been labeled and databased and 85 species have been identified. Activity 3: We continued identifying honey bee-collected pollen using light microscopy. Across four sites with large reconstructed prairies, the main contributors of pollen were non-native legumes in the early and mid-summer and native and non-native Asteraceae in the later season. To increase taxonomic resolution, we are collaborating with researchers at three United States Geological Survey (USGS) centers to sequence DNA. Comparisons of DNA with microscopy results are being conducted to gain better species-level resolution. This comparison has confirmed certain native species as important food sources across sites, including *Dalea purpurea* (purple prairie clover), and shown unexpected contributions of wetland flowers. Activity 4: Bee nests from 2015 were reared and bees and nests pinned. An expanded stem nest study was installed in April 2016. Three arrays were installed to test bee use as a function of stem height, diameter and plant species. The field portion of this study is ongoing as of the date of the update.

Project Status as of March 15, 2017

Activity 1: Dan Cariveau continues to mentor two graduate students and recruited two more students starting in fall 2017. He is teaching a new graduate course in experimental design. Finally, he has been awarded two grants. One is to study exotic plant management effects on native bees. A second project is to study Rusty-Patched Bumble Bee populations along roadsides. Activity 2: We finished updating the database for bee specimens at the University of Minnesota's Insect Collection. Joel Gardner has verified the identity of over 13,000 specimens and 276 species. Joel will be identifying species from Apidae and Halictidae. In our field study, we collected approximately 10,000 specimens from over 200 species in two regions in Minnesota. Approximately 40% of these specimens have been identified to species. We found a number of rare species including the federally-endangered Rusty-patched Bumble Bee (*Bombus* affinis). Once species identification is completed, we will compare our collections to those in the historic database at the UMN Insect Collection. Activity 3: We continue to update pollen images on the Bell Museum's Minnesota Diversity Atlas website. We will conduct sampling to update a seed mix optimization model. Activity 4: We are rearing bees and wasps from stem nests. Emerged bees and wasps have been collected and pinned. We are entering, organizing and checking data for analysis. Dissemination: We held a meeting for ENTRF pollinator projects. Eighteen projects presented their results and/or plans. We held break-out sessions on research, habitat management, and outreach.

Project Status as of September 15, 2017

Activity 1: Dan Cariveau has recruited one MSc and two PhD students. He has taught three different courses and is developing a fourth course on Data Management for Biologists. He has been PI or Co-PI on three federal proposals. One proposal to study pollen loads in native bees using NextGen sequencing was funded by the United States Department of Agriculture. The two other proposals are still in review. Activity 2: Nearly all of the specimens 13,000 specimens in the University of Minnesota Insect Collection have been identified and databased. This has led to a total of 15 new Minnesota state records. There are some problematic species and we have hired a taxonomist to work on identification. We also collected over 10,000 specimens in 2015 and 2016 and all have been identified. Activity 3: We collected pollen loads from honey bees at two more sites and the content of these pollen loads are currently being analyzed. We began a new project to study the pollinator plantings in the City of Minneapolis as well as nearby community gardens. In addition to meeting the objectives of Activity 3, we were able to leverage funds to mentor four undergraduate students (2 from the University of Minnesota and two Urban Scholars) and one Step-Up high school student. We are currently organizing and analyzing these data. Activity 4: We have collected, identified and databased all specimens from the 2016. We are currently analyzing these data and writing a manuscript for peer review.

Amendment Request October 20, 2017

We are requesting a reallocation of funds to supplement salaries for all Activities. For Activity 1, we are requesting an extra $10,000 be allocated to meet University increase in baseline salary and benefits for Dr. Cariveau, which will cover his position for the amount of time originally requested (90% at 3.3 years). After this funding, the University of Minnesota is committed to full funding of Dr. Cariveau's position. The increased baseline salary and associate benefit costs were not anticipated when the project was first conceived in 2014, and will be covered by reducing travel funds from Activities 2, 3 and 4 (see below). For Activity 2, we request to increase salary to $210,991 to complete identification, curation and databasing of bees from field research and historic collections at the University of Minnesota Insect Collection, by hiring a new bee taxonomist, research assistant and research technicians. We have acquired some new historic collections and the new taxonomist will verify species records. To cover these salaries, we reduced salary for the post-doctoral researcher, whose work is nearly complete on this Activity and has additional funding from other sources. In addition, we used less travel funds than anticipated. For Activity 3, we are requesting an increase in salary to $138,951. We will use these funds to complete a number of objectives. First the salary will be used to create a robust plant – pollinator relational database using MySQL. Second, we will collect pollen from bees and in addition to identifying and counting pollen based on light microscopy, we will also use Next Generation Sequencing. This technique allows for more accurate identification of pollen grains. Sequencing costs will be covered by a USDA grant to Cariveau (as Co-PI). Third, we will collect seed cost data from multiple seed companies. This is critical for understanding costs associated with pollinator plantings. For Activity 4, we are requesting to increase salary to $131,318 to complete the analysis of a number of interesting results, writing and production of extension materials. We are reducing the salary originally budgeted for the research coordinator, who has completed her work on this Activity, to provide increased salary for the taxonomist, research assistant and research technicians to finalize the research and conduct outreach.

To supplement the salaries, we are requesting to reallocate funds from travel (Activities 2, 3, 4), common garden set-up (Activity 3) and supplies (Activity 4). The research projects outlined in Activities 2 through 4 did not require travel expenses as requested in the original budget. We request that the total funding for travel for the entire project be reduced from $41,000 to $14,596. For Activity 3, we completed a round of common garden experiments and have decided to modify the experiment by partnering with the City of Minneapolis to sample bees in common garden-pollinator plots in parks. Minneapolis received separate funding

to install pollinator plots and we saw this as an opportunity to sample bees in a manner consistent with our original objectives in Activity 3. Therefore, we are requesting that Equipment funds for Activity 3 be reduced from $12,000 to $5,600. As we did not need as many supplies for Activity 2, we are requesting an overall reduction in supplies from $10,000 to $8,400. Finally, had originally planned on using $2,000 to acquire specialized training to better identify our specimens. However, as we have hired a trained taxonomist, we are able reallocate those funds to this position. We are not requesting any changes in funds for extension and outreach but will be using salary to better carry out these efforts.

Project Status as of March 15, 2018

Activity 1: Dan Cariveau has published a number of peer-reviewed manuscripts. He was also awarded funding from United States Department of Agriculture. He is teaching courses on statistical analyses and data management. Activity 2: Most specimens from historic and field-based collections have been identified although we are working on finalizing identification of difficult groups. We have acquired new collections from past collectors and have been identifying these specimens. We are close to conducting analysis on historic and current collections. Activity 3: We are finishing identification of plants and bees collected from research on pollinator plots in build by the City of Minneapolis Parks. We are also finishing curation of insects and plants collected from community garden project conducted in summer 2017.

Project Status as of November 15, 2018

Activity 1: Dan Cariveau has spent much of the time since the last update starting a number of new research projects. This funding has come from ENRTF, the Foundation for Food and Agriculture Research, and United States Department of Agriculture. He is developing a new course on pollinator biology for undergraduates at the University of Minnesota. For the rest of the activities, we are focusing on writing up results. Activity 2: We are still finalizing the identification and databasing of specimens. As we have acquired a few new collections, we are working to organize, identify and database these specimens. Activity 3: We completed a second spring season collecting bees from flowers in urban community gardens. We are writing a manuscript for publication. Activity 4: The research for this project has been completed and we are finalizing data analysis and writing up results for publication.

Amendment Request August 2019

We request a reallocation of funds to increase amount for salary. To compensate for this, we request an equal reduction in funds for travel, printing, and supplies. In total, this will be $15,717 more for salary. For Activity 2, we request to reallocate $10,478 more to salary. We received more bee samples, especially from some historic collections, than we anticipated. Furthermore, we hired an expert taxonomist and this allowed us to more accurately identify and verify bee species. We therefore needed for salary to complete these identifications. This was incredibly beneficial as we were able to add a number of new, high-quality records to our database. For Activity 3, we also needed to better identify bee specimens and to collect and analyze data on bee by plant interactions. These databases were large and contained a number of misidentified specimens. Therefore, we are requesting to reallocate $5,239 to salary for Activity 3. To make up for this increase in salary, we request a reallocation from travel, printing and supplies. We needed less travel than predicted and request a reallocation of $3,130 from the travel budget (-$500 from Activity 2, -$2325 from Activity 3, and -$500 from Activity 4) to salary. In addition, we have been incorporating findings from Activities 2, 3 and 4 into our outreach talks but have used other funds for to travel to outreach events. We are requesting a reallocation of $12,500 from printing (-$4500 from Activity 2, -$4000 from Activity 3, and -$4000 from Activity 4) to salary. We were slightly delayed when due to new bee specimens. We have used other funds for this this current summer (e.g.

Dan Cariveau's start-up) and will continue to do so for publishing peer-reviewed manuscripts.

We note that none of the objectives have changed in this grant. Further, we are not requesting any budget changes for Activity 1.

Amendment Approved by LCCMR 9/30/2019.

Overall Project Outcomes and Results: June 2019 OVERALL STATUS

There is a large knowledge gap regarding the distribution, floral preferences, habitat use, and nesting ecology of the more than 400 native bee species in Minnesota. This funding provided the first important and comprehensive step to fill this gap. For Activity 1, the University of Minnesota hired Dr. Daniel Cariveau in September 2015. Since starting as an Assistant Professor, Dr. Cariveau has built a large, highly-productive lab group focusing on native bee ecology and conservation. This includes five graduate students, three postdoctoral research associates, four full-time research staff and over 20 undergraduate research technicians. He has raised over $3 million in state and federal funds and has published ten manuscripts in that time. He has also helped organize projects throughout the state and has built relationships with MNNDR, Pheasants Forever, MNDOT, USFWS, and The Nature Conservancy. For the second activity we collected over 10,000 specimens of 268 species and verified the identity of over 13,000 specimens and nearly 350 species from historic collections. We have thus documented the current and past distribution and abundance of Minnesota's native bees. This provides critical baseline data that will inform native bee conservation. For the third activity, we compiled data on over 45,000 native bee by plant interactions. We sampled bees in urban and prairie ecosystems. We have used these collections to develop lists of plants for habitat and these data have generated research into minimizing restoration costs. In the fourth activity, we documented how plant species and management activities influence nesting of stem-nesting bees. This work is a critical step as most research addresses only floral use by bees. The results of this work can be used by homeowners to better manage nesting habitat. We are in the process of publishing results in peer-reviewed journals. Data will be open access upon publication.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: New Faculty Position to research, teach, and coordinate pollinator ecology, U MN

Description: Due to recent attention about the unprecedented decline of bees, a number of statewide projects have been initiated to study and conserve MN insect pollinators. This attention and study is timely, even overdue, for this economically and ecologically important group. But to be efficient, the diverse efforts must be coordinated. This activity will create a new and critically needed interdisciplinary faculty position to lead and coordinate efforts at the U MN, and to help consolidate and accelerate the many other pollinator efforts that are ongoing and planned across the state (listed on page 1). This faculty position will include research responsibilities on a basis of 70% time, to help expand our base of knowledge about pollinators, and also teaching responsibilities at 30% time to educate others and train the next generation in methods relevant to pollinators and the project.

At the UMN, a new professor position on pollinator habitat ecology would be distinct from, but would complement and enhance, efforts of M. Spivak (expertise in honey bee pathology, breeding and behavior), K. Oberhauser (monarch butterfly biology and citizen science), and other faculty that study prairie-grassland ecology, flowering cover crops in agricultural lands, beneficial insect ecology and biological control, and effects

of pesticides on pollinators and other beneficial insects. We anticipate that after a national search, the new professor will begin working no later than September 2015.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 339,144
Amount Spent: $ 339,144
Balance: $ 0

Activity Completion Date: June 30, 2019

Outcome	Completion Date	Budget
1. New Assistant Professor of Pollinator Habitat Ecology hired and initiates new interdisciplinary research and teaching program.	September 2015	$339,144
2. Coordination of efforts at the UMN on pollinators and habitat. Collaborations formed with other statewide pollinator projects.	June 30, 2019	
3. Curriculum adaptations and new course offerings in place.	June 30, 2019	
4. Pollinator research programs beyond this project established and underway.	June 30, 2019	

Activity Status as of December 15, 2014

M. Spivak is chair of the search committee for a new tenure track, Assistant Professor position in Pollinator Ecology. She selected a search committee comprised of five faculty members and one graduate student member in September 2014 (listed below). The committee wrote the position description and advertisement for the new job, with input from Deans of two colleges (Dean Buhr of the College of Food, Ag, and Natural Resource Sciences, CFANS) and interim Dean Hayes of the College of Biological Sciences, CBS). The chosen applicant will negotiate tenure home in one of two departments: Department of Entomology in CFANS, or the Department of Ecology, Evolution and Behavior in CBS. The position was advertised nationally in October. The committee will begin reviewing applications on December 19, 2014. If a sufficient number of qualified applicants have applied by that date, the committee will close the search and begin arrangements for conducting interviews in spring 2015.

Search Committee:

Name	Department	College
Marla Spivak	Entomology	CFANS
George Heimpel	Entomology	CFANS
Karen Oberhauser	Conservation Biology	CFANS
Clarence Lehman	Ecology, Evolution and Behavior	CBS
Elizabeth Borer	Ecology, Evolution and Behavior	CBS
David Mueller	Plant Biology	CBS
Ian Lane (graduate student)	Entomology and Horticulture	CFANS

We have begun coordination of efforts and collaborations with other statewide agencies on pollinator

and habitat projects (see Section V: Dissemination for list of collaborators). On May 21 2014 the DNR hosted a meeting comprised of 25+ people from 8 different organizations that are conducting 9+ different projects on pollinators in Minnesota. This meeting was attended by LCCMR staff. A second meeting will be held on January 22, 2015 The Minnesota Zoo, also to be attended by LCCMR staff.

A reading group on pollinators has been meeting bi-weekly at the University of Minnesota to review literature on life-histories and current research on native bees. Attendees include Colleen Satyshur, Marla Spivak, Elaine Evans, Joel Gardner, Ian Lane and Karl Foord from the U of MN, Diane Larson and Jennifer Larson from the USGS, Crystal Boyd from the MN DNR and author and landscape designer, Heather Holm.

A week long class on native bee identification will be held January 12-16, 2015 organized by project staff. The class, "Tallgrass Prairie Bees: An Identification Training Workshop, will be led by Dr. Mike Arduser, a bee identification expert from the Missouri Department of Conservation. The event will be hosted at the University of Minnesota and is supported by the University of Minnesota's IonE mini-grant program and the Minnesota Department of Natural Resources. A networking event will be held January 12th, which will be open to interested local pollinator researchers. A public talk will be held January 13th in the evening, and a research talk will be presented January 14 in the afternoon. Both of these talks are open to the public.

Conversations have been initiated research groups at the University of Wisconsin and Iowa State University, with the goal of forming an Upper Midwest consortium of researchers and others interested in pollinators and habitat enrichment.

Activity Status as of August 15, 2015

Dr. Dan Cariveau, specialist in native bees and pollinator ecology, was hired at the Assistant Professor in the Entomology department, with a start date of September 1, 2015. ENRTF is covering 90% of his salary for 3.3 years, and the College of Food, Agriculture and Natural Resource Sciences at the University of Minnesota is covering 10% of his salary for 3.3 years. Dan is teaching course on Science Communication and Ethics. He is working to expand an undergraduate course on *Pollinator Protection in Managed Landscapes* (Co-Taught with Eric Watkins in Horticulture and previously co-taught by Marla Spivak). Dan is also developing a new graduate-level course on Pollinator Ecology to be taught in the Fall of 2016.

Another LCCMR pollinator projects update meeting was held Jan 22 and plans are forthcoming for another meeting this fall. Dan Cariveau has planned a meeting in October for interested parties in the MN DNR and University of Minnesota Entomology museum. The focus is to standardize collection and database protocols for future projects on native bees.

Dan Cariveau has begun a research program beyond this project. He submitted a proposal to ENTRF in April 2015. If funded, this project would focus how to best implement prairie restorations to conserve native bee communities. He is currently working with Dan Shaw (BWSR), Greg Hoch (MN DNR) and Marissa Ahlering (TNC) to locate sites for research in spring 2016.

Activity Status as of February 15, 2016

Another LCCMR pollinator projects update meeting was held Nov 3 2015 at the University of Minnesota-St Paul Campus. The meeting was led by Colleen Satyshur and Dan Cariveau. The next full meeting will be held in fall 2016. Groups have been encouraged to communicate and hold smaller topic-based meetings in the meantime.

Dan Cariveau's LCCMR grant was recommended for funding. He will begin research this coming summer using start-up funds from the University of Minnesota. He has recruited three new graduate students and a postdoc to study how habitat influences native bees.

Activity Status as of September 15, 2016

Dan Cariveau began research on western Minnesota prairie ecosystems in summer of 2016. This was supported by start-up funds and an ENTRF project 'Data-Driven Pollinator Conservation Strategies'. He has also submitted grants to USDA, the National Park Service, and LCCMR to study native bee conservation. He is teaching two graduate courses: *Scientific Communication and Ethics* and *Applied Experimental Design*. In addition, he is co-teaching *Pollinator Protection in Managed Landscapes* for undergraduates. He has also spoke at numerous events including the Pollinator Summit at the University of Minnesota Arboretum and the Minnesota Department of Agriculture's Pollinator Summit. He is training two graduate students in native bee ecology and pollination. Finally, he is planning for a LCCMR pollinator projects meeting in early 2017.

Activity Status as of March 15, 2017

Dan Cariveau is advising two students working on native bee conservation in prairie restoration sites. Further, he has received two different grants. One is from the Central Ecosystems Study Unit and the US National Park Service ($89,815) to study the effects of exotic plant removal on native pollinators. This project will survey for wild bees in areas with and without buckthorn removal. A second grant is to survey and develop monitoring protocols for the federally endangered Rusty-Patched bumble bee along Twin Cities roadside (MN Department of Transportation - $111,264). Both of these studies will begin in the summer of 2017. Dr. Cariveau is also teaching *Applied Experimental Design* – a graduate-level course in statistics. He will be bringing in at least two new graduate students to study native bees in the fall of 2017.

Project Status as of September 15, 2017

Dan Cariveau has recruited 3 new students for a total of 5 graduate students. One student received two fellowships: CFANS Diversity and University of Minnesota Diversity Of Views and Experiences (DOVE) for three full years of funding. Another earned a National Science Foundation Graduate Research Fellowship for three years of funding. The third new student received a one year fellowship from Department of Ecology, Evolution and Behavior. He has a number of proposals in review and was awarded a USDA funding as a Co-PI (PI Dave Andow) to study pollen loads of native bees in prairie ecosystems. He gave invited presentations at the University of North Dakota, University of Illinois Urbana-Champaign, and the Ecological Society of America meetings. At these talks, he has highlighted the funding and research from this and other ENRTF projects.

Project Status as of March 15, 2018

Dan Cariveau was awarded a $1,000,000 grant from the United States Department of Agriculture. This grant will expand on much of the work in this current ENRTF grant. Dan was also awarded a Foundation for Food and Agriculture Research grant as a CoPI. This is a large multi-institutional grant that includes Dan is teaching a new course on data management and relational databases. He has had three papers co-authored in peer-review journals including *Science*, *Oikos* and *Agriculture, Ecosystems, and the Environment*. He is teaching a new course on data management for biologists.

Project Status as of November 15, 2018

Dan has focused on starting a number of projects this fall. As part of a project funded by USDA and LCCMR, he recruited over 30 landowners to participate in an experimental pollinator habitat project that has resulted in the installation of 277 acres of new pollinator habitat. In addition, he has launched a large pollinator-seed mix project that was funded through the Foundation for Food and Agriculture Research. He has given a number of invited talks. This has included presentations geared towards other pollinator ecologists (Entomological Society of America Meeting in Vancouver, BC and the University of Manitoba in Winnipeg, Manitoba). He has also gave a number of talks to the general public (Café Scientifique and the UMN Arboretum Pollinator Symposium). This semester he developed a course in pollinator biology targeted to undergraduates.

Final Report Summary: June 30, 2019

Since starting in September 2015, Dr. Cariveau has built a large lab focused on native bee ecology and conservation. His lab currently has five graduate students, three postdoctoral researchers and four full time research staff. The Cariveau Native Bee Lab has trained over 15 undergraduate researchers. Further, Dr. Cariveau has been an outside member for nine graduate students with nearly all of these students focusing in native bee research. He has obtained over $3,000,000 in state and federal research funds. The overwhelming majority of this work is focused on native bee ecology and conservation. This research includes urban, suburban and rural areas in Minnesota. Much of the lab's research is focused on pollinator habitat while also including important questions in pollination ecology and the monitoring of the federally endangered Rusty-Patched Bumble Bee (*Bombus affinis*). He has authored and coauthored ten peer-reviewed manuscripts, including an article in Science. He has continued to disseminate the results of his research and has been invited by his academic to present his research four times at national annual meetings and has been part of seven invited speaker seminar series. In addition to presenting to scientific audiences, Dr. Cariveau has presented over 20 talks to the general public throughout Minnesota.

ACTIVITY 2: Wild Bee Pollinator Surveys in Prairie-Grassland Habitats

Description: An estimated 350-400 species of native bees reside in MN, but this estimate has never been validated. It is critical to conduct thorough field surveys of native bees for current documentation of their species diversity and abundance. A survey consists of sampling bees over a three-year period in critically defined regions of Minnesota, preserving the bees for museum storage, identifying the bees to species, and entering the bee information into a comprehensive database. Surveys of wild bees in a particular region must be conducted over a minimum of three years due to natural fluctuations in population abundance of bees over time; one-year sampling efforts may not reveal rare or declining species, and are not representative of long-term population changes. Surveys involve sampling defined areas over regular periods (e.g., biweekly, or monthly), following standard procedures: transects are delineated and bees are collected with insect nets in morning and afternoon sampling bouts; bowl-traps are set out along transects to collect a wider sample of bees and other insect pollinators over frequent intervals throughout the season. All collected bees are later mounted on insect pins, labeled, and identified to species. Finally, the information about each bee is entered into a database for access and archival storage. Pinning and labeling, although delicate and detailed work, can be done by undergraduates. Identifying bees to species requires highly trained specialists, of which fortunately several are at U MN. The DNR will be compiling the first database and state list of wild bees in MN (Wild Bee Surveys in Prairie-Grassland Habitats), to which we will contribute our specimen data.

We will collect bees from various sites within three areas in southeastern MN with a history of bee collections (see Visual Map and Graphic, attached). These surveys will complement those proposed by the DNR, which will be conducted on high quality native prairie and restored prairie-grassland sites throughout the Minnesota Prairie Region in western MN. Focusing survey effort on areas with historical bee collections will enable comparison of current collection records with museum specimens. We are in communication with the project managers of the DNR to closely coordinate and collaborate on our proposed activities.

Several Minnesota bumble bee species are considered to be in decline (*Bombus pensylvanicus*, *B. affinis*, *B. terricola*, *B. fervidus* and *B. ashtoni* (Cameron et. al 2011, Evans et. al 2008)). However, to accurately determine if a species is in decline, the diversity and abundance of present-day bees must be compared to a historical database of bees collected in the same area. The first such historical comparison of MN bees was conducted recently by J. Gardner (Master's thesis), who documented species loss (11 species) and gain (4

species) of one family of bees, the Megachiliadae (leafcutter bees) in Itasca State park by comparing his 3-year collection with museum specimens collected in Itasca State Park in the 1930s. Our survey will use a similar approach to examine changes in species diversity in southeastern MN since the 1930s. In addition, we will continue to gather specimens from other collector and ensure that they are accurately identified by a trained taxonomist.

Diversity and species richness of native bees, and abundance of honey bees, will be determined using a trapping system developed by Sam Droege of the USGS. The traps consist of colored cups containing water and detergent. The cups are placed atop stakes and spaced at regular intervals in a sampling area. Bees are attracted to the colors. Traps will be set for designated intervals and times, such as every 24 hours every three weeks over the summer. These cup traps support an estimate of species richness and diversity. Additional collections will be made by sweep netting vegetation to collect larger pollinators such as bumble bees. Sweep net surveys will be conducted periodically along multiple transects per plot---such as along ten 100 m transects per plot every three weeks. Additionally, within each plot, multiple spot surveys will focus on bee-preferred flower patches. Blue vane traps will be set out during sweep net surveys as an additional complement.

Summary Budget Information for Activity 2:

ENRTF Budget:	**$ 229,069**
Amount Spent:	**$ 229,069**
Balance:	**$ 0**

Activity Completion Date: June 30, 2019

Outcome	Completion Date	Budget
1. Bees surveyed over 3 year period in three southeastern MN sites using standardized sampling methods in collaboration with DNR	June 30, 2019	$ 229,069
2. Bees identified and curated for museum storage	June 30, 2019	
3. Species richness and abundance of bees collected from southeastern MN compared to historical museum specimens in that area to document loss or gain of pollinator species.	June 30, 2019	
4. Bee information entered into a comprehensive database compiled by DNR.	June 30, 2019	

Activity Status as of December 15, 2014

Bee specimens in the University of Minnesota Insect Museum are being verified and databased through collaborative efforts of personnel funded both on this project and the MN DNR 006-A Wild Bee Surveys in Prairie-Grassland Habitats project. Joel Gardener (Masters degree in Entomology, and bee identification specialist) was hired to verify identifications of Minnesota bees in the University of Minnesota Insect Museum. While going through the collection to verify species identifications, Joel Gardner will also sort and identify previously undetermined specimens from bee genera of particular conservation interest, including cleptoparasites, floral specialists and habitat specialists. Not all insect collectors have expertise in bee collection, making it essential to verify identifications. In some cases, bee taxonomists have made new discoveries and identifications that need to be brought in line with current bee taxonomy. In addition, there are specimens that have been donated to the museum without being identified. Verification of existing identifications as well as organization and identification of previously undetermined material is necessary to give as complete and accurate a picture as possible for determining historic bee distributions in Minnesota. Verified identifications will also be used by the DNR in their creation of a list of all Minnesota bees. Joel has verified and databased 2424 specimens from 70 species to date. These records include three probable new state records for MN. From this point forward, the DNR will be responsible for all databasing of MN bee specimens in the U of MN Insect Museum. There are an estimated 27,000 bee specimens from Minnesota in the U of MN Insect Museum. Joel

will continue to verify species identifications.

Elaine Evans (PhD candidate in Entomology) was hired and has identified potential areas for surveys of wild bee pollinator surveys in prairie-grassland habitats. The criteria used for site selection are the prevalence of plant species known to support bee populations and the existence of historical records of bees at the site or near to the site. Bee diversity has been shown to be connected with plant diversity. Elaine met with the MN DNR Regional Plant Ecologist to identify areas with diverse plant communities including rare plants. Information from this meeting was used select thirty-four potential sites. Three of these sites were visited for on-site evaluation. Additional on-site evaluations will take place once more detailed plant community information has been analyzed for these sites as weather permits. GIS analysis using plant information layers available from the DNR will be used to determine suitability of sites for bee surveys. Bee collecting will begin when bees become active in Late April or early May with sweep netting surveys, possibly supplemented with pan traps. Precise collection methods will be determined once site selection is finalized.

Activity Status as of August 15, 2015

Databasing and verification of Minnesota bee specimens in the University of Minnesota Insect Museum is continuing. Additional databasing of specimens from the Insect Museum is being done by volunteers led by Crystal Boyd of the MN DNR. Many specimens need verification to confirm the species identity. To date, Joel Gardner has verified 6,007 individual bees belonging to 210 species. Three of the six families present in MN have been completely databased and verified (Andrenidae, Colletidae, and Melittidae), and two are about half done (Megachilidae and Halictidae). One family (Apidae) is currently mostly undatabased.

In the 2015 field season, bee collections took place within two ecological subsections of the Eastern Broadleaf Forest province: the Anoka Sand Plain and the Saint Paul-Baldwin Plain. These ecological subsections were chosen because they have the greatest number of historical records. Four locations, two within each ecological subsection, were surveyed every third week from May through September at previously identified areas rich in historic bee records or near those areas. An additional two locations, one within each ecological sub-section, were randomly chosen and also surveyed every third week. These additional sites were selected by randomly choosing a township within the ecological subsection and locating parks or other natural areas within that township. If an appropriate survey area could not be found within that township, an adjacent township was used. One randomly chosen location was surveyed within each ecological subsection. A total of six locations were surveyed during each collection. For each site, we conducted seven sampling rounds.

Elaine Evans and Joel Gardner collected bees and assessed floral abundance during each visit. Bees were collected by sweep netting and pan traps. At each location on each survey date, five 50 m^2 flower patches were swept and all bees found in the nets were collected. Floral abundance was estimated within two separate 1 m^2 quadrats within the 50 m^2 flower patch. At each location, three arrays of 18 pan traps were set up approximately 600 m from each other, in areas appropriate for traps (typically open areas). These arrays were set up before 10 am and taken down after 4 pm.

Approximately 2,300 bees were collected via sweep netting. Collections were made from 129 different flower species. Pollen samples were collected from flowering plants to enable future analysis of pollen collected by bees. These samples are being added to the reference library of pollen samples in the University of Minnesota Bee Lab. Pan trap collections have not yet been processed, so the number of specimens collected via this method is not yet known.

Most bees have not yet been identified, but several rare species in the collections were noted during collection, including *Bombus affinis*, a bumble bee of special conservation concern, *Lasioglossum swenkii*, a crepuscular sweat bee specializing on evening primrose flowers, and *Dianthidium simile*, a ground nesting bee that nests only in sandy habitats. Preparation, databasing, and identification of specimens are on going.

Activity Status as of February 15, 2016

Databasing and verification of Minnesota bee specimens in the University of Minnesota Insect Museum is continuing. Many specimens need verification to confirm the species identity. To date, Joel Gardner has verified 8,482 individual bees belonging to 264 species. Four of the six families present in MN have been completely databased and verified (Andrenidae, Colletidae, Melittidae, and Megachilidae), and one is nearly complete (Halictidae). One family (Apidae) is currently mostly undatabased.

All of the approximately 2,300 bee specimens collected by sweep netting have been pinned and are currently being labeled, databased, and identified. 1,442 specimens have been labeled and databased. 447 have been identified to species. Approximately 800 bees from pan traps have been pinned. 420 of these have been labeled. Most await identification. Approximately 3000 bees from pan traps are unpinned.

Preparations for the 2016 field season have begun, with site selection and obtaining permission to collect at these sites. After analysis of the historic records currently databased from the U of MN Insect Collection, it has been determined that there are insufficient numbers of historical records to justify the addition of a third ecological subsection for the upcoming field season. Sampling will continue in the St Paul Baldwin Plains Moraine and Anoka Sandplain subsections, with additional effort added to pollen collection.

Activity Status as of September 15, 2016

Databasing and verification of Minnesota bee specimens in the University of Minnesota Insect Museum is continuing. To date, Joel Gardner has verified 11,944 individual bees belonging to 276 species. Four of the six families present in MN have been completely databased and verified (Andrenidae, Colletidae, Melittidae, and Megachilidae), and one is nearly complete (Halictidae). One family (Apidae) is currently partially databased.

Elaine Evans and Joel Gardner just completed a field season sampling wild bees on the Saint Paul-Baldwin Plain and the Anoka Sand Plains. Most of the approximately 5,000 bee specimens collected by sweep netting have been pinned. Of these bees, 4,312 specimens have been labeled and databased. Of those, 787 have been identified to species. Of the approximately 4,000 bees collected from pan traps, 1,910 have been labeled and databased. Of those, 587 of these have been identified to species.

In total, 83 species of bees have been identified from these surveys. Species of particular note include the rarely found bees *Xenoglossa kansensis* and *Dianthidium simile*. Several sites have also housed rare bumble bees including *Bombus terricola* and *B. affinis*. Approximately 80% of specimens are awaiting identification that is scheduled for this winter. Sweep netting collections include floral records with collections from 135 different plant species. Reference pollen samples have been collected from these plants. Pollen from current and historical bee pollen loads will be analyzed to determine whether patterns of plant use by wild bees have changed over time.

Activity Status as of March 15, 2017

Databasing of Minnesota bee specimens at the University of Minnesota Insect Collection is complete. To date, Joel Gardner has verified 13,096 individual bees belonging to 276 species. Four of the six families present in MN have been completely databased and verified (Andrenidae, Colletidae, Melittidae, and Megachilidae), and the remaining two (Apidae and Halictidae) are databased but identifications are still being verified.

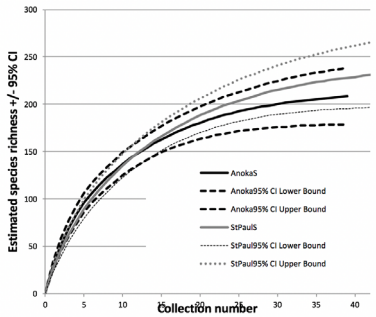

Figure 2.1 Sample based rarefaction curve for bee species richness for two ecological sub-sections. Data points beyond the vertical dashed line (reference sample) were extrapolated to three times the reference sample using non-parametric methods

Collections from 2015 and 2016 have yielded approximately 10,000 specimens. 4,201 specimens have been identified to species. After identification of approximately 40% of collections, we have found a total of 206 species or species groups. Collections from the Anoka Sand Plain ecological sub-section yielded 154 bee species or species groups (Fig 2.1). Collections from the Saint Paul Plains-Moraines ecological sub-section have yielded 161 species (Fig 2.1). The species richness between ecological subsections is similar (Fig 2.1).

Overall, the most common bee genera were *Lasioglossum*, *Andrena*, and *Ceratina* (Figure 2.2). There were 5 genera that were only found in the Saint Paul Plains-Moraines: *Coelioxys, Dufourea, Epeolus, Protandrena*, and *Pseudopanurgus*. There were 3 genera only found in the Anoka Sand Plains: *Anthophora*, *Dianthidium*, and *Xenoglossa*.

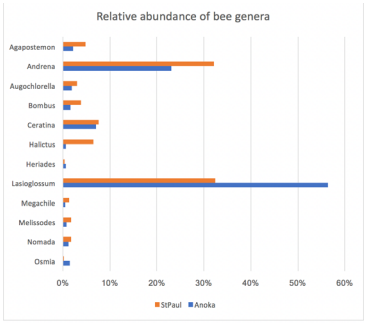

Figure 2.2. Relative abundances of bee genera found in each ecological subsection. Only those genera with relative abundances higher than 1% are included.

Species of particular note include the rarely found bees *Anthidium psoraleae*, *Dianthidium simile*, *Hylaeus nelumbonis*, *Lasioglossum nelumbonis*, *Lasioglossum swenki*, *Megachile rugifrons*, *Protandrena bancrofti*, and *Xenoglossa kansensis*. Several sites have also housed rare bumble bees including *Bombus terricola* and *B. affinis*. Sweep netting collections include floral records with collections from 201 different plant species. Reference pollen samples have been collected from these plants. Pollen from current and historical bee pollen loads will be analyzed for a subset of bees.

Once verification of the historic collections in the University of Minnesota Insect Collection is complete, comparisons will be made between current and historic collections in the two examined ecological sub-sections.

Project Status as of September 15, 2017

Verification of most of 13,000 previously identified Minnesota bee specimens at the University of Minnesota Insect Collection has been completed. These collections represent 238 species or species groups. Several new MN state records were discovered during the verification process as they were previously misidentified. To date this project has discovered over 15 new state records for MN. Additional historic materials with collections from the collections of Dr. Catherine Reed from the 1990s are currently being verified and databased by newly hired research assistant and research technicians to add to the breadth of the historic collections. Currently, 1,312 of approximately 3,000 specimens have been verified and databased.

Collections from 2015 and 2016 have yielded approximately 10,500 specimens of which 10,378 have been identified and databased. These collections include 241 species or species groups, including several new state records for MN.

Nearly all current and historical specimens have been identified and databased. However, there are a number of challenging species that will need verification by hiring a new bee taxonomist specialist. Once these tasks are completed, analyses to compare current and historical collections will begin.

Project Status as of March 15, 2018

Verification of the 13,000 previously identified Minnesota bee specimens in the University of Minnesota Insect Collection has been completed. Additional historic materials from the collections of Dr. Catherine Reed from the 1990s are currently being verified by a newly hired bee taxonomic specialist and databased by research technicians to add to the breadth of the historic collections.

Collections from 2015 and 2016 have yielded 10,478 specimens which have all been databased. Some taxonomically difficult specimens still need verification, but to date 268 unique bee species have been recorded from over 125 plant species. Nearly all current and historical specimens have been identified and databased. However, there are a number of challenging species still need verification. Once verification is completed, analyses to compare current and historical collections will begin.

Project Status as of November 15, 2018

Nearly all of the specimens in the University of Minnesota Collection and field collections have been identified and databased. We are cleaning up a few records. There are a few remaining difficult species (in the following genera *Lasioglossum (Dialictus), Hylaeus, Nomada, and Melissodes*). We are still sorting through some of the newly acquired specimens (e.g. Catherine Reed's collection noted in March 2018 update). This has taken more time than we had anticipated. This is, in part, due to the organization of the specimens and incorrect identifications. Nonetheless, these specimens are valuable and useful to detect historic changes. We will use these specimens to compare with the collections done in previous years of this activity. In particular, we will compare species richness between current and historical collections. Also, we will document changes in relative abundance for different bee species. This will help us understand whether certain species are increasing or decreasing through time. We will begin working on manuscripts for publication in the coming months.

Final Report Summary: June 30, 2019

This activity provided a number of important results. We were able to document the distribution and abundance of the bee fauna in a unique region in Minnesota – the Anoka Sand Plains and the Saint Paul Baldwin Plains Moraine. Most of the native bee studies have focused on prairie regions. We collected over 10,000 specimens and, at present, 268 species of bees. This is approximately 70% of all known bee species in Minnesota. There are few hundred specimens remaining to identify and as these are particularly challenging species, it will take some more time to get them identified. This is common in native bee studies in which genus-level experts and type specimens from museums in other regions are needed to verify identification. There were a number of unique and notable species. In total, at least 15 species are new Minnesota state records. We recorded five individuals of the federally endangered Rusty-Patched Bumble Bee (Bombus affinis) at two different sites. We also observed two specimens at two sites of the rare and declining Yellow-Banded Bumble Bee (Bombus terricola). The Rusty-Patched Bumble Bee records have been submitted to the United States Fish and Wildlife Service and have been used to establish high priority areas for this species' recovery. For the other bee species, we will use the records from the study to update the species list and range maps. Specimens of rarely collected species and floral specialists are particularly notable due to their contributions to documentation of their floral associations and distributions. Floral specialists from our collection include Lasioglossum swenkii, a crepuscular sweat bee specializing on evening primrose flowers, Xenoglossa kansensis, a specialist on curcubits, Lasioglossum nelumbonis, a specialist on water lilies, and Anthidium psoraleae, a specialist on pea flowers. Rarely collected species including Megachile rugifrons, Protandrena bancrofti, Dianthidium simile, a ground nesting bee that nests only in sandy habitats, and Xylocopa virginica. Xylocopa virginica is commonly collected in more southern states, but our sighting documents a range extension for this species.

Specimens are currently housed in the Cariveau Native Bee Lab, and will be accessioned into the UMN Insect Collection after all specimens have been identified and peer-reviewed manuscripts are published. We also verified most of the 13,781 specimens of native bees in the University of Minnesota Insect Collection. There are over 350 species in this collection with specimen records dating back to 1895. We are also in the process of comparing relative abundance and species distribution between the current collections with the historical collections in the UMN Insect Collection. We used hand nets to collect 4,767 bees that were visiting flowers. We recorded the species of flower collected for each specimen. The collection includes 238 unique bee species collected from 196 plant species. This list was used to design a large-scale pollinator seed mix experiment. The goal of this experiment is to create cost-effective and ecologically-effective pollinator habitat. This bee by plant database will continue to inform native bee research in Minnesota and to address important conservation needs.

ACTIVITY 3: MN Floral Resources for Bees

Description: We will Identify and document forbs and other plants that contribute the most to nectar and pollen resources for all bees on conservation and production lands, while providing benefits such as wildlife habitat, water purification, carbon storage, and soil improvement.

The background for this activity is that flowers differ widely in their value to bees. Flowers vary greatly in the amount and nutritional content of the nectar and pollen that they produce. Some bee species require specific flowers to complete their development, and such specialist bees are more likely to be in need of conservation. We presently know too little of the specialist bee-flower relationships for Minnesota bees. Documentation of plant species from which bees are collected during field surveys will create a list of which bees use which flowers. More detailed plant use information can be gathered from identification of pollen collected by bees by microscopic analysis.

For honey bees, the traditional floral resources and honey producing plants in Minnesota include early blooming trees (willow, maple, oaks), dandelions, fruit trees and other flowering trees and shrubs, particularly American basswood and European lindens, clovers, alfalfa, many species of wild and garden flowers, and late blooming flowers like asters, goldenrod and sunflowers. As some clover plants (sweet clovers) are listed as invasive by many agencies, it is critical to find alternative native or non-native, but non-invasive, floral sources that can be viable substitutes for these clovers. The value of native flowers for commercial honey bees is not known. Learning which if any native flowers are used by honey bees can inform other state projects, such as those sowing native flowers in prairies, along roadsides, as crop borders, or in other managed areas, for the benefit of commercial honey bee populations.

In particular, this activity will bring together three ideas, which are only partially understood: (A) the attractiveness of specific flowering plants to bees, and (B) the flowering season of native plants in MN, and (C) the suitability of specific flowering plants for conservation projects. The combination of these three ideas will support recommendations to landowners for efficiently increasing pollinator resources. To this end we propose five actions.

(1) Gather the existing knowledge on favorability of native grassland forbs for wild and honey bees from the standard scientific literature and in consultation with local experts. We will create a MySQL relational plant – pollinator database with records of visits curated from the literature as well as from the Cariveau Lab. These bee specimens will be verified by a taxonomist.

(2) Place honey bee colonies near native forbs and determine which contribute most to honey production and pollen collection. We will place healthy honey bee colonies near areas selected to have good populations of native flowers. We will quantify the diversity of pollens collected by honeybee colonies to estimate overall use of floral resources across the foraging range of the honey bees (i.e. 2 mile radius from

colonies, or 8,000 acres). Colonies at each location will have pollen traps and collected pollen will be classified where possible to species, using a pollen reference library currently being compiled in M. Spivak's lab. In addition, honey samples will be collected from the combs inside the same colonies at each site for analysis of pollen grains trapped in the honey, which will help determine the primary sources of honey. This analysis will quantify how much of the total honey-bee diet comes from wildflowers in the surrounding area, and will help inform how much wildflower acreage is needed to support honey bee colonies as a primary pollen and nectar source.

(3) We will examine pollen collected by wild bees to understand the categories of plants that successfully supply pollen to these bees. We will survey existing habitats with high densities of forbs within representative background landscapes, collect bees from flowers and pollen from bees to determine floral use, and make basic estimates of floral availability. This will allow us to evaluate which flowers are used by which wild bees. We will concentrate in two different regions of Minnesota conducive to wild bees, including southeast and southwest as possible. We have already collected a number of bees from SW Minnesota and will collect more in SE MN. On a subset of pollen loads we will use light microscopy to identify and count pollen grants. Some of these pollen loads will be analyzed using NextGen sequencing.

(4) Position the estimated best candidate flower species in small monoculture plots near each other and determine which are visited most by wild bees. From our background research list we will establish common gardens with candidate forbs planted in small monoculture plots, with randomization and replication. The goal will be to present wild bees with a common native garden in two or more different surrounding landscapes, such as in a high percentage agriculture or a high percentage conservation lands. This can be accomplished by such methods as planting native flowers or placing pallet planters of candidate species in desired landscapes. In these gardens all flowers of all candidate species will be equally available to bees in the area so we can determine preference. We will quantify the amount of flowers per plant species and determine bee use and preference.

(5) Document and explore the costs and logistics of planting these native forbs as a resource for landowners looking to plant pollinator plots. Seed mix cost data will be gathered from a host of seed companies. This will enable us to better estimate the economics of planting various seed mixes.

Summary Budget Information for Activity 3:

ENRTF Budget:	**$ 158,592**
Amount Spent:	**$ 158,658**
Balance:	**$ 233.75**

Activity Completion Date: June 30, 2019

Outcome	Completion Date	Budget
1. Existing knowledge on favorability of native grassland forbs for wild and honey bees gathered and indexed.	Feb 30, 2015	$158,592
2. Determination of native forbs species that contribute most to honey production and pollen collection by honey bees.	Dec 30, 2019	
3. Determination of floral preferences and pollen species collected by wild bees through survey work in natural areas and in replicated monoculture plots of best candidate flower species	Dec 30, 2019	
4. Documentation of costs and logistics of planting identified native forbs as a resource for landowners looking to plant pollinator plots.	Dec 30, 2019	

Activity Status as of December 15, 2014

To determine the relative contribution of native wildflowers to the total diet-breadth of honey bees, we placed three colonies of honey bees adjacent to three forb-rich prairies in SE Minnesota, each with over 50 acres of prairie plants. Our field sites are outside the Minneapolis-St. Paul metro area, including one site near the border with Wisconsin. The plant communities maintained within these prairie sites correspond to the pollinator plantings recommended by the Xerces Society and the NRCS for the Upper Midwest. This summer (2014), we collected pollen (from pollen traps) and nectar (from comb) gathered by honey bees biweekly over the growing season. We have also been constructing our own pollen reference library by collecting flowers and making slides of pollen found in and around Minnesota prairie plantings. After processing the pollen and honey to remove everything but the hard outer walls of the pollen grains (Jones 2014), we are using microscopy to identify the floral sources of the pollen grains in these food sources by comparing their structure to our pollen reference collection. For example, after identifying the structures of 500 pollen grains in a microscope slide made from a pollen sample, if half of all grains counted matched the pollen structure of our reference slide of bee balm (*Monarda fistulosa*) made up half of all grains counted, we would estimate that half of all the pollen in that sample came from bee balm. This information will help determine the extent that honey bees visit native species for nectar and pollen, and if there are native flower species that they find particularly attractive. Such attractive native flowers could add to, or substitute for, traditional non-native honey plants.

In addition, pollen will be analyzed from bees collected in Activity 2, the survey and historic comparison of wild pollinators, as well as pollen-bearing specimens in the University of Minnesota Insect Museum, to determine both historical and current plant use. These collections will focus on areas where historic bee records are prevalent.

Colleen Satyshur (Masters degree in Biology) was hired and is gathering and indexing background literature and planning experimental designs for the next growing season. To choose candidate flowers, we are compiling and comparing lists of flowers recommended for pollinator grassland plantings. We have also been researching methods of quantifying bee floral use, and are currently favoring the use of a “dust-buster”-type vacuum sampler and a fixed-area transect to determine number and species of bees and a fixed-area transect to quantify the amount of floral resources. Plans are being discussed to conduct these surveys both in floral choice gardens consisting of blooming native plants placed in different landscapes and at prairie restoration fields. Three restoration companies have been contacted and site-visits conducted.

Activity Status as of August 15, 2015

We continued our analysis of pollen and nectar collected by honey bees placed near restored prairie sites to determine the relative contribution of native wildflowers to the total diet-breadth of honey bees. A large proportion of the pollen collected by honey bee colonies placed at Prairie Restorations, Inc in Princeton, MN came from non-native plants in the bean family, including *Trifolium*, *Melilotus*, and *Lotus corniculatus*. Pollen from native Asteraceae made up a large proportion pollen collected in August and September. Native *Tradescantia* (spiderwort) was collected by honey bees in the early summer and *Impatiens* (touch-me-not) pollen later in season.

The pollen collected from colonies at Belwin Nature Conservancy, Afton, MN also showed an especially large proportion of pollen from non-native plants in the family Fabaceae. About 90% of all pollen grains collected in July came from *Trifolium*, *Melilotus*, and *Lotus corniculatus*. Maple and buckthorn pollen made up substantial proportions of the pollen early in the season and aster pollen contributed significantly later in the season. In mid-August, about 7% of the pollen grains came from the family Plantaginaceae, including the native flower *Veronicastrum virginicum* (Culver's root).

To assess floral preferences, we built floral planters using standard-sized shipping pallets that are approximately two feet deep. We contracted with Minnesota Native Landscapes Inc to construct and plant these pallets. Plants chosen were based on lists of pollinator seed mixes and to include a broad array plant taxonomic

groups. Also, we included plants favored by some oligolectic bees of Minnesota (these are bees that only collect pollen from a limited number of plant species). Species chosen were: *Dalea purpurea, Veronicastrum virginicum, Solidago speciosa, Helianthus, Liatris ligulistylis, Coreopsis lanceolata, Pycnanthemum virginianum, Mondarda fistulosa, Vernonia fasciculate,* and *Asclepias incarnata.* Two plant species were planted in each pallet, randomly paired, such that a complete "choice garden" consisted of 5 pallets. These pallets were arranged in a circle and so that each plant species had some room around it and would be ideally equally noticeable and available to bees.

These pallets were set-up at two locations. One at Minnesota Native Landscapes production fields and one on the Saint Paul Campus of the UMN. At both Minnesota Native Landscapes and UMN location we set up two choice garden rings, one of each variety. Pallets were kept at Minnesota Native Landscapes until just before plants started to bloom so that they received equal care and environmental conditions. Pallets were delivered to UMN on July 29th 2015 and floral survey methods began the same week

Flowers visitors were surveyed using a vacuum sampler. We conducted 15-minute surveys. During each survey, we collected bees foraging on blooming plants. Surveys were conducted weekly on the sunniest days possible each week and not before 9am. Surveys are still being conducted. The bees are frozen and pinned for later identification. In addition, we counted the number of blooms on each plant.

In addition to surveying bee use of pallet planters, we are surveying bee use of the same plant species in Minnesota Native Landscape's production fields. Each week, two 48in.x20in. areas are being sampled in each field of the target plant species that is in bloom. These areas are sampled for 15 minutes each and on the same day as pallets are sampled. Numbers of blooms in the areas are also counted. This is to provide a comparison to bees using pallets as fields are very large and established and generally contain a dense concentration of flowers of a particular species.

The results of these surveys will be used to expand work on floral preferences under the lead of the new native bee ecologist, Dan Cariveau.

Activity Status as of February 15, 2016

This summer and fall we continued identifying honey bee-collected pollen using light microscopy. At the site in Northfield, near prairies restored by the Carleton College Arboretum, the main contributors of pollen appear to be non-native legumes (Fabaceae) in the early and mid-summer and a mix of native and non-native Asteraceae in the later season. To get better taxonomic resolution, we also established a collaboration with researchers at three United States Geological Survey (USGS) centers to sequence the DNA in our pollen samples. We have sent 60 mixed pollen samples and 36 unripe honey samples for sequencing. Once the DNA is sequenced, the sequence data will be processed by a bioinformatics expert at the USGS to compare them to sequences uploaded to online databases. This process will produce a list of species and genera represented in our samples that we will match with our microscopy results to get better species-level resolution. By combining both approaches we will be able to give more specific recommendations to land managers as to which native prairie species can contribute substantial amounts of food to honey bee colonies.

Surveys of native bees visiting floral choice pallet planters continued until 10-1-15 when the last plants stopped blooming for the year. The last production fields in bloom were on 9-11-15. A total of 10 surveys were done at each choice garden location. Pallets at UMN-St Paul were returned to Minnesota Native Landscapes Inc. on Wednesday 11-4-15 where their staff have cared for and stored the pallets for overwintering at their farm. All bees have been pinned and identified to genus, some to species. A total or 638 specimens were collected from 12 genera and 26+ species, including a male and female of one species that is not currently known to live in Minnesota, *Lasioglossum lustrans*.

Figure 1 shows the average number of wild bees caught in 15 minutes on different plant species. *Ascelpias incarnata* was the most used plant species by wild bees (Fig. 1). We are currently analyzing the data to

determine whether certain bee taxa differed in plant use. Only 5% of bee visits to plants on palettes were from honey bees. We also conducted a field-level survey of some of the same plant species growing at a native plant nursery where honey bees made up 73% of the visits to these native plants. The most used native plants by honey bees were *Veronicastrum virginicum*, *Pycnantemum virginium*, and *Vernonia fasciculata.* Dan Cariveau is analyzing these data and is using the findings to study bee preferences in the summer of 2016.

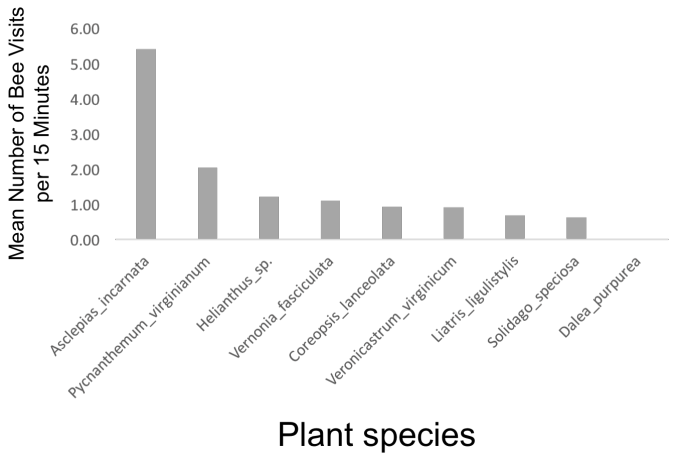

Figure 3.1. Mean number of bee visits to each flower species over 15 minute periods.

Activity Status as of September 15, 2016

To help determine which native prairie flowers can contribute to honey bee colony nutrition and productivity, we collected pollen and unripe honey from colonies periodically during the summer and fall. Our colonies were located in near large reconstructed prairies around the Twin Cities area.

We use slides of pollen collected from flowers as a reference for comparison with grains in the pollen loads and stored nectar of bees. We have collected, identified, and made slides of pollen from 90 species of flowers in and around our native prairie sites. We have also made progress in photographing and describing pollen from Minnesota native flower species in a large pollen reference collection housed at the University of Minnesota. We have photographed over 200 species so far. We recently established connections with the LacCore Facility (https://tmi.laccore.umn.edu/) and the Bell Museum of Natural History (http://bellatlas.umn.edu/) at the University of Minnesota so that we can begin sharing our photos and descriptions online with other bee researchers and the public.

In addition to making slides of our pollen samples under the microscope, in January we collaborated with researchers at the United States Geological Survey to sequence the DNA in our pollen samples using the protocol that they recently developed. The sequencing data does not give us proportions of different species, but it will help us to confirm our pollen identifications and identify pollen grains more specifically (ex. to species rather than simply to genus). The sequencing results have already helped us to identify unknown pollen types; for example, it helps differentiate species within families of plants that have similar pollen structures, such as within the asters and within the mustards. Overall, the results indicate a large contribution of native tree pollen in the spring and summer, non-native Fabaceae pollen in the summer and fall, and a mix of native and non-native aster pollen in the late summer and fall. In addition, we have identified several native prairie plants that contribute to colony food stores, including *Dalea purpurea* (purple prairie clover), *Helianthus* (sunflowers), *Impatiens* (touch-me-nots), *Allium* (wild onion/chives/garlic), *Solidago* (goldenrods), *Symphyotrichum novae-angliae* (New England aster), and *Symphyotrichum cordifolium* (blue wood aster).

We will be starting new research based on these and other findings in summer 2017.

Activity Status as of March 15, 2017

We have added 984 images of pollen from 138 species of Minnesota plants to the Bell Museum's Biodiversity Atlas website. New research is in the planning stages for summer 2017. We will be hand netting bees throughout southern Minnesota and using these data to parametrize a new optimization model for generating effective and cost-efficient seed mixes.

Project Status as of September 15, 2017

In the summer of 2017 we collected additional pollen loads from returning honey bee foragers at two field sites. At one field site our honey bee colonies had access to large restored prairies. At the other site, they had access to large plots of single species of prairie plants, including anise hyssop (*Agastache foeniculum*). Once analyzed, these samples will help us determine under what conditions honey bees will collect pollen from prairie flowers.

In the summer of 2017, we partnered with the City of Minneapolis and Mary Rogers in the Department of Horticulture at the University of Minnesota to sample pollinator plantings constructed by the Minneapolis Parks Department. The City of Minneapolis received funding to create pollinator plantings in a manner similar to our experimental approach outlined in Activity 3. We also sampled community gardens near plantings to determine bee species using the gardens. In total, we visited 12 sites over 37 different sampling days. We collected nearly 2,000 native bees. As we were in High Priority Zone for the federally endangered rusty-patched bumble bee, we collected, photographed or simply identified and released all bumble bee specimens. In addition, we recorded plants species being visited by all bees to assess floral preference. We are currently databasing, curating, and identifying specimens.

This project had a novel, multi-tiered mentorship program. Drs. Cariveau and Rodgers mentored two University of Minnesota undergraduate students. These students received their own funding through the Undergraduate Research Opportunity Program at the University of Minnesota. In addition, the City of Minneapolis recruited two Urban Scholars to participate in sampling. The Urban Scholars program provides mentorship and funding to undergraduate students from diverse backgrounds to conduct scholarly work with the City of Minneapolis. Drs. Cariveau and Rodgers also recruited a Step-Up student. The Step-Up program is aimed at providing internships to high school students that experience barriers to employment.

Project Status as of March 15, 2018

We are finishing curating and identifying specimens from this past summer. Nearly all species have been identified to genus and many to species. In total, we collected a total of 2647 specimens and 19 different bee genera. Of those 720 were collected in pollinator plantings and 1927 in community gardens. We are working to identify plants from photographs. A number of these plants were challenging to identify as they were ornamentals or weeds and there are not books available for identification.

Project Status as of November 15, 2018

We conducted a second field season to assess bee diversity and abundance in urban areas and community gardens. This resulted in approximately 1,000 new specimens. For all specimens, we have recorded which flower species the native bee was visiting. We have finished the identification of all of these specimens and have nearly 115 species recorded from 3200 specimens. These specimens are currently being added to the database. Using these and all data collected from funding in Activity 3, we will create a plant list of preferred flower species. In addition, we have acquired seed costs for a good number of these plants and cost and logistics information (i.e. establishment) will be included in these plant recommendations. Using the specimens and plant data collected from the 2017 and 2018, we are in the process of writing a manuscript for a peer-reviewed

journal.

Final Report Summary: June 30, 2019

We collected data from nearly 45,000 plant by bee interactions. This included databases from the Cariveau Lab as well as neighboring states. We then limited this to plant species found in seed mixes. We then ranked the top four plant species per three bloom periods (early, mid, late) based on the number of bees collected from each plant. The plants are listed below. These findings were also used to construct a large multi-species seed mix experiment with funding from the Foundation for Food and Agriculture Research. This project began in the fall of 2018 and will continue through 2020.

Family	Common Name	Scientific Name	Bloom Time
Apiaceae	Golden Zizia	*Zizia aurea*	Early
Asteraceae	Philadelphia fleabane	*Erigeron philadelphicus*	Early
Asteraceae	Lanceleaf Tickseed	*Coreopsis lanceolata*	Early
Asteraceae	Common Yarrow	*Achillea millefolium*	Early
Asclepiadaceae	Butterfly Milkweed	*Asclepias tuberosa*	Mid
Asteraceae	Pinnate Prairie Coneflower	*Ratibida pinnata*	Mid
Asclepiadaceae	Swamp Milkweed	*Asclepias incarnata*	Mid
Verbenaceae	Swamp Verbena	*Verbena hastata*	Mid
Asteraceae	New England Aster	*Symphyotrichum novae-angliae*	Late
Campanulaceae	Great Blue Lobelia	*Lobelia siphilitica*	Late
Asteraceae	Stiff Goldenrod	*Oligoneuron rigida*	Late
Asteraceae	Blackeyed Susan	*Rudbeckia hirta*	Late

We have incorporated these data into a large-scale MySQL database. The Cariveau Native Bee Lab has created a protocol for data entry and data quality. We have developed data standards and implemented metadata. The database is open to all members of the Cariveau Lab and other studying native bees in Minnesota. Once students and postdocs have published the results of their research, we will make those data available to the general public and other scientists. This database is also informing the list for Minnesota bees. Zach Portman, PhD, a taxonomist and Joel Gardner (currently a PhD student at University of Manitoba focusing on native bee taxonomy) re-identified the specimens for our databases. This is critical as past identifications were done were not by professional taxonomists and there were a number of errors. Therefore, we have one the best sampled and most highly resolved native bee by plant interaction database in the United States.

We were able to assess pollinator use of plants in urban areas. First, we created pollinator plantings. Second, we sampled native pollinators from community gardens in the Twin Cities Metro Area. This project was led by Aaron Irber who mentored college students from the Urban Scholars Program and high school students from the step-up program. The field crew collected 3113 bee specimens from 114 species. In addition, we found a specimen of Pseoudoanthidium nanum (family: Megachilidae). This is an exotic species that was first detected in New Jersey in 2008, in New York and Maryland in 2013 and 2014, respectively, and then again in Ohio in 2017. This specimen was the first record collected in Minnesota. It could become an invasive species and this record will be vital to understanding the spread of this species. As this was such a unique find, we wrote a manuscript that has been accepted for publication in the Great Lakes Entomologist. A second study used species planted in

the large containers to assess pollinator visitation. We found that two species: Swamp Milkweed (Asclepias incarnata, family: Asclepiadaceae) and Virginia Mountain Mint (Pycnanthemum virginianum; family: Lamiaceae) were the most visited plant species (see Figure 3.1 above).

Morgan Carr-Markell has completed her research on pollen collection by honey bees near native prairie restorations. As part of her research, Morgan recorded the waggle dance of honey bees. She used the duration and angle to create a probability density cloud to determine where the bees where foraging. In addition, from a subset of foragers, she collected pollen being carried by the worker. She then identified that pollen using light microscopy and NextGen Sanger sequencing. From the probability density clouds, Morgan found that honey bees did not forage on prairies for much of the year. The exception was at one site where honey bees visited a prairie in the late summer. These foragers were primarily collecting pollen from Goldenrods at this time. The pollen analysis showed the honey bees preferred non-native species including Alsikie/White Clover (Trifolium repens/hybridum; family: Fabaceae), Bird's-foot Trefoil (Lotus corniculatus; family: Fabaceae) and Yellow Sweet Clover (Melilotus officinalis; family: Fabaceae). The honey bees did visit some native prairie plants including Goldenrods (Solidago spp.; family: Asteraceae), Purple Prairie Clover (Dalea purpurea, family: Fabaceae), Hyssop (Agastache sp., family: Lamiaceae), White Prairie Clover (Dalea candida, family: Fabaceae), Ragweed (Ambrosia spp., family: Asteraceae), Partridge Pea (Chamaecrista fasciculata, family: Fabaceae), and species in the Asteraceae family and tribe Heliantheae. This species was most likely a species in the genus Rudbeckia (e.g. Blackeyed Susan (Rudbeckia hirta)). These results will help inform how to best create habitat for honey bees and native bees. A key next step will be to better design habitats that are tailored to either domestic or native bees.

We are completing the final stages of assessing pollen use of two native bee species on prairie sites. Alan Ritchie, MSc student, collected pollen from two species of native bees: a species of green sweat bee, Augochlorella aurata (family Halictidae) and a species of long-horned bee (Melissodes trinodis). Alan collected a total 39 A. aurata pollen samples from 6 sites and 12 M. trinodis samples from 6 sites. He also collected 59 flowering plants to create a plant library. This library contains genetic sequences from known plants and thus is used to identify what is in the pollen load. We are still in the process of cleaning the large dataset and Alan will be incorporating this research into his thesis in which he will defend in December 2019. This project has been funded by United States Department of Agriculture.

ACTIVITY 4: Wild Bee Nesting Sites

Description: Pollinators need floral resources during the growing season but also need nesting sites for reproduction and over-wintering. Therefore, management of areas that are designed to help pollinators must provide for nesting, and again very little is known about that topic. Many bee species nest underground but approximately 30% nest in stems, trunks, and other parts of the above-ground vegetation. Spring burning or fall harvesting of biomass can interfere with above-ground nesting sites and other practices such as grazing could conceivably interfere with below-ground sites. This activity will begin to identify and document plants and plant communities that provide nesting and overwintering sites, especially for Minnesota's cavity-nesting native bees, and provide ideas and advice to moderate possible damage to those sites.

The first fall, we will examine senesced aboveground vegetation characteristic stem diameters that could be used by wild bees and create a database of the sizes and characteristics of vegetation that contains evidence of overwintering pollinators. Subsequently we will also create "trap nests" using natural vegetation that bees would encounter in the area. These new forms of trap nests will be made from remnant plant stems of various species, some placed and oriented vertically to simulate standing vegetation and some horizontally to simulate vegetation that has been crushed down. We will place the trap nests in sampling areas and record which plants are used and the overall presence and when possible, the species identification of stem nesting bees. We will also test methods of visual surveys, such as examining hollow plant stems with a miniature

borescopes to determine if they are being used as nest sites.

The areas selected for study in this activity will correspond where possible with other activities on the project, but additional areas where we, members of the DNR, or others have encountered and reported stem-nesting bees will also be candidates for survey. Results will be part of the recommendations on plants species to benefit pollinators.

Summary Budget Information for Activity 4:

ENRTF Budget: $136,895
Amount Spent: $136,995
Balance: $ 0

Activity Completion Date: June 30, 2018

Outcome	Completion Date	Budget
1. Investigate plants and plant communities that provide nesting and overwintering sites for Minnesota's native bees	June 30, 2017	$136,895
2. Senesced aboveground vegetation surveyed and database of the contents created	Dec 15, 2014	
3. Traditional and innovative trap nests placed in the field to begin surveys.	June 15, 2015	
4. Visual survey methods examined.	Aug 15, 2016	
5. Bees inhabiting "trap nests" made from natural vegetation evaluated.	June 30, 2017	
6. Recommendations to eliminate or moderate possible damage to overwintering native bee sites and lists of plant species that benefit stem-nesting pollinators.	June 30, 2017	

Activity Status as of December 15, 2014

Pollinator grassland plantings provide both food for bees and nesting substrates. Generally, little soil disturbance occurs in grassland management, but many regimes include the removal of vegetation, which could contain nests of stem nesting bees. Colleen Satyshur (Masters degree in Biology) was hired to identify and document plants and plant communities that provide nesting and overwintering sites for Minnesota's cavity-nesting native bees. She began by determining if bee nests could be found during visual searches. If nests could be found, they would give us preliminary information on bee species, stem characteristics and plant species that are used as nests. During late summer, 2014, visual searches for nests in grassland plant stems were conducted opportunistically in established grassland plots near the UMN Saint Paul Campus, in three prairie restoration companies outside the metro, and in two private residences. We collected 341 potential bee nests in 28+ different plant species. 111 of these stems have been opened and bee nests documented. Stems collected during July and August were more likely to contain a live adult bee along with any nesting activity in progress. Later collections generally are yielding completed nests with any bees (or wasps) in pre-pupal or pupal stages in which they would presumably pass the winter. These pre-pupae and pupae cannot be easily identified so we are attempting to rear bee nests to determine bee species when they emerge as adults.

In the coming growing season, we plan to test bee nesting preference in different plant species. Stems will be presented either by snipping already present dead stems from the previous year or by placing previously collected stems in grassland plantings as trap nests, a presentation of stems used to attract stem nesting bees. In preparation for this we collected stems from 24 different grassland forbs at the end of the growing season. Trap nests from these stems will be prepared during this winter and will be placed in the field in early spring. Information recorded from nests collected this past summer and fall, such as stem diameter and nest length, will be used to guide trap construction.

Not all grassland plants are suitable for stem-nesting bees. Documenting the physical characteristics of grassland plants and comparing them to characteristics in stems containing bee nests will aid in predicting other plant species to test as potential nesting habitat for stem nesting bees. We have begun to database grassland stem characteristics that could influence their suitability to wild bees, such as stem diameter, presence of pith, and thickness of the cortex.

Activity Status as of August 15, 2015

Stem containing possible nests and collected in 2014 continued to be opened and nests reared through May 2015. Bee nests were found in approximately 50 stems and represent at least 8 bee species, 11 native grassland plant species and 3+ non-native grassland plants. This data provided us with range of nest lengths and opening diameters that we used to plan methods for the stem nesting choice arrays run this summer (see below). Stems continue to be collected in 2015 at a more limited pace.

Stem nesting choice arrays were set up and run in growing season 2015. Stems of 2014 growing season that were collected at restoration companies in fall 2014 were cut to length and the diameters of the pith and woody portion measured. Selected species and diameter classes were used for stem choice arrays. Three arrays were set up in April 2015. Two were established on the UMN-Saint Paul campus in agriculture plots planted in grassland mix prior to 2009 and left largely undisturbed since. During opportunistic nest collection in these plots we found representatives of all of the different bee taxa found to date in stems so these plots were a good location to test nest substrate preference. One array was set up at Belwin Conservancy near Afton, MN at a restored prairie and represents a larger grassland than the campus plots. Twenty-one species of native grassland forbs were used in arrays. With four possible diameter classes and three replicates per diameter class per plant species were present this yielded 46 different plant-diameter combos. Stems were monitored weekly for signs of nesting by looking for active pith excavation and by using an otoscope that allowed view of the top 1-3 inches of each hollow stem. The otoscope is a new method for observation that we have been testing and it has proved useful. Any bees seen in stems were recorded. It was often possible to identify the genus and gender without disturbing the bee. Vouchers or photographs were obtained when possible. Female bees were disturbed as little as possible to allow nesting. Stems displaying definite evidence of nesting by any arthropod, including spiders and ants, or stems displaying conditions that were unclear were collected and opened and nests were documented. A new stem of the same type was then placed in their location. In the case of stem occupancy by a bee, an additional stem was added to the array in a randomly selected location until such time as the original stem was no longer occupied. At all times we strived to maintain 3 available stems of each type in each array. Active nesting is still happening at the date of this report and arrays are still being monitored and maintained. We anticipate nesting will discontinue around October. Stems with nests have been reared in the lab to capture occupants. Some nests will need to be reared through the winter to document contents as many bees overwinter in pre-pupal stage and cannot be readily identified.

In addition to the arrays we took advantage of an opportunity to work in two pollinator gardens on campus. These gardens were planted by the Monarch Lab (Dr. Karen Oberhauser), and contain many native plants as well as some cultivars and non-native garden plants. Growth from 2014 was left standing in these gardens over the winter and we obtained permission to cut some stems and leave these standing through the 2015 growing season to monitor them for any bee use. In total we began with approximately 930 stems of 23 different plant species. These were monitored in a manner similar to the arrays on a weekly basis in early spring and summer when nesting is most intense an at least biweekly for the rest of the summer. These stems are still being monitored. These gardens provide us with a slightly different set up than arrays in that stems are in a variety of orientations and angles to the ground that reflect the growth habits of that plant species. We measured angles and lengths of stems to determine if they affected nesting preferences by bees. For all of the stem nesting studies, physical characteristics of stems collected in fall continued to be documented in spring for

beginning of a reference list.

Activity Status as of February 15, 2016

Stem nest choice array experiments were left in the field until bee activity ceased for the year as determined by activity seen in the arrays and in surveys by other portions of this project. Belwin array was brought in on 10-6-15 and St. Paul campus arrays were brought in on 10-5-15. Stems with known or potential nests continued to be reared in the lab, first at ambient and then transferred to winter incubation temperatures in late October and early November. The majority of stems have been opened to determine their nest status and stems containing emerged bee or wasp nests were pinned for reference all emerged wasps or bees pinned as well. Stems containing current nests of wasp or bee pre-pupa are being reared over the winter and will soon be brought out to warmer temperatures to promote complete development to adults.

Pollinator garden experiments successfully showed that leaving cut stems from previous years can provide nest habitat for stem nesting bees and wasps. Some of these wasps collect hundreds of aphids for their young and would also provide a benefit to gardeners. All cut stems were collected by 10-29-15 and brought into the lab for rearing. They are receiving the same treatment as stems from the choice arrays. The majority of these stems have also been opened, old nests pinned, any emerged bees or wasps pinned and active nests placed in winter storage temps, as with choice arrays. Gardens will not be used as experiments next year but will be used as an education resource.

In 2016, we will be conducting a study to determine which plants are most used by stem nesting bees. Further, we will study whether plant height has an effect on bee use of stems for nesting. This is important as it will inform decisions about mowing regimes. Mowing is a common management strategy in reconstructed prairies and the results of this work will determine best mowing height for stem nesting bees.\

Activity Status as of September, 2016

Large nest-stem choice arrays were installed in three locations on April 14th, 18th and 22nd, 2016. These arrays are still in the field at the date of this report. One array was placed on the UMN campus agricultural fields in a grassland plot. The other arrays are set in Shakopee Mdewakanton Sioux Community Buffalo Pasture alluvial flood plain and in Saint Croix Savanna Scientific Natural Area. Both of these high-quality restored grasslands contained native flowering plants and were predicted or documented to have high numbers of stem nesting bees. Each array is comprised of 320 stems of 4 different grassland forb species. Each species is divided into 2 stem diameter size classes and placed at 2 different heights off the ground. The higher stem height matches height used last summer while the low height (20 cm) was chosen to mimic a reasonable grassland management conservation mowing height. The forb species represent the species most used for nesting during the previous year. Up until this season, this project only experimented with forb species. However, information gained from incidental nest collections during this project indicate that grasses may be used so we implemented an additional array on the University of Minnesota Twin Cities campus this summer to further explore the viability of grasses as bee nest sites.

The first half of the nesting season has been highly successful with over 75 nests currently being reared in the lab. We continue to pin emerged adult bees and wasps and completed nests. Field nest-stem choice arrays will be run until bees stop flying for the year-likely early October. Lab activities of rearing bees and opening and pinning bees and nests, identifying bees and entering and analyzing data will continue until all nests have emerged next summer.

The large number of nests collected to date is very promising and our project is showing indications of several interesting results. This year we collected 2 nests of a leaf cutter bee, *Megachile* species, which we have not previously recorded nesting in stems. Additionally, common knowledge is that most stem nesting bees in Minnesota have 1 generation per year, but data from our project indicates that several species in the genus

Hylaeus have 2 generations per summer and the *Megachile* species may have up to 3 generations per summer.

For education purposes, campus pollinator gardens stems were cut April 4th, 2016 and stems in the MN Horticulture Display garden were cut April 1st, 2016, thus exposing new garden managers and patrons to the idea of dead stems supporting healthy bee populations.

Activity Status as of March 15, 2017

Stem nest choice arrays were removed from the field on 10/19/2016 for St Croix, 10/21/2016 for Shakopee, and 10/24/2016 for St. Paul Campus. There are currently 144+ bee nests and 109+ wasp nests being reared in two incubators on campus. The temperature in the incubators will be incrementally raised this week in order to start warming the nests for emergence. Wasps and bees that have emerged over the past summer from the early season nests have been pinned and identification is in process. There are over 750 specimens pinned, of which 226 are bees. Data collected from the summer are being prepared for statistical analysis, but the final data will not be completed until all of the bees have emerged from their over-wintered stems and are pinned and identified. We are exploring possibility of identifying vegetation in bee's nests with DNA analysis that would be funded by other sources. Vegetation from 30+ bee nests has been collected for this pilot project.

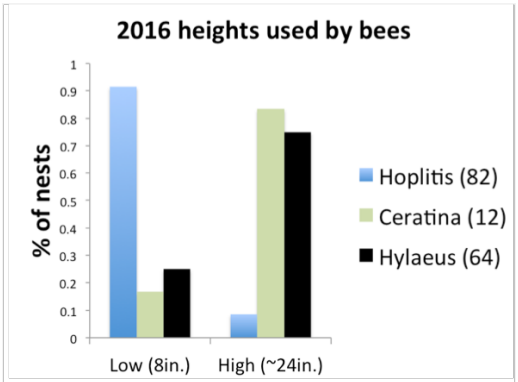

Figure 4.1. Preferences, based on percentage of recorded among bee genera for low and high nest heights. Bees were given a choice of two stem heights for nesting.

Project Status as of September 15, 2017

All bees collected in 2016 were identified to species. We are still identifying non-bees such as wasps. All specimens are being prepared to vouchering to University of Minnesota Insect Collection. Overall, we found large differences in preference among bee species to different heights of nests (Figure 4.1). One genus, *Hoplitis*, preferred low nests with over 90% of nests of this genus in stems approximately 8 inches off the ground. In contrast, the two genera, *Ceratina* and *Hylaeus*, preferred higher nests with approximately 85% and 75% of nests in stems approximately 24 inches off the ground (Figure 4.1). We are currently working on the statistical analyses of these results and have begun writing up the results for a scientific publication. In addition, we are preparing an outreach publication for gardeners on how to best manage for stem nesting bees.

Colleen Satyshur used the findings of Activity 4 to successfully acquire a University of Minnesota Futures grant for a total of $220,000; thus we are able to reduce her salary allotted to this Activity. We hired a new Research Assistant to conduct statistical analysis and publication writing. This work will focus on merging science and art to inform and excite the public regarding native bee nesting and conservation. In addition, this proposal will fund research to understand which plant species stem nesting bees are using to line their nests.

Project Status as of March 15, 2018

We are nearly finished with the statistical analysis and have been writing up the manuscript for publication. The patterns of nest height preferences seem to be robust after analyses and we are looking forward to submitting this to a peer reviewed journal in 2018.

Project Status as of November 15, 2018

We have completed the statistical analysis for this research and have begun writing a paper to be

submitted to a scientific publication.

Final Report Summary: June 30, 2019

This activity was focused on determining how to best create and manage nesting habitat for stem-nesting bees. The overwhelming majority of research on native bee communities is focused on bees visiting flowers. However, bees are central place foragers and the nest is a critical component of a bee's survival and reproduction. The lack of studies on nesting biology are due to the challenge of conducting nesting studies. This activity was focused getting more information on how plant species, mowing height, and plant stem diameter affected nesting choice of bees. We chose four plant species based on surveys: New England Aster (Symphyotrichum novae-angliae), Rocky Mountain Blazing Star (Liastris ligulistylis), Bee Balm (Monarda fistulosa), and Stiff Goldenrod (Oligoneuron rigida). We placed broken, dead stems of these species in an array. For each plant species, we set plant height at 20 cm or 60 cm. This represents common mowing heights for conservation mowing. We selected plants that stems from each plant with a narrow (3 – 4 mm) or wide (4-5 mm) diameter. Each of the these three treatments (plant species, plant height plant width) were replicated 20 times each for 320 stems per array. We constructed a total of 3 arrays.

We found a number of bee species in the stems. As is common with most native bees, common names are not used for these species so we use scientific names. The most abundant bees were those in the genus Hoplitis (family: Megachilidae) with 82 nests. Of those nests, 36 were H. polisifrons. We also found one H. producta and one H. truncata. The other nests we were not able to identify to species. The second most abundant group was those in the genus Hylaeus (family: Colletidae) with 41 nests. Hylaeus mesillae comprised 39 of those nests with the two other probably being Hylaeus rudbeckiae. The third most abundant where Stelis lateralis (family: Megachilidae). However, this species is a cleptoparasite of H. polisifrons and H. producta so it is not constructing nests but laying eggs on the pollen balls of their hosts. The larvae of the this cleptoparasite kill the host larvae and then consume the pollen. We found 11 nests of bees in the genus Ceratina (family: Apidae) including C. mikmaqi (8) and C. dupla (3). Finally, we found two nests for Megachile brevis (family: Megachilidae).

We were able to conduct statistical analysis for two genera: Hoplitis and Hylaeus. We did not have a large enough sample size for the other species. We lumped all species into one group for analysis. We found that Hoplitis preferred stems of a larger diameter ($p=0.0002$) and stems of low height ($p=0.0002$). We did not find an effect of plant species. Hylaeus preferred stems of low height ($p = 0.005$). They also strongly preferred Monarda fistulosa over the other three plant species ($p<0.001$). This work provides important information for creating nest habitat for stem nesting bees. First, we suggest that land managers and home owners keep dead plant stems for these bees. In particular, Bee Balm is a particularly good plant. In addition, land managers and home owners can clip dead stems at a height of 20 cm. This can inform mowing standards for large-scale habitat projects. For homeowners, they need not leave up tall stems in gardens and pollinator plots. Dead stems are often not preferred by landowners as they can look unseemly. Being able to reduce the height may increase landowners' willingness to keep dead stems for these species. We are still writing a final version of this research for publication. It is nearly finished. The results from this study are being incorporated into our outreach and extension materials.

V. DISSEMINATION:

Description: With the hiring of a new faculty member who specializes in pollinator biology and ecology, we will form a statewide working group to foster collaboration and coordination of all surveys and studies of pollinators and pollinator habitat. We will work closely with MN DNR, MN NRCS, Pheasants Forever, other state agencies and interested associations to construct a database of MN bees, landscape maps and assessments,

demonstration sites, best management practices, peer-reviewed scientific papers, and long-term plans for sustaining pollinators and helping Minnesota beekeepers. Results will provide tangible ways that private land owners and public land managers can provide pollinator habitat for MN insect pollinators. The project will provide examples for other states in our region to adapt and expand.

Status update as of December 15, 2014

We have begun coordination of efforts and collaborations with other statewide agencies on pollinator and habitat projects. On May 21, 2014 the DNR hosted a meeting comprised of 25+ people from 8 different organizations that are conducting 9+ different projects on pollinators in Minnesota. This meeting was attended by staff from LCCMR. A second meeting will be held on January 22, 2015 at The Minnesota Zoo, also to be attended by LCCMR staff. Below is the list of people and agencies that attended or are part of the collaboration.

Organization	Names	Projects
MN DNR	Carmen Converse, Crystal Boyd, Gerda Nordquist, Bob Welsh, Robert Dana	ENRTF 14-006-Wild Bee Surveys in Prairie-Grassland Habitats, ENRTF 14-017-A Prairie Butterfly Conservation, Research and Breeding Program, and 2013 Pollinator Habitat Bill
MDA	Kevin Cavanaugh and Greg Regimbal	2013 Pollinator Habitat Bill
Minnesota Landscape Arboretum	Peter Moe and Sandy Tank	ENRTF14-073-C Bee Discovery Center at the Minnesota Landscape Arboretum
Minnesota Wildflowers	Katy Chayka	ENRTF 14-020-A Expand the Minnesota Wildflowers Online Botanical Reference - MN Wildflowers Info
Minnesota Zoo	Tara Harris, Cale Nordmeyer, Erik Runquist	ENRTF 14-017-A Prairie Butterfly Conservation, Research and Breeding Program
Pheasants Forever	Matt Holland	ENRTF 14-072-C Minnesota Pollinator Partnership
University of Minnesota	Elaine Evans, Colleen Satyshur, Joel Gardner, Marla Spivak, Vera Krischick	ENRTF 14-146-F Enhancing Pollinator Landscapes, ENRTF 14- 151-F Protecting Bees by Understanding Systemic Insecticides

Status as of August 15, 2015

Colleen Satyshur organized another LCCMR pollinator projects update meeting on Jan 22, 2015 at the Minnesota Zoo. Presentations were made by Elaine Evans-Enhancing Pollinator Landscapes, Vera Krischik-Understanding Systemic Insecticides as Protection Strategy for Bees, Sandy Tanck-Pollinator Education Center at the Minnesota Landscape Arboretum, Matt Holland-Minnesota Pollinator Partnership, Erick Runquist and Robert Dana-Imperiled Prairie Butterfly Conservation, Research and Breeding Program, Crystal Boyd- Wild Bee Pollinator Surveys in Prairie-Grassland Habitats, Kevin Cavanaugh-2013 pollinator habitat bill MDA, Bob Welsh-2013 pollinator habitat bill DNR. The group decided to try to meet 2 times a year-avoiding field seasons, and to have longer presentation times per group and to include recipients of LCCMR graphs from different years that were also working on pollinators.

A bee identification course, "Tallgrass Prairie Bees: An Identification Training Workshop" was held, January 12-16, 2015. It was funded by the MN Department of Natural Resources and an IonE minigrant from UMN and organized by this grant staff and DNR staff. There were 21 class participants from 15 organizations. A

new MN state bee record was found. The Research lecture drew 50 participants and the outreach talk 45 participants and the mixer was attended by 24 people, including eight people who were not class participants such as Representative Jean Wagenius and staff from The Nature Conservancy, the Minnesota DNR and the University of Minnesota.

Dan Cariveau has begun to work with multiple entities including the University of Minnesota Entomology Museum, Minnesota DNR and other data holders to develop and encourage the adherence of database and data management protocols. This will ensure that the results of this research and other ENTRF funded native bee research is reliable, well-verified and publicly accessible.

Status as of February 15, 2016

Colleen Satyshur organized an LCCMR pollinator projects update meeting Nov 3, 2015 at the UMN-Saint Paul campus. Moderated by Dan Cariveau, presentations were made by: Dan Cariveau-Enhancing pollinator landscapes, Vera Krischik-Understanding Systemic Insecticides as Protection Strategy for Bees, Sandy Tanck-Pollinator Education Center at the Minnesota Landscape Arboretum, Ian Lane- Pollinator Habitat Enhancement, Karen Oberhauser -Effects of Grazing Versus Fire for Prairie Management, Britt Forsberg -Minnesota Native Bee Atlas, Erik Runquist and Robert Dana-Imperiled Prairie Butterfly Conservation, Research and Breeding Program, Crystal Boyd-Wild Bee Pollinator Surveys in Prairie-Grassland Habitats, Kevin Cavanaugh- MDA Update on 2013 Pollinator Habitat Bill, Wiley Buck and Sarah Foltz Jordan and Oakley Biesanz- Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation. Two groups were not able to attend but sent updates: Matt Holland-Minnesota Pollinator Partnership and Dan Shaw- BWSR Update on Pollinator initiative. This was a larger meeting than in the past with projects from M.L. 2013- M.L. 2015. It was decided to hold another meeting in Fall 2016 and that smaller topic specific break-out groups may arrange among themselves to meet in early 2016. One such meeting has already been held on research methods, arranged by Karen Oberhauser, and was attended by project personnel.

Colleen and Morgan Carr-Markell gave an interview to the Woodbury Bulletin about research at Belwin. http://www.woodburybulletin.com/news/region/3797835-u-m-researchers-study-bee-population-belwin-conservancy Colleen provided photos from this project to MN Landscape Arboretum for new pollinator exhibit (LCCMR funded project M.L. 2014 09f)

Dr. Cariveau has spoken at a number of events. This includes the Minnesota Department of Agriculture Pollinator Summit as well as a webinar hosted by the University of Minnesota's Integrated Pest Management Webinar series (http://ncipmhort.cfans.umn.edu/)

Status as of September 15, 2016

Dan Cariveau has spoken at a number of events including the Minnesota Department of Agriculture's Pollinator Summit, Pollinator Friendly Alliance's Poll*nation Event, the University of Minnesota Landscape Arboretum's Pollinator Summit, and the Yellow Medicine Soil and Water Conservation District. Along with Marla Spivak and Karen Oberhauser, Dan was a guest on the Tom Weber show on June 27 to discuss pollinator habitat. Colleen Satyshur presented preliminary results of the stem nesting study at the University of Minnesota Landscape Arboretum's Pollinator Summit. Planning is ongoing for an upcoming meeting among PI's and participants in ENRTF funded pollinator projects for early 2107.

Status as of March 15, 2017

Colleen Satyshur and Dan Cariveau organized an annual LCCMR Pollinator Projects Update meeting held Dec 7th 2016. The meeting included recently complete, current and recently funded projects receiving funding from ENTRF related to pollinators. There were a total of 18 projects and 28 attendees. Meeting was held at the University of Minnesota Saint Paul campus. Three breakout sessions were included in this meeting to discuss

research, outreach and habitat management.

Project Status as of September 15, 2017

Dan Cariveau has given three scientific and five outreach talks that have highlighted some of the results of this proposal. Colleen Satyshur has spoken about this research to the University of Minnesota Board of Regents and has conducted a number of outreach talks. Elaine Evans is now an Assistant Extension Professor and has given three outreach talks on this work. She also conducted a webinar for Master Gardeners that highlighted the results of stem nesting work. Aaron Irber, who works with Colleen Satyshur, had a two information tables one at the stem nesting bees at Pollinator Symposium at the Arboretum and a second at the Pollinator Party hosted by Pollinate Minnesota.

Project Status as of March 15, 2018

We have given a number of outreach events. Elaine Evans has given five outreach talks using the findings from this grant. These include a number of webinars as well as outreach talks for Master Gardeners. Aaron is scheduled to conduct outreach in the coming months. Colleen Satyshur and Dan Cariveau have been collaborating to conduct a meeting for ENRTF pollinator related projects. This meeting will take place in March 2018.

Project Status as of November 15, 2018

We have presented the results from the funding. In March, we hosted a symposium on pollinator projects funded by ENRTF. There was a total of 21 presentations from 15 agencies or organizations. Dan Cariveau has presented results at the Bell Museum's Café Scientifique in September and University of Minnesota Arboretum's Pollinator Symposium in October 2018. Elaine Evans along with the Department of Natural Resources organized and led a bee identification course. There were 16 people in attendance from 10 organizations. This event also had a research lecture in which 50 people attended. Dr. Evans also presented results from this funding at the Minnesota Native Plant Society, the Upper Midwest Regional Master Gardner's Conference, the Mississippi River Green Pollinator Ambassadors program, University of Minnesota Pollinator Party and the Ecology Fair at the University of Minnesota's Coffman Memorial Union.

Final Report Summary: June 30, 2019

Using this funding we were able to reach a wide array of audiences. For one, we held a total of four organizational symposia that focused on ongoing pollinator work being funded by the Environmental and Natural Resources Trust Fund. At these symposia, individuals with projects funded through ENRTF discussed the scope, results and importance of their findings. A major goal of these symposia was to prevent overlap and encourage collaboration. Therefore, we also held break-out sessions at these meetings and discussed new project ideas along with how to share results from current research. These symposia typically involved 15 – 20 presentations with 30-50 participants. Staff and LCCMR members attended a number of these symposia. In addition, we presented nearly 30 outreach talks and 3 scientific presentations that focused on the research being conducted from this proposal. Some of these talks included large audiences and were broadcast widely, such as interviews with the Minnesota Public Radio. In addition we also spent the summer of 2017 managing a novel, multi-tiered mentorship program. Drs. Cariveau and Rodgers mentored two University of Minnesota undergraduate students. These students received their own funding through the Undergraduate Research Opportunity Program at the University of Minnesota. In addition, the City of Minneapolis recruited two Urban Scholars to participate in sampling. The Urban Scholars program provides mentorship and funding to undergraduate students from diverse backgrounds to conduct scholarly work with the City of Minneapolis. Drs.

Cariveau and Rodgers also recruited a Step-Up student. The Step-Up program is aimed at providing internships to high school students that experience barriers to employment. Finally, we created an outreach document titled Nesting Habitat for Stem Nesting Bees. All of the content of this document is compiled and the design is being finalized.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 784,000	1 Asst Professor at 90% FTE for 3.3 years; 1 post-doctoral researcher at 1 FTE for 3 years; 1 research coordinator at 1 FTE for 3 years; 1 Entomological specialist/research asst at 50% FTE for 2 years, 4 research technicians at 30% FTE each, 2 years each.
Equipment/Tools/Supplies:	$ 23,000	Supplies for collecting, pinning and curating insects, insect nets, stem-trap nests, voice recorders, flagging, meter tape, planting of common gardens, plants, shovels, use of truck with water tank, etc.
Printing:	$ 12,500	Preparation of printed extension materials for dissemination, plus peer-reviewed publication at standard open access fees
Travel Expenses in MN:	$ 42,500	Travel to field sites to conducts surveys, and collecting bees on common gardens; travel to assemblies/ meetings to share research and results
Other:	$ 2,000	Specialized pollinator training for staff; estimated reached by researching fees for courses and training materials.
TOTAL ENRTF BUDGET:	**$ 864,000**	

Explanation of Use of Classified Staff:
Explanation of Capital Expenditures Greater Than $5,000:
Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 12.5 FTE
Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: NA

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			

General Mills, research donation to M. Spivak, cash support	$ 50,000	$50,000	Funds will be used toward establishing a pollen reference library. Pollen collected from bees in Activity 3a and b, and supplies for pollen ID will be identified by personnel hired on General Mills funds.
State			
University of Minnesota: College of Food, Agriculture and Natural Resource Sciences (CFANS) and College of Biological Sciences (CBS)	$ 325,000	$266,289	In-kind "start-up" funds for new faculty member; standard amount to equip a new lab and begin research; see letter of support from Dean Levine (CFANS) and Dean Elde (CBS)
TOTAL OTHER FUNDS:	**$375,000**	**$316,289**	

VII. PROJECT STRATEGY:

A. Project Partners:

Marla Spivak, Professor in Entomology, U MN is project manager and will be responsible submitting project reports. **Clarence Lehman,** Associate Dean for Research in the College of Biological Sciences and Professor in Ecology, Evolution and Behavior, U MN, with M. Spivak will lead the search and hiring for a new faculty position related to this project. This faculty position will include research responsibilities on a basis of 70% time, to help expand our base of knowledge about pollinators, and also teaching responsibilities at 30% time to educate others and train the next generation in methods relevant to pollinators and the project. Two University of Minnesota colleges, CFANS and CBS, will supply space and collegiate support. Together with that new faculty member, M. Spivak and C. Lehman will oversee the research and outreach activities and will be responsible for administration of funds and the direction of employees. Entomological specialists **Elaine Evans, Colleen Satyshur**, and **Joel Gardner** will be key participants. M. Spivak will contribute in-kind expenses toward the analysis of pollen in her lab, and both M. Spivak and C. Lehman will contribute time to the project, funded by other sources.

B. Project Impact and Long-term Strategy:

The current, widespread decline of pollinators has become critical and threatens our supply of fruits and vegetables. The causes of decline of honey bees and wild, native bees are not completely known, but include fewer flowers, increased disease and pests, more insecticides, and loss of nesting sites. Fortunately, the present crisis for pollinators comes at a time when society recognizes the severity of the problem and is motivated to act to improve pollinator resources and environment. The goal of this project is to enhance pollinator habitat by providing new and reliable supplies of nectar and pollen for wild bees and honey bees, across the entire growing season in key beekeeping regions of Minnesota. This project will help create a new and critically needed interdisciplinary faculty position to lead and coordinate the research proposed here, and to help consolidate and accelerate the many other pollinator efforts that are ongoing and planned in this state. Improving conditions for pollinators will also improve conditions for birds and other wildlife, reduce soil erosion, improve water quality, and further beautify the landscape of Minnesota.

C. Spending History:

Funding Source	**M.L. 2009 or**	**M.L. 2011 or**	**M.L. 2013**

	FY10	FY12-13	or FY14
USDA-NIFA (M. Spivak PI) for 3 year study in Prairie Pothole Region of ND on "Influence of mid-continent land-use trends on floral diversity and pollen availability to sustain bee health, diversity and ecosystem services"	$499.044		
General Mills Research donation to reference library for honey bee collected pollens (M. Spivak PI)		$150.000	
ENRTF for Bee Pollinator Habitat Enhancement (Bee Lawns) (M. Spivak PI)			$200.000

VIII. ACQUISITION/RESTORATION LIST:

IX. VISUAL ELEMENT or MAP(S): See attached.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET:

XI. RESEARCH ADDENDUM:

XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than December 15, 2014, August 15, 2015, February 15, 2016, September 15, 2016, March 15, 2017, September 15, 2017, March 15, 2018, November 15, 2018; A final report and associated products will be submitted between June 30, 2019 August 15, 2019.

Environment and Natural Resources Trust Fund
M.L. 2014 Project Budget
Project Title: Enhancing Pollinator Landscapes, 146-F
Legal Citation:M.L. 2014, Chp. 226, Sec. 2, Subd. 06a and M.L. 2015, Chapter 76, Section 2, Subdivision 19
Project Manager: Marla Spivak
Organization: University of Minnesota
M.L. 2014 ENRTF Appropriation: $864,000
Project Length and Completion Date: **5** years, June 30, 2019
Date of Report: Amendment Request

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Sep 30, 2019: Activity 1 Budget	Amount Spent	Activity 1 Balance	Sep 30, 2019: Activity 2 Budget	Amount Spent	Activity 2 Balance	Sep 30, 2019: Activity 3 Budget	Amount Spent	Activity 3 Balance	Sep 30, 2019: Activity 4 Budget	Amount Spent	Activity 4 Balance	Sep 30, 2019: Total Budget	TOTAL BALANCE
BUDGET ITEM	**Pollinator Ecologist: New UMN Faculty**													
Personnel (Wages and Benefits)	$ 339,144.00	$339,144.00	$0.00	$221,469.00	$221,469.00	$0.00	$144,190.00	$143,956.25	$233.75	$131,318.00	$ 131,318.00	$0.00	**$836,121.00**	**$233.75**
New UMN Assistant Professor:, $329,144 ($67% salary + 33.11% benefits) 90% FTE for 3.3 years														
Elaine Evans, Post-doctoral researcher: $170,360 (66.4% salary + $33.6% benefits)1 FTE for 3 years, Activity 2														
Colleen Satyshur, Research Coordinator: $179,011 (66.4% salary, 33.6% benefits), 1 FTE for 3 years, Activities 2 and 3														
Joel Gardner, Entomological specialist and research assistant: $44,073 (66.4% % salaray, 33.6% benefits), 2 years, 0.5FTE, Activity 2 and 4														
Research technicians: $46,059.75 (92.6% salary, 7.4% benefits), 4 months/year, 2 years,4 individuals/year, Activities 2 and 3.														
Equipment/Tools/Supplies														
Supplies for collecting, pinning and curating insects, insect nets, stem trap nests				$ 5,000.00	$ 5,000.00	$0.00	$ 1,000.00	$ 1,000.00	$0.00	$ 2,400.00	$ 2,400.00	$0.00	**$8,400.00**	**$0.00**
Field equipment: voice recorders, flagging, meter tape, etc							$ 913.00	$ 913.00	$0.00				**$913.00**	**$0.00**
Set up common gardens: cost of plants, pots, shovels, rental of semi for transporting pallet-planters or rental of water truck							$ 5,100.00	$ 5,100.00	$0.00	$ 500.00	$ 500.00	$0.00	**$5,600.00**	**$0.00**
Printing														
Peer reviewed publications at standard open access fees: $1,500 each				$ -		$0.00			$0.00	$ -		$0.00	**$0.00**	**$0.00**
Design and printing Extension Materials				$ -		$0.00			$0.00	$ -		$0.00	**$0.00**	**$0.00**
Travel expenses in Minnesota														
Travel to field sites for conducting surveys and collecting bees and planting common gardens				$ 2,405.00	$ 2,405.00	$0.00	$ 7,689.00	$ 7,689.00	$0.00	$ 2,677.00	$ 2,677.00	$0.00	**$12,771.00**	**$0.00**
Travel to assemblies in Minnesota to share research and results				$ 195.00	$ 195.00	$0.00	$ -	$ -	$0.00	$ -		$0.00	**$195.00**	**$0.00**
COLUMN TOTAL	**$ 339,144.00**	**$339,144.00**	**$ -**	**$ 229,069.00**	**$229,069.00**	**$ -**	**$ 158,892.00**	**$158,658.25**	**$ 233.75**	**$ 136,895.00**	**$ 136,895.00**	**$ -**	**$864,000.00**	**$233.75**