M.L. 2015 Project Abstract
For the Period Ending June 30, 2018

PROJECT TITLE: Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation
PROJECT MANAGER: Wiley Buck
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 08f

APPROPRIATION AMOUNT: $ 400,000
AMOUNT SPENT: $ 377,761
AMOUNT REMAINING: $ 22,239

Overall Project Outcome and Results

Greening and our partners Xerces, Maplewood Nature Center, and U of MN, advanced prairie and oak woodland restoration practices for vegetation and pollinators in multi-faceted fashion. We implemented quality restorations and enhancements, and gathered 12,000 data points, analysis of which is already guiding restoration, pollinator, and engagement practices. Improvements include a successful climate-resilient approach to oak restoration; using conservation haying to benefit prairie plants and pollinators; refining our approach to pollinator refugia, overwintering and nesting needs during restoration; improving student knowledge of native plants and pollinators; implementing citizen science practices for valuable data collection and outdoor citizen engagement; increasing our understanding of native pollinators' macro- and micro- floral resource needs; improving pollinator habitat along trails; and documenting the federally endangered rusty-patched bumble bee. This program further accomplished 32 acres restored, including 6,000 bur oaks, 12,000 pollinator plants, and 45,000 milkweed seeds getting into the ground.

Project Results Use and Dissemination

Dissemination of the results is also multi-faceted and robust, underway and promising to continue beyond the grant period. This includes the publication of a bee monitoring guide for citizen science, and five presentation-ready reports; five social media outreach avenues reaching thousands; eight conference presentations reaching over 400 professionals; partnering with five local government land-owning units; and active engagement of over 1,500 citizens, including 841 K-12 students, 45 Master Naturalists, 200 citizen scientists, and 235 restoration volunteers.

Environment and Natural Resources Trust Fund (ENRTF) M.L. 2015 Work Plan Final Report

Date of Report: November 7, 2018

Final Report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2018

PROJECT TITLE: Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation

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Location: Chisago, Dakota, Ramsey, Washington

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$400,000**
	Amount Spent:	**$377,761**
	Balance:	**$22,239**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 08f

Appropriation Language:
$400,000 the first year is from the trust fund to the commissioner of natural resources for an agreement with Great River Greening for the eighth phase of the Metropolitan Conservation Corridors partnership to pilot and evaluate innovative restoration techniques aimed at improving the resilience of bur oak communities to changing climate conditions and enhancing prairie management to benefit pollinators with the help and engagement of citizen volunteers. Expenditures on restoration efforts are limited to the identified project corridor areas as defined in the work plan. A list of proposed restorations must be provided as part of the required work plan. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation

II. PROJECT STATEMENT: Refining restoration practices to ensure continued cost-effective success in the face of climate change and the native pollinator crisis, is addressed by studying several restoration activities and sites. This project addresses these urgent real world challenges by: 1) comparing the seedling viability across three ecotypes of bur oak; 2) monitoring the pollinator communities and their relationship to vegetation at two restoration sites; 3) researching the effect of prairie restoration haying, a practice with promising cost-benefit potential in the metro area, on soil nutrients, vegetation, and pollinators; and 4) embedding citizen science programs, student outreach, and volunteer events throughout these activities to experientially inform and engage the public on these important and timely topics.

The project will be implemented on four restoration sites, two of which host multiple activities.

Table 1: Activity by Restoration Site Summary

SITE / ACTIVITY	Central Corridor	Fish Creek Open Space	Bald Eagle-Otter Lakes Regional Park (Ramsey Co.)	Allemansrätt Wilderness Park	Pilot Knob Hill
Planting and Researching Viability of Three Ecotypes of Bur Oak	√	√	√	√	
Pollinator Habitat Restoration and Citizen Monitoring of Pollinators, Vegetation		√			√
Researching Effects of Haying on Vegetation, Soil N, Pollinators	√				

The project will be carried out by a compelling partnership comprised of The University of Minnesota Center for Forest Ecology, Xerces Society for Invertebrate Conservation, City of Maplewood, and Great River Greening. Results will guide oak community plantings and restoration, inform metro area prairie haying practices as it relates to pollinator conservation and vegetation management, provide valuable data to a bumble bee database including rare species searches, and engage 1,250 citizens including 800 K-12 east metro students.

III. OVERALL PROJECT STATUS UPDATES:

Amendment Request (07/02/2015):
Greening respectfully requests to begin spending our 2015 appropriation, retroactive to July 1st, before our 2014 appropriation is fully expended. In general, deliverables and budgets for the respective appropriations are based on the specific project lists for each appropriation, and are substantially different between the appropriations. In addition, projects #4, 5, and 6 in the 2015 restoration list are ready to begin, including July pollinator and bumble bee surveys, and will need the full 3-year grant period to meet the deliverables. The 2014 appropriation is largely allocated to a suite of projects underway, with several projects in advanced development (e.g. enlargement of existing Allemansratt 2014 project) poised to complete the allocations.

Amendment Approved by LCCMR 07/06/2015

Project Status as of February 1, 2016:

The project is underway, on schedule, and on track to meet the deliverables for all Activities. Work conducted includes: procurement of three ecotypes of bur oak acorns; over 150 citizens engaged in various aspects of pollinator monitoring at Fish Creek Open Space and Pilot Knob Hill; documentation of the rare bumble bee *Bombus fervidus* at Pilot Knob Hill; and baseline vegetation and pollinator data and first prescribed haying treatment at Central Corridor.

Two clarifications are made in the workplan, the first being clarification on the interpretive program for the K-12 students in Activity 2, Fish Creek Open Space. The revised, improved text is underlined clarifying the number of activities in which each individual student will be engaged. The second clarification is to specifically include tree and shrub plant material as a part of the pollinator plantings; the revised underlined text reflecting this clarification is included in the budget below as well as in Attachment A.

Project Status as of August 1, 2016:
The project progressed significantly in the past six months with bur oak germination and site selection on track; continued pollinator activities at Fish Creek and Pilot Knob Hill; and conservation haying moving along in its second season

An additional 447 citizens were engaged in pollinator interpretation at Fish Creek Open Space, another 18 at Pilot Knob Hill, and 191 at Central Corridor; documentation of a second and third rare bumble bee species was made at Pilot Knob.

Project Status as of February 1, 2017:
The project progressed significantly in the past six months in all three activities and is on schedule.

Highlights included planting all research oaks; drafting sections of the bur oak write-up; federal endangered listing of a bumble bee present at Pilot Knob; active dissemination; and engaging an additional 249 volunteers, including 69 youth, in these projects.

The restoration list has been updated to reflect the site change between Spring Lake Park and Allemansrätt Park noted in the main document only of the August 1 2016 update.

Activity 1 and the Fish Creek portion of Activity 2 are now shared (pending approval of 2014 amendment request) between this 2015 appropriation and Greening's 2014 appropriation.

Amendment Request (08/16/2017):
Greening respectfully requests to shift $21,000 into Activity 1: Professional/Technical/Service Contracts, subsection "TBD (competitive bid)..." from the same category in Activity 2.

This change is needed to meet the upcoming higher costs of exclosure fencing for the research bur oaks than anticipated. The original fencing estimate did not take into account the added expense due to sloped terrain, limited access, and upgrade to rabbit exclosure fencing above more typical deer exclosure fencing. The reduction in Activity 2 Contracts is allowed because of two items. First, there is no need to contract out a vegetation survey at Pilot Knob Hill. To make the connection between restoration and pollinators, the floral associations are recorded as part of the bumble bee surveys, which will be complemented by vegetation monitoring by Greening staff during non-survey months in fall 2017 and spring 2018. Second, contracted fencing exclosure services for Activity 2 were never needed for installed pollinator plugs and shrubs at the Fish Creek site, because the work was completed by volunteers.

We would like to also shift an additional $878 into Activity 1: Professional/Technical/Service Contracts, subsection "TBD (competitive bid)...", from Activity 1: Other/Out of state travel. We have completed all out of state travel and have $878 remaining as we did not take out any overnight lodging, and a budgeted trip to North Dakota was not needed as the preferred northwestern Minnesota acorns were sourced instead.

For Activity 1: Equipment/Tools/Supplies, we propose to add 'fencing materials' to the list of approved purchases. We anticipate supplementing the contracted fencing work with sustained, localized fencing improvements by staff and/or volunteers, to maximize protection of the research oaks from rabbits.

Amendment Approved by LCCMR 11/28/2017

Project Status as of August 1, 2017:
All projects are underway and all three activities are on schedule. Highlights include completion of baseline data collection, and first year growth data collection underway on the research oaks; successful continuation of the Fish Creek and Pilot Knob citizen science pollinator monitoring and training activities; and completion of professional spring pollinator, soil, and vegetation surveys at Central Corridor.

Amendment Request (02/01/2018):
Greening respectfully requests to shift $2,500 from Activity 3 Personnel (Personnel budget decrease to $9,535) to Activity 2 Personnel (Personnel budget increase to $26,315), for staff time leading an additional pollinator survey/community event, the Bioblitz at Fish Creek Open Space in June 2018.

Amendment Approved by LCCMR 02/15/2018

Project Status as of February 1, 2018:
All three activities progressed on schedule. Fall data collection was completed at all four sites for Bur Oak Acceleration and Migration Research growth data was collected at all fours sites; one citizen science workshop and the final two public bee monitoring events were successfully completed at Fish Creek Open Space; the final three bumble bee surveys were completed at Pilot Knob Open Space; and Central Corridor 2017 vegetation, soil and pollinator surveys and fall conservation haying were completed. Data analysis is underway and two more citizen science workshop events at Fish Creek have been scheduled for 2018.

Overall Project Outcomes and Results:
Greening and our partners Xerces, Maplewood Nature Center, and U of MN, advanced prairie and oak woodland restoration practices for vegetation and pollinators in multi-faceted fashion. We implemented quality restorations and enhancements, and gathered 12,000 data points, analysis of which is already guiding restoration, pollinator, and engagement practices. Improvements include a successful climate-resilient approach to oak restoration; using conservation haying to benefit prairie plants and pollinators; refining our approach to pollinator refugia, overwintering and nesting needs during restoration; improving student knowledge of native plants and pollinators; implementing citizen science practices for valuable data collection and outdoor citizen engagement; increasing our understanding of native pollinators' macro- and micro- floral resource needs; improving pollinator habitat along trails; and documenting the federally endangered rusty-patched bumble bee.

Dissemination of the results is also multi-faceted and robust, underway and promising to continue beyond the grant period. This includes the publication of a bee monitoring guide for citizen science, and five presentation-ready reports; five social media outreach avenues reaching thousands; eight conference presentations reaching over 400 professionals; partnering with five local government land-owning units; and active engagement of over 1,500 citizens, including 841 K-12 students, 45 Master Naturalists, 200 citizen scientists, and 235 restoration volunteers. This program further accomplished 32 acres restored, including 6,000 bur oaks, 12,000 pollinator plants, and 45,000 milkweed seeds getting into the ground.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Accelerated Migration of Bur Oak Ecotypes for Climate Resilience
Description: Natural colonization by adapted native plants in response to a changing Minnesota climate is hindered by lack of seed source, invasive species, and fragmented habitat. Without careful intervention, weedy invasive species could come to dominate our vegetation. Oak trees, with their low natural rate of migration, extended age to maturity, and importance to Minnesota, are especially in need of human-assisted accelerated

migration. In this study, we will complete early year growth and survival comparison of three ecotypes – local, southern, and northwestern – of bur oak *(Quercus macrocarpa)* at four metro sites to determine which if any ecotype fares better. The local ecotype acorns will originate from the 7-county metro area, the southern ecotype from 200-300 miles south (e.g. Des Moines, IA) and the northwestern ecotype will be from North Dakota / northwestern MN area, with its temperature extremes. Dr. Lee Frelich and his students will design the study, collect growth and survival data on 2000 stems of each ecotype, analyze the results, and write a report. Greening will collect (either directly or through purchase) and germinate acorns from verified sites; plant 6000 stems engaging 150 volunteers; fence (contracted services) and manage the plantings (using a mix of staff and contracted services); and produce informational materials for restoration practitioners based on the results. Verifying acorn collection sites will include driving to the out-of-state collection sites to photograph, take coordinates, and determine authenticity of wild-grown trees.

All data will be statistically analyzed and a report prepared for conference presentation. This report will help refine oak planting to help ensure the continued success of oak community restorations.

Summary Budget Information for Activity 1: **ENRTF Budget: $ 201,118**
Amount Spent: $ 195,467
Balance: $ 5,651

Outcome	**Completion Date**
1. Early year growth and survival by oak ecotype determined; report written and prepared for publication/presentation	5/1/18
2. Informational materials for restoration practitioners prepared for distribution/presentation	6/30/18

Activity Status as of February 1, 2016:
Several bushels each of bur oak (*Quercus macrocarpa*) acorns from Des Moines IA, Minneapolis MN, and Roseau MN were procured, and then sown at the DNR Badoura Nursery. Collection coordinates have been collected and photo-documentation of the source trees scheduled for this winter.

A subcontract to University of Minnesota for the research services of Dr. Lee Frelich has been fully executed.

Activity Status as of August 1, 2016:
In the spring and summer, we completed an extensive review by Greening, landowners, and U of M, of potential planting/study sites for the bur oak ecotype research, and ultimate choice of sites. The updated site selection is summarized in the table above. Sites were chosen to minimize confounding variables between sites and will consist of bur oak planting into grassland sites this fall. Site prep, herbivory protection, and installation are scheduled in time for October plantings.

Documentation of the acorn source trees were completed this winter. DNR Badoura Nursery has confirmed germination of Des Moines and Roseau acorns, but for reasons yet to be determined does not have a planting bed for the Minneapolis acorns. We will use Rice Co. seedlings that Badoura was growing independently but following the same procedure, if these Minneapolis source trees cannot be located.

Activity Status as of February 1, 2017:
The bur oak propagation seedling lots were photo-documented at the DNR Badoura nursery, and the 6000 bur oaks shortly thereafter were received and planted throughout the four (4) planting sites, in fall 2016. Height measurements were started until snow accumulation forced the end of that activity; the remaining measurements are scheduled for March 2017. Advanced drafts of Introduction, Background, Research Design, and Methods sections of the research write-up were completed.

A total of 102 volunteers, including 51 youth, were engaged in the planting.

Activity Status as of August 1, 2017:
Baseline data was collected in the spring and first year growth data collection is underway. Permanent deer and rabbit protection fencing installation has been delayed due to unexpected expense, but is on schedule for installation this fall.

Activity Status as of February 1, 2018:
First year growth/survival data collection was completed by University of MN Dr. Lee Frelich and his student in fall 2017. Permanent deer and rabbit protection fence installation is complete at three sites; the fourth site will not to be fenced due to low deer pressure.

Final Report Summary:
Data from the fall 2017 and fall 2016 growth measurements were tabulated and analyzed, and a summary report for presentation completed (Accelerated Migration of Bur Oak Ecotypes for Climate Resilience. Frelich, L and Toot, R. 2018). This report outlines the study methods and analyzes 10,000 data points in detail, and identifies some significant differences in height between local, southern, and northwestern ecotypes. Beyond the significance found in these first years of early growth/early survival data, this activity and report sets up the baseline data for medium- and long-term research results, capturing the response of three bur oak ecotypes to climate over different time periods. A final report has been written and submitted, and disseminated; data collection by the U of M has continued past the grant period.

Bur oak, with its slow growth and natural rate of migration and habitat importance, is one of the most important tree species in Minnesota to plant and monitor. Beyond the significance of the research, five old fields in four different natural areas have been restored to oak woodland with 6000 bur oak seedlings planted and protected.

A total of 137 volunteers assisted with the planting and surveying of these oaks, receiving information about the project.

ACTIVITY 2: Citizen Engagement for Pollinator Habitat Restoration and Monitoring
Description: Pollinators are keystone species in prairies and woodlands, sustaining wild plant communities that in turn provide food and shelter for a myriad of other wildlife. Despite the recognized importance of pollination services, there is a rapidly growing body of evidence that both wild and managed pollinators are in serious decline, including several bumble bee species in Minnesota that have declined precipitously in recent years.

Vegetation restoration and pollinator management are intricately related. In order to merge the best science from both fields, and also have a broad public impact stemming from today's unprecedented public interest, we will form a working partnership between Greening, Xerces Society for Invertebrate Conservation, and Maplewood Nature Center each with their respective expertise. This collaboration will provide a suite of engagement opportunities for citizens to actively learn about pollinators, restoration, and their relationship, including citizen science monitoring to K-12 school outings with expert interpretation, to restoration volunteer opportunities, ranging from plugging of pollinator-friendly prairie plants to bumble bee surveys at restored sites.

Pollinator monitoring by citizens, students, volunteers and experts will focus on bees. Bees are an amazingly diverse and very important group of insects, yet they remain poorly understood by the general public. When most people hear the word "bee," a single species comes to mind, the European honey bee. However, in Minnesota, there are more than 350 species of native wild bees, including many extremely important pollinators of crops, wildflowers and trees. Most of these 350 species can only be identified by specialists. However, with a little practice and guidance, volunteer citizen scientists can learn to identify the most common bee species and "species-groups" found in Minnesota. Since research has found that the diversity measured by easily identifiable species-groups correlates with the more robust, species-level data collected by bee experts, the approach of measuring diversity of easily identified bees is expected to give an accurate measure of local bee community structure, status, and responses to habitat enhancement.

Citizen science is increasingly recognized as a valuable tool for generating meaningful scientific data and understanding of the distribution and conservation needs of pollinators. In addition, citizen science, like volunteering and interpretation, serves to increase participants' science literacy, environmental stewardship, and connections to nature and place. By developing and implementing pollinator citizen-science programs at restored sites in the metro area, this project will engage and educate participants about Minnesota's diverse pollinators and restored habitats. At the same time, valuable data on both the diversity and abundance of bees that are present on restored habitat, and how the composition of those pollinators change over the course of restoration, will be generated. Potential uses for this data include: quantifying the effectiveness of restoration efforts to promote pollinator populations; understanding the pollinator requirements of wild flowers dependent on insect pollinators; potentially documenting the occurrence and habitat of rare pollinators; and, simply, identifying the types of bees present on a particular site.

Fish Creek Open Space

At Fish Creek Open Space, a robust program with restoration, outreach, and citizen-science initiatives will accelerate the restoration of pollinator habitat in these recently restored prairie habitats; monitor the pollinator community; gather valuable bumble bee data; document relationships between pollinators, floral resources and restoration; and engage K-12 school children and the general public through outreach and citizen science.

Xerces will lead the pollinator and bumble bee monitoring including a 150-person citizen science program, and submit data to web-based Bumble Bee Watch. Maplewood Nature Center will lead and design an interpretation program for 800 distinct K-12 east-metro students and others, engaging each of them in two or more of the following activities: pollinator observation, catch-and-release insect capture, bee photography, and habitat restoration. Greening will conduct focused pollinator habitat restoration, including plugging pollinator-friendly forbs with 50 volunteers. During all citizen engagement activities, the tie-in between restoration practice and pollinator management will be explored, and results and processes shared.

For the 150-person citizen science program, in addition to the activities above, we will:

- Conduct onsite education and outreach to school groups and families about native plant restoration, pollinator conservation, and kid-friendly citizen science projects (Maplewood)
- Conduct four specialized training courses for the more serious participants, on pollinator and native plants, and the relationship between the two. Trainings will cover plant and pollinator symbiosis, biology, identification, conservation, habitat restoration, and introduction to a continental citizen-science monitoring project: Bumble Bee Watch (http://bumblebeewatch.org/) (Great River Greening, Xerces, Maplewood).
- Conduct six public surveys/monitoring for bumble bees and other pollinators in the restored and remnant areas of the site (Xerces, Maplewood)
- Develop a Minnesota Citizen Science Pollinator Monitoring Guide including a photo guide to MN bee groups, monitoring protocols, and sample data sheets. Incorporate this tool in the specialized training courses; school group outreach; and public monitoring (Xerces)

Pilot Knob Hill

At Pilot Knob Hill, Greening will monitor vegetation (using contracted services) including spring forbs and bloom coverage, and soil nitrogen levels (staff will collect while contracted services will analyze), and further restore pollinator habitat by plugging pollinator-friendly plants with 50 volunteers. At the same time, Xerces will implement spring-to-fall bumble bee monitoring including focused searches for the rusty-patch bumble bee and other rare Minnesota species.

Bumble bee surveys will be conducted throughout the study period, with special attention to diversity, abundance, floral preferences, nesting habitat, and the presence/absence of declining species that have a high likelihood of encounter. In an effort to capture the maximum diversity of bumble bees on site, pollinator monitoring will be conducted three times per year for the duration of the three year study, engaging and training 50 volunteer citizen scientists over this time period. All floral associations will be recorded during the surveys. Since many bumble bees are large and readily identifiable to species in hand from photos, catch-and-release methods will be employed

During all citizen engagement and volunteer activities, the tie-in between restoration practice and pollinator management will be explored, and results and processes shared. Data will be evaluated, and a case study report prepared.

Summary Budget Information for Activity 2: **ENRTF Budget: $ 117,395**
Amount Spent: $ 112,533
Balance: $ 4,862

Outcome	Completion Date
1. 1,100 citizens engaged, including 800 K-12 students	6/15/18
2. 3 yr of bumble bee, vegetation, and soil N monitoring and pollinator habitat at Pilot Knob Hill completed, data reported.	6/30/18
3. 3 yr Citizen Science monitoring program, pollinator habitat restoration at Fish Creek completed, data reported	6/30/18

Activity Status as of February 1, 2016:
The Fish Creek K-12 program launched in September 2015 with five classes visiting the site. Each class received two hours of preparation in the classroom; and spent about 3.5 hours at the site surveying and identifying pollinators, hiking, and planting a total of 1100 pollinator plugs. The classes included three fourth grade classes totaling 65 and 10 teachers and chaperones from Harambee Elementary School in Maplewood; and two seventh grade classes totaling 32 students plus 5 adult chaperones from Crosswinds Art and Science School in Woodbury.

The first session of specialized adult training "Bee-come a Bee Monitor" was held on September 12 and 13. The 26 participants learned about bee identification and monitoring in this nine-hour workshop: interest in the specialized training is very strong, and includes a wait list. This training was followed by the pilot monitoring visit the following day during which these trained adults set up five transects and collected data at Fish Creek. An advanced draft of the 'Upper Midwest Citizen Science Monitoring Guide: Native Bees' was developed by Xerces Society and then distributed and field tested at the two-day training.

Bumble bee surveys were conducted at Pilot Knob Hill in July, August, and September engaging over 40 volunteers. During the process, 423 bumble bees were identified and released, representing seven different species including one rare species, *Bombus fervidus*. This species was recently identified by International Union for Conservation of Nature (IUCN) as vulnerable to extinction (http://www.iucnredlist.org/search), based on range and relative abundance declines in recent years. One cuckoo bee species, *Bombus citrinus*, was observed, which may be a signal of ecosystem heath, since cuckoo bees can be highly specific in terms of the bee hosts which they will cleptoparasitize. Over 400 floral associations were documented. All volunteers were engaged in planting prairie smoke (*Geum triflorum*) plugs in the mowed shoulder of a gravel hiking trail, to improve habitat and provide active learning experience about 'bee lawn' habitat in mowed areas.

Activity Status as of August 1, 2016:
In May and June, Maplewood Nature Center led outings for 10 fourth grade classes at the site Each class received two hours of preparation and pollinator education for the fish creek field trip in the classroom; and spent about 1.5 hours at the Fish Creek site, hiking the site, and planting a total of 2000 prairie wildflowers in the seeded prairie restoration. A total of 270 K-12 students were engaged in the process along with 32 adult chaperones. Greening hosted two corporate group events during this period, engaging another 145 volunteers (13 trained Volunteer Supervisors and 132 corporate volunteers) in restoration and management of the site. These volunteers planted 6000 plugs, removed invasive species, and received a roving presentation on pollinators and habitat.

To begin the second year of citizen monitoring at Pilot Knob Hill, a bumble bee survey was conducted engaging 18 volunteers. A total of 104 bumble bees comprising 6 different species were recorded at the site. Two species were detected that had not previously been documented from the site: the American bumble bee (*Bombus pensylvanicus*) and the rusty-patch bumble bee (*Bombus affinis*), both threatened species that have been in serious decline in this region and elsewhere; a third rare species was documented at the site in 2015, yellow bumble bee (*Bombus fervidus*). The presence of these three rare species at Pilot Knob Hill is of great significance to conservationists trying to understand the distribution and needs of these species, and will inform the management of the site going forward. Also as part of the citizen monitoring, over 100 floral associations were documented., and all volunteers planted wild strawberry (*Fragaria virginiana*) plugs in the mowed shoulder of a gravel hiking trail, to improve habitat and provide active learning experience about 'bee lawn' habitat.

Soil nitrogen samples were taken under a different allocation and included a control plot dominated by Canada goldenrod. The soil nitrogen sampling will be expanded during the remainder of the 2016 growing season to include comparisons between mowed and unmoved habitat; forb rich vs forb poor areas; and Canada goldenrod dominated areas vs grass dominated.

Activity Status as of February 1, 2017:
At Fish Creek, Greening conducted focused pollinator habitat restoration, including plugging 288 pollinator-friendly grasses and forbs, and planting 75 early-flowering shrubs with 69 general volunteers including 17 youth, exceeding our general volunteer deliverable.

Maplewood and Xerces completed a specialized pollinator identification training for over 40 attendees, in September 2016, recruiting primarily from Minnesota Naturalists Association, which included a classroom and a field component. Maplewood continued with recruiting school groups for pollinator education days at for Fish Creek for spring 2017. The fourth specialized training, focused on pollinator overwintering habitat/refugia, is being developed for winter 2017-18; a bumble bee survey is being developed to supplement the sustained pollinator transect monitoring.

The second and third 2016 citizen science bumble bee surveys were held at Pilot Knob, one open to the public and one held for experienced Greening volunteer supervisors. These surveys engaged a total of 23 citizen scientists and continued with the innovative non-lethal bumble bee survey protocol developed by Xerces, and included active trail shoulder habitat enhancement with plugging of early blooming, short-stature forbs.

Reported in the August 1, 2016 update, the rusty-patch bumble bee (*Bombus affinis*) was documented in July 2016 at Pilot Knob. Since then, this species has been approved for listing as a federally endangered species. Given this listing and the presence of two additional rare bumble bee species at Pilot Knob, Greening worked with Xerces and Colleen Satyshur, Research Coordinator, Department of Ecology Evolution and Behavior, University of Minnesota (as a follow through activity from the "*2016 LCCMR pollinator projects meeting*") to expand and sharpen bumble bee over-wintering refugia guidelines and specifications; these were implemented when Greening conducted woody encroachment removal at Pilot Knob (2016 appropriation) this past winter.

Activity Status as of August 1, 2017:
A total of 273 K-12 students, from 13 classrooms at 5 schools, and 33 adult chaperones, participated in the Fish Creek pollinator activities during spring 2017. Students participated in classroom preparation, field activities, surveys / monitoring, and restoration activities.

Pilot Knob Hill bumble bee survey was completed in July with an additional species documented; August and September surveys are scheduled.

Activity Status as of February 1, 2018:
Fish Creek Open Space: A total of 112 students and teachers from Carver Elementary participated in Fish Creek pollinator activities with Maplewood Nature Center and Greening on September 26 and September 27. On September 28, 21 Century College students volunteered for a planting event, and on October 19, 48 3M employees and 6 volunteer supervisors planted plugs for pollinators at Fish Creek Open Space. The final 2 of 6 total public monitoring events for bumble bees and other pollinators were completed at Fish Creek this summer and fall. Maplewood, Xerces, and Greening staff are planning the final citizen science workshop for April 2018, which will educate adult learners on winter pollinator habitat, followed by dissemination at a Fish Creek Bioblitz in June 2018.

Pilot Knob Open Space: Greening, Xerces Society, and U of MN Bee Lab held citizen science bumble bee surveys on July 14, August 25, and September 15 at the Pilot Knob Hill site. These public events were attended by 16, 17, and 12 volunteers respectively, and included bee identification (the red-belted bumble bee (*Bombus rufocinctus*) was added to the site list) and training, and active education about 'bee lawn' habitat, which guided the volunteer pollinator forb planting of calico aster (*Symphyotrichum lateriflorum*), ground plum (*Astragalus crassicarpus*), pussytoes (*Antennaria neglecta*), longleaf bluets (*Hedyotis longifolia*), and blue-eyed grass (*Sisyrinchium campestre*). In addition, 11 volunteers (3 adults and 8 youth) from Boy Scout Troop #264 planted 200 forbs/grasses on October 15, 2017. The citizen science bumble bee surveys are now complete and data analysis is underway.

Final Report Summary:

Fish Creek Open Space

Partners co-hosted the sixth and final citizen science workshop in April, 2018 that trained adult learners on creating and managing nesting and overwintering bee habitats; and led 38 volunteers for the Fish Creek Bioblitz in June, 2018. Participants included 28 adults and 5 youth, resulting in observations of 232 different species .

A total of 156 adults received specialized pollinator training, including 45 Master Naturalists; 6 adults sustained their effort to conduct transect surveys on prairie remnant, prairie restorations, and old field all at this one location. This included the development and use of a new guide, Xerces' Upper Midwest Citizen Science Monitoring Guide Native Bees.

A total of 841 K-12 students were reached with both a classroom and field component; through testing these students exhibited statistically significant gain in native pollinator and native plant identification skills. An additional 71 people received interpretive information through the bio-blitz and grand opening. Another 224 adults volunteered for pollinator habitat restoration, and received pollinator/plant interpretation. These adult volunteers, and the K-12 students, planted a combined total of 11,800 pollinator plugs/pots, and 75 pollinator shrubs, and released 45,000 milkweed seeds in our first-ever 'pod cast'.

The Monitoring Guide has been put to use on other projects and will continue into the future. This guide employs a non-lethal method appropriate for surveying sites hosting our native federally endangered rusty-patched bumble bee. Participation in this program for the professionals as well as the citizens has raised pollinator awareness and knowledge on a suite of avenues. The transect survey results indicated that 'old field' may play an important role in pollinator refugia during the restoration process, allowing pollinators to re-colonize a nearby prairie reconstruction after site prep and seeding. The workshop on nesting and overwintering habitats indicate a potential positive effect for stem nesters with conservation haying, mowing, and grazing; as well as the need for woody debris refugia during winter removal, all of which will help increase pollinator habitat value during prairie management.

Pilot Knob Hill

The nine survey, 3-year bumble bee survey data analysis was completed, including floral associations and blooms, and a presentation-ready report made. Soil nitrogen data did not prove to have analytical value.

A total of 122 citizens volunteered for the nine bumble bee surveys over 3 years, collecting over 800 bumble bees, spanning ten species including federally endangered rusty-patched bumble bee and two additional rare species, along with floral associations and surveys; and planted 395 pollinator forbs focused on 'bee lawn' species in the mowed trail shoulder. In addition, 11 Boy Scouts volunteered and planted an additional 200 plugs, for a total of 595 plugs and 133 volunteers. The bee survey, plant identification, and habitat restoration activities proved to be engaging and educational for the volunteers.

These same survey methods are now being employed on additional sites, with the intent of making bumble bee surveys a frequent component part of overall site surveys. Bumble bees have proven to be a readily identified group, are a very important group of pollinators, and are considered indicative of the total pollinator population.

Bloom associations will guide future management of this site, making sure to retain sufficient populations of the visited species. Furthermore, the trailside plantings are being monitored for establishment, to add to the growing body of knowledge on appropriate, successful native bee lawn species, in this case on the mowed shoulder of a recreation trail.

ACTIVITY 3: Prescribed Haying for Pollinators and Prairie

Description: At Central Corridor, a restored prairie site in the metro area, Greening will implement haying as a restoration and management tool, collect data on plant diversity, spring forbs, bloom coverage, and soil nitrogen levels on hayed and un-hayed (control) plots.

Haying will be led by Greening and implement by a local service provider during the first two weeks in August on five plots, the timing of which follows traditional prairie haying practices and nesting bird guidelines, and with the expectation that it will promote cool-season forbs over mesic warm-season grasses. Five plots of four to five acres each will be hayed, with five un-hayed control plots of similar size and composition and moisture gradient. Nitrogen samples will be collected by Greening staff in late April with 20 total soil samples in each unit. Soil samples will be collected by staff across a transect traversing the long center of each individual unit, with analysis by a qualified lab. Vegetation samples will be collected across the same transect by staff, using ten 1-square meter quadrats. Quadrats will be analyzed for presence-absence, cover, and bloom cover, in early June, mid-July, and late September.

Since floral variables alone give an incomplete assessment of the effectiveness of prescribed haying as a prairie management technique, another component of this study, led by Xerces, will examine pollinator abundance, diversity, and floral interactions in hayed and control plots. Haying methods will be designed to minimize direct and indirect negative effects to pollinators, e.g., by mowing as late as possible after peak bloom while still meeting farmer hay-quality objectives, and by haying in a patchy matrix leaving uncut areas that provide food and nesting resources for bees throughout the entire season. Anticipated benefits of haying to pollinators include higher diversity and abundance of forbs during the spring season when nectar and pollen is most limited; lower abundance of nitrophilic forb species; higher forb-to-grass ratio; and reduced thatch/easier access to soil for ground nesting bees.

Pollinator monitoring will be conducted every three to four weeks from May to September, weather permitting, for the duration of the study. Surveys will consist of timed visual transect walks using sweep nets to collect/record all pollinating insects in flight or on vegetation/flowers in designated survey areas of control and test plots. All flower associations will be recorded. Catch-and-release methods will be used when possible for large, readily identifiable insects such as many bumble bees and butterflies. All collected insects will be curated and identified to the lowest practical taxonomic level.

All data will be statistically analyzed and a report prepared for conference presentation. This report will help refine haying as a prairie management tool in Minnesota, for its effects on both plants and pollinators, particularly in the metro area.

Summary Budget Information for Activity 3: **ENRTF Budget: $ 81,487**
Amount Spent: $ 69,761
Balance: $ 11,726

Outcome	Completion Date
1. Effect of prairie haying on floristic diversity, soil N, pollinators at Central Corridor determined. Report written, prepared for presentation/publication.	6/30/18
2. Informational materials for restoration practitioners prepared for distribution/presentation	6/30/18

Activity Status as of February 1, 2016:
Baseline data was collected on vegetation, soil Nitrogen and pollinators. A service contract was executed and the first rigorous haying treatment conducted, followed by 3 more sample periods. All baseline data was

collected; spring 2016 is the first season when noticeable differences between hayed and un-hayed plots are anticipated.

Activity Status as of August 1, 2016:
At Central Corridor Conservation Haying project, two pollinator surveys and two vegetation surveys were completed in the last six months. The results of the pollinator surveys by Xerces Society are pending, with data analysis scheduled for the dormant season. Vegetation surveys were conducted by Greening staff. The first survey showed twice as many blooms in hayed versus non-hayed treatments. The second vegetation survey, which is focused on soil nitrogen and its relationship to plant diversity and invasive species, has been completed and data analysis is pending. Summer 2016 haying is expected to begin in August.

Activity Status as of February 1, 2017:
At Central Corridor, haying was conducted for the second year on select research areas. The vegetation was clipped and material removed, creating improved conditions for low-stature, early blooming forbs for spring 2017. The timing was delayed and less than ideal for nitrogen removal, due to high amounts of precipitation and wet soil conditions at the more desirable time period. The sub-contractor list for the 2017 haying RFP has been expanded.

Soil nitrogen surveys were conducted in December and showed no significant difference between hayed and un-hayed plots. Further review of the 2016 vegetation survey data revealed significant gaps in the data collection; Greening has since changed site managers for this activity and has designed a more rigorous survey for 2017.

Xerces compiled the baseline pollinator data from 2015 and reported on it at the "*2016 LCCMR pollinator projects meeting*". Xerces collected 2016 pollinator data over the growing season.

Activity Status as of August 1, 2017:
For the period ending June 30, pollinator soil and vegetation surveys were completed for May and June. Data has been collected, including soil analysis by U of M soil lab, and tabulated. Analysis will occur during the dormant season. Additional surveys are scheduled for July and August.

A haying subcontractor has been chosen and formal agreement expected to be signed in August. Maintenance by Greening crew is ongoing and included mowing of a large patch of non-native invasive Canada thistle and wild parsnip, in one of the hayed units shortly before the July survey. Affected data was noted.

Activity Status as of February 1, 2018:
At Central Corridor, conservation haying was conducted in fall 2017 for the third year on select research areas. The prairie vegetation was clipped and material removed, creating improved conditions for low-stature, early blooming forbs, and possibly affecting soil nitrogen levels.

Vegetation, soil, and the final pollinator surveys were completed in August and September. Xerces Society completed a draft report of monitoring findings at Central Corridor, detailing observed floral associations of pollinators, bumble bee community structure, monarch nectar plant associations, and monitoring implications. These findings suggest that May, June, July, and August should be prioritized for native bee monitoring, due to the highest diversity, abundance, and relative abundance of native bees on flowers at these times. Transect data regarding the impact of conservation haying on floral diversity and bloom coverage was collected and will continue into the spring; analysis of the relation between hayed and un-hayed for pollinator abundance is underway.

Final Report Summary:
Statistical analyses and reports were completed on pollinator, vegetation, and soil nitrogen surveys.

A profile of native pollinator visitation to the site by month was completed, identifying key months for native bee surveys, key monarch nectaring sources, and key floral resources. The profile also revealed a lack of floral resources in June. These findings will guide or restoration of an adjacent prairie, directing us to emphasize June floral blooms in that restoration, to complement the otherwise robust pollinator forb resources in the prairie that was studies.

The haying study revealed that haying resulted in significantly more forb coverage, and significantly higher forb:grass ratio, than un-hayed units. Additionally, the pollinator study observed an increase in native bee abundance and diversity in hayed units for the month of May. Soil nitrogen analyses did not identify any significant changes as a result of haying. Overall, haying appears to be an appropriate tool for periodic thatch removal and disturbance, to which prairies are adapted, and may promote earlier floral resources for pollinators. Combined, these analyses will guide the management of this prairie for the combined benefits of forbs and pollinators, and expand into guiding management of other sites.

V. DISSEMINATION:

Description:

Greening anticipates periodic reporting on this project through our various electronic media outlets: The Greening monthly e-newsletter (reaches 7,000) (subscribe at www.greatrivergreening.org); Facebook (900 likes) (Like us on Facebook https://www.facebook.com/greatrivergreening); and Twitter (400 followers) (Follow us on Twitter https://twitter.com/greatrivergreen)

Periodic reports may also appear on:

- The U of MN Center for Forest Ecology web page is found at http://cffe.cfans.umn.edu/index.htm
- Maplewood Nature Center website: www.maplewoodnaturecenter.com; newsletter Maplewood Living: Seasons Environmental Insert (http://www.ci.maplewood.mn.us/index.aspx; Type in "Seasons" in the search box); Facebook (https://www.facebook.com/pages/Maplewood-Nature-Center/121697461192602?fref=ts); Maplewood Review : http://www.bulletin-news.com/ramsey-co-maplewood-review
- Xerces Society for Invertebrate Conservation e-newsletter (subscribe at www.xerces.org); Wings magazine (subscribe at www.xerces.org); Facebook (https://www.facebook.com/pages/Xerces-Society/111872242162708?fref=ts) and Twitter (https://twitter.com/xerces_society) and web page (www.xerces.org).

Results will be shared with colleagues including the Metro Conservation Corridors partnership. Some of the data collected will be input into a continental database, in addition to being shared with local pollinator experts. Deliverables include preparing reports and slideshows for eventual publication and/or presentation. Publications and presentations will likely occur after the grant period.

Status as of February 1, 2016:

Greening featured the bumble bee survey at Pilot Knob in our September 2015 e-news (now reaching 7200 subscribers), and then posted the story on our website (http://www.greatrivergreening.org/bee-aware/). Greening also featured the work in three Facebook posts (now at 1200 likes).

Greening, Xerces, and Maplewood Nature Center co-presented at the "Fall 2015 LCCMR Pollinator Projects Update Meeting". Activities and results to date were presented to approximately 20 colleagues, and the draft 'Upper Midwest Citizen Science Monitoring Guide: Native Bees' was distributed for review and comment.

Status as of August 1, 2016:

One public and two private volunteer events were held at Central Corridor during this period. At these events, volunteers received a presentation on the conservation haying activities underway. Greening featured volunteer events at Fish Creek and Pilot Knob in three Facebook posts (now at 1300 likes). The Xerces Society featured the July 2016 bumble bee survey at Pilot Knob in a blog post: http://www.xerces.org/blog/two-rare-species-spotted-during-minn-bumble-bee-survey/.

Status as of February 1, 2017:
On July 18, 2016 Greening ecologist Stephen Thomforde presented on "Biomass Harvest via Haying" employed at Central Corridors, at the North American Prairie Conference, with 380 conference attendees and approximately 60 presentation attendees.

On December 5, 2016, Laura Gould, Greening intern and Macalaster College student, presented a poster highlighting the bur oak accelerated migration project (Activity 1). The presentation was attended by approximately 50 attendees, primarily students, staff, and professors.

During fall 2016, volunteer events at Allemansrätt Park, Pilot Knob, Fish Creek, and Central Corridor were publicized via 9 emails to Greening's e-list (about 8,500 subscribers), Greening's Facebook page (over 1,400 likes), Twitter (nearly 600 followers), a community outreach event (PolliNATION Festival, Sept 11, 2016), and about 280 fliers distributed to community members.

Fall volunteer events involved 141 adult general volunteers, 69 youth volunteers, and 19 trained volunteer supervisors. Volunteers included members of the general public, public and private organizations, school groups, and private institutions. All volunteers received a 'roving presentation' with visual aids on the project, restoration activities, and site in addition to training on the day's restoration activities; volunteer supervisors received this information in written format as well to prepare them to receive and answer questions.

On December 7th, 2016, Greening, Xerces, and Maplewood co-presented and participated in the "*2016 LCCMR pollinator projects meeting*", and continued with follow-up to afternoon break-out sessions.

Status as of August 1, 2017:
During Spring 2017, two press articles disseminated information about the projects (but without Trust Fund recognition despite our written efforts): On May 30, 2017, an article highlighting Greening's related study on accelerated migration of bur and white oaks was published by St. Thomas (http://www.stthomas.edu/news/measuring-future-minnesotas-trees-climate-change/). On March 21, 2017 the Star Tribute published an article highlighting the rusty patched bumble bee identified at Pilot Knob (https://www.greatrivergreening.org/bumblebee-endangered/). Both were shared on Greening's website (approximately 1,500 views per month), Facebook page (over 1,400 likes), Twitter (over 600 followers).

On March 9, 2017 the *Best Practices for Pollinators in the Real World Summit, for Minnesota Counties, Municipalities, Leaders,* with 150 attendees, highlighted work at these projects: 1) A presentation by the Xerces Society noted the rusty-patch bumble bee identification at Pilot Knob, along with only two additional recent records in Minnesota; 2) The non-lethal capture technique used at Pilot Knob Hill was mentioned specifically during a monitoring training session led by Dakota County.

Status as of February 1, 2018:
On November 11, 2017, Maplewood Nature Center naturalists Kayla Wolfe, Oakley Biesanz, and Ann Hutchinson presented at the MN Naturalists Association Annual Conference, sharing the PowerPoint on native bees and reviewing K-12 students' pre-assessment and post-assessment response to measure the efficacy of the three-year pollinator education program at Fish Creek Natural Area. The conference break-out session was delivered to 7 naturalists; presenters recognized the Trust Fund during the presentation. At the conference the previous year, Maplewood Nature Center interpretive naturalist Oakley Biesanz presented "Bumble Bees and Wanna-Bees," sharing bee education activities, geared to 4-6th graders, to 35 attending naturalists; presentation included Trust Fund recognition.

Fall volunteer events at Pilot Knob and Fish Creek Open Space involved 113 adult volunteers/participants, 124 youth, and 6 trained volunteer supervisors; volunteers included members of the general public, public and private organizations, school groups, and private institutions. Events were publicized/volunteers were recruited via 18 emails to Greening's e-list (about 8,500 subscribers), posts to Greening's Facebook page (over 1,400 likes), and 530 volunteer recruitment fliers (with LCCMR ENRTF reference and logo) were distributed at service and volunteer fairs in summer/fall 2017. In addition, 7 emails were sent to Greening's volunteer supervisors (about

350 subscribers) and 6 supervisor packets containing project information were distributed to volunteer event supervisors.

Final Report Summary

Greening, Maplewood Nature Center, and Xerces presented at the March 2018 'LCCMR Pollinator Projects Update Conference' hosted by the Cariveau Bee Lab at the U of M. A total of 47 people attended representing 15 organizations.

Accelerated Migration of Bur Oak Ecotypes for Climate Resilience: Final Report by Frelich, L and Toot, R. will be posted on the U of MN Center for Forest Ecology web page. Greening and our four lgu land-owning partners, have a vested interest in the success of these oak restorations and will remain keenly attuned to the results, thereby guiding future plantings.

The table below summarizes the Dissemination outputs by type:

Description:	Metrics:
Presentations: • Greening, Xerces, and Maplewood Nature Center presented at three annual *LCCMR Pollinator Projects Update Conferences* hosted by the U of M's Cariveau Bee Lab (est. 100 attendees total). • Greening presented on 'Biomass Harvesting via Haying' featuring the Prescribed Haying for Pollinators and Prairie activity, at the *2016 North American Prairie Conference* (60 attendees). • A Greening intern presented a poster highlighting the bur oak accelerated migration project at the December 2016 *Macalaster College student intern poster presentation*. (50 attendees) • Xerces highlighted bumble bee and floral resources monitoring at Pilot Knob, including the Citizen Science Monitoring Guide, at *Best Practices for Pollinators in the Real World Summit, for Minnesota Counties, Municipalities, Leaders* (150 attendees) • Maplewood Nature Center presented at two MN Naturalists Association annual conferences, presenting on the student engagement at Fish Creek Natural Area. (42 attendees), and regularly integrated the findings into programming	Activities and results were presented in-person to over 400 people.
Media : Greening featured the Pilot Knob bumble bee survey in September 2015 monthly e-news; results were posted on website and Facebook page. An article on the related, previously-funded accelerated migration of bur and white oak study was posted by the University of St. Thomas (Measuring the Future of Minnesota's Trees). A Star Tribune article on the rusty patch bumble bee highlighted a photo of the specimen documented at the Pilot Knob site. Star Tribune: Rusty patched bumblebee first of species called endangered. Both articles were subsequently posted to Greening's e-news and website.	

A feature article on the findings at the Pilot Knob Bumble Bee surveys is posted on the Xerces web page: Two Rare Species Spotted During Minnesota Bumble Bee Survey *Accelerated Migration of Bur Oak Ecotypes for Climate Resilience: Final Report* by Frelich, L. and Toot, R. is scheduled to be posted on U of MN Center for Forest Ecology web page	
Active Engagement and Recruitment: A suite of citizen participation, including K-12 field trips, citizen science monitors, professional training, public and private volunteer groups was an integral part of the dissemination of results as well as program deliverables (reported above), , Recruitment for citizen participation, which included brief descriptions of the activities and proper acknowledgement, reached > 30,000 citizens many of them more than once. Greening recruited volunteers for the Pilot Knob bumble bee surveys once per year as part of overall volunteer recruitment, via social and printed media as part of our larger event recruitment, and Maplewood Nature Center recruited participants for the citizen science training several times per year.	Over 1550 citizens, including 841 K-12 students and 712 volunteers participated in this program. Greening social media outreach includes 8,500 e-newsletter subscribers, >680 Twitter followers, and Facebook (>1600 likes). Maplewood Nature Center and Xerces Society conducted outreach via social media, printed material, and networking; >20,000. Greening distributed approximately 750 hard copy flyers recruiting volunteers for the Pilot Knob bumble bee surveys, at an estimated 15 outreach events and other avenues.
Publications and Reports: *Accelerated Migration of Bur Oak Ecotypes for Climate Resilience: Final Report* by Frelich, L. and Toot, R. Xerces' Upper Midwest Citizen Science Monitoring Guide Native Bees pdf. Maplewood Nature Center's Fish Creek Pollinator 4-8 Program ppt Xerces' *Citizen Engagement for Pollinator Monitoring: Bumble Bee Monitoring Final Report 2015-2017 Pilot Knob Hill* Xerces' *Prescribed Haying for Pollinators and Prairie: Pollinator Monitoring Final Report 2015-2017* Greening's *Prescribed Haying for Pollinators and Prairie: Response of vegetation and soil nitrogen to haying in a restored prairie Final Report*	

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 50,960	Staff time for oversight, volunteer events, restoration implementation, procuring services, vegetation monitoring, soil sampling.
Professional/Technical/Service Contracts:	$ 302,046	100K U of M; 101K Xerces; 34K Maplewood; 74K oak fencing, watering, nursery growing, soil analysis, haying.
Equipment/Tools/Supplies:	$ 17,001	Forb and grass plugs, shrubs and trees, with individual herbivory protection; soil amendments/mulch, acorns, herbicide; fencing
Capital Expenditures over $5,000:	$	
Printing:	$ 123	Handouts, poster boards, signs
Travel Expenses in MN:	$ 4,143	
Other: Volunteer Event Expenses	$ 3,366	Approved food and beverage, tent/table/chair /toilet rentals, overnight security, gloves and safety glasses, hand tools.
Other: Out of State travel	$ 122	Travel to Iowa and North Dakota for acorn source verification, procurement
TOTAL ENRTF BUDGET:	**$ 377,761**	

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: 1.1

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 3.2 (including graduate student)

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
South Washington Watershed District (cash)	$7,800	$7,800	Central Corridor activities
Local Government Units (cash)	$8,000	$8,000	Activities at Fish Creek, Pilot Knob Hill, Allemansratt, Otter Lake
Private Corporations (cash)	$11,200	$11,200	Volunteer Events
Xerces Society (in-kind)	$1,000	$1,000	Printed materials
City of Maplewood (in-kind)	$4,500	$4,500	Staff time, materials, supplies
Ramsey County Parks (in-kind)	$1,500	$1,500	CCM crew time at Otter Lake

NFWF 2016 Monarch Conservation Fund	$12,200	$12,200	Fish Creek, Allemansratt, Pilot Knob, and Central Corridor activities
TOTAL OTHER FUNDS:	**$46,200**	**$46,200**	

VII. PROJECT STRATEGY:

A. Project Partners:

- Dr. Lee Frelich, Director, The University of Minnesota Center for Forest Ecology. Recipient of $100,000 ENRTF for research design, oversight, data collection, analysis, report preparation, for Activity 1, including graduate assistant, and undergraduate assistant(s).
- City of Maplewood Nature Center. Recipient of $34,000 for Nature Center staff, busing to/from Fish Creek for school group pollinator monitoring, interpretation, and restoration; printed materials. Activity 2.
- Xerces Society for Invertebrate Conservation. Recipient of $100,850 ENRTF funds for design and oversight for citizen science monitoring of pollinators; design, identification, curation, data collection, analysis for monitoring of pollinators in hayed vs. unhayed prairie plots; printing of materials. Activities 2 and 3.
- Metro Conservation Corridors Partnership, for planning and coordination.

B. Project Impact and Long-term Strategy:

This project will inform and guide oak restoration throughout the state. The long term strategy is for the most viable oak ecotypes to be used in restorations. Growth and survival data in later years, such as the 5 and 10 year marks, and later, of the oaks will also prove informative and useful. As such, future ENRTF proposals may be submitted for review, in addition to pursuing other funding sources.

This project will inform restoration practitioners on pollinator communities during restoration, and help guide restoration activities to promote pollinators. Collecting the same floral and pollinator data in the future (e.g. 3, 5, 10 years and beyond) will also prove informative and useful. As such, future ENRTF proposals may be submitted for review, in addition to pursuing other funding sources.

Haying is a proven prairie vegetation management tool but is rarely used in the metro area due to lack of agricultural infrastructure. This project will be a metro area demonstration of haying, inform haying practices so they can benefit pollinators, and has the potential to accelerate the development of haying into a cost-saving management and restoration practice in the metro area.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
ENRTF M.L. 2009. MeCC V: Restore/Enhance Significant Habitat	7/1/09-6/30/11	$155,000
ENRTF M.L. 2011. MeCC VI: Restoring our Lands and Waters	7/1/11-12/1/14	$400,000
ENRTF M.L. 2013. MeCC VII: (Fish Creek Acquisition by FMR)	7/1/13-6/30/16	$162,000
ENRTF M.L. 2013. MeCC VII: Restoring our Lands and Waters	7/1/13-6/30/16	$208,000
ENRTF M.L. 2014. Upland and Shoreline Habitat Restoration in the Greater Metropolitan Area	7/1/14-6/30/17	$300,000
OHF M.L. 2011, 1st Special Session, Ch 6, Article 1, Sec 2, Subd. 5(d) Metro Big Rivers Habitat - Phase II (Fish Creek portion)	7/1/11-6/30/14	$ 40,000
OHF ML 2012, Regular Session, Ch 264, Article 1, Sec 2, Subd 5(b) Metro Big Rivers Habitat - Phase III (Fish Creek portion)	7/1/12-6/30/15	$176,337

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:

A. Parcel List:

See Attached

B. Acquisition/Restoration Information:

1. All restoration activities completed with these fund will occur on land permanently protected by a conservation easement or public ownership.
2. The anticipated restoration outcomes for the oak plantings are that $\geq$ 33% of the planted oaks will survive and exhibit growth by the end of the grant period; that the enhanced pollinator habitat will be established; and that haying will result in a higher diversity of native prairie forbs. Management plans will include the research and monitoring designs such that management will support the research and monitoring goals of the restoration; these plans are kept electronically in project folders.
3. The pollinator habitat improvements will follow the Board of Soil and Water Resources "Native Vegetation Establishment and Enhancement Guidelines". The oak ecotype study, by its nature of comparing local ecotype to southern ecotype and northwestern ecotype, requires a research variance from the BWSR guidelines.
4. Maintenance of the restorations becomes the responsibility of the landowners after the grant period; Greening requires a statement accepting that responsibility to be signed by the landowners.
5. Greening will continue to give consideration to CCM for restoration activities, particularly their summer youth crews.
6. Identifying which techniques worked and which ones did not is a central principle to the entire project; evaluations at the end of the grant period will be completed by the Project Team. The three year evaluations will be led by Great River Greening, with anticipated participation by the research organizations given the inherent value in the 'third year' evaluation data.

IX. VISUAL COMPONENT or MAP(S):

See Attached.

X. RESEARCH ADDENDUM:

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than February 1, 2016, August 1, 2016, February 1, 2017, August 1, 2017 and February 1, 2018. A final report and associated products will be submitted between June 30 and August 15, 2018.

Environment and Natural Resources Trust Fund
M.L. 2015 Project Budget

Project Title: Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation
Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 08f
Project Manager: Wiley Buck
Organization: Great River Greening
M.L. 2015 ENRTF Appropriation: $400,000
Project Length and Completion Date: 3 Years, June 30, 2018
Date of Report: November 2, 2018

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	**Accelerated Migration of Bur Oak Ecotypes for Climate Resilience**			**Citizen Engagement for Pollinator Habitat Restoration and Monitoring**			**Prescribed Haying for Pollinators and Prairie**				
Personnel (Wages and Benefits)	$22,815	$22,075	$740	$26,315	$26,315	$0	$9,535	$2,570	$6,965	$58,665	$7,705
Wiley Buck, Project Manager/Ecologist: $7,924 (78% salary, 22% benefit); 4% FTE for 3 years.											
Candice McElroy, Grants Administrator: $7,000 (80% salary, 20% benefit) 5.6% FTE for 3 years.											
Rebecca Tucker, Ecologist: $8,884 (85% salary, 15% benefits); 4% FTE for 3 years											
Steve Huckett, Director of Conservation: $3,635 (90% salary, 10% benefits); 1.5% FTE for 3 years.											
Eric Ogdahl, Karli Cich; Ecological Assistants: $14,865 (est. 86% salary, 14% benefits); est. 13% FTE for 3 years											
Katie Brom, May Yang; Volunteer Managers: $8,851 (87% salary, 13% benefits); 7% FTE for 3 years.											
David Schmitz,Field Coordinator: $1,428 (86% salary, 14% benefits); 1% FTE for 3 years.											
Alex Wergrzyn, Chance Meyer; Restoration Technicians: $1,935 (93% salary, 7% benefits); 2% FTE for 3 years											
William Smith, Director of Finance: $2,857 (81% salary, 19% benefits); 1% FTE for 3 years.											
Sandy Lewis, Administrative Assistant: $1,286 (86%salary, 14% benefits). 1% FTE for 3 years.											
Professional/Technical/Service Contracts											
U of MN Center for Forest Ecology. Research Design, Oversight, Data Collection, Analysis, Report Preparation.	$100,000	$100,000	$0							$100,000	$0
Xerces Society for Invertebrate Conservation. Design and oversight for citizen science monitoring of pollinators; design, data collection, analysis for monitoring of pollinators; bee expert honorarium; printing of materials.				$38,233	$35,295	$2,938	$62,617	$62,617	$0	$100,850	$2,938
City of Maplewood. Nature Center staff, busing to/from Fish Creek for school group pollinator surveys and restoration, printed materials.				$34,000	$34,000	$0				$34,000	$0
TBD (competitive bid). Site preparation, fencing/tree caging and watering, nursery custom growing, soil N testing, vegetation monitoring, haying services.	$66,719	$65,822	$897				$8,200	$4,312	$3,888	$74,919	$4,785
Equipment/Tools/Supplies											
Acorns, plugs, shrubs/trees, soil amendments, mulch/tree mats, herbicide, fencing.	$5,500	$2,225	$3,275	$14,495	$14,448	$47				$19,995	$3,322
Restoration tools and supplies: chainsaw/brushcutter supplies and repair; flagging; herbicide sprayer; protective equipment.	$337	$147	$190	$368	$181	$187				$705	$377
Printing											
Signs, posters, large maps, volunteer handouts	$500	$50	$450	$664	$71	$593	$336	$2	$334	$1,500	$1,377
Travel expenses in Minnesota											
Mileage to/from sites, meetings, purchases	$2,775	$2,678	$97	$2,220	$1,205	$1,015	$799	$260	$539	$5,794	$1,651
Other											
Out-of-state travel to Iowa to verify acorn source, mileage	$122	$122	$0							$122	$0
Volunteer Event Expenses: 5 events (3 oak planting and 2 forb plugging). 250 volunteers total at $11/volunteer for approved food/beverage, gloves, safety glasses, boot brushes, table/chair/portable toilet rentals, hand tools; 1 tent rental ($450) for larger oak event with overnight security to protect event set up ($250).	$2,350	$2,348	$2	$1,100	$1,018	$82				$3,450	$84
COLUMN TOTAL	**$201,118**	**$195,467**	**$5,651**	**$117,395**	**$112,533**	**$4,862**	**$81,487**	**$69,761**	**$11,726**	**$400,000**	**$22,239**

Environment and Natural Resources Trust Fund
M.L. 2015 Parcel List

Project Title: Metro Conservation Corridors Phase VIII - Enhancing Restoration Techniques for Improved Climate Resilience and Pollinator Conservation
Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 08f
Project Manager: Wiley Buck
Organization: Great River Greening
M.L. 2015 ENRTF Appropriation: $400,000
Project Length and Completion Date: 3 Years, June 30, 2018
Date of Report: November 7, 2018

#	Acquisition or Restoration Parcel Name	Geographic Coordinates Format: [Deg.]° [Min.]' [Sec.]" [Hemis.]		Actual Cost	County	Site Significance	Activity Description	# of Acres	# of Shoreline Miles	Type of Landowner	Status
		Latitude	Longitude								
1.1	Bur Oak Accelerated Migration: Central Corridor	1) 44° 51' 40.284" 2) 44° 51' 44.964"	1) -92° 54' 32.364" 2) -92° 54' 39.2034"	$22,977	Washington	Prairie and Savanna Habitat	Planting and Researching Three Ecotypes of Bur Oak	2		Watershed District	Complete
1.2	Bur Oak Accelerated Migration: Fish Creek Open Space	44° 53' 49.9194"	-92° 59' 53.1594"	$13,989	Ramsey	Prairie, Savanna, Woodland Habitat	Planting and Researching Three Ecotypes of Bur Oak	0.5		Municipality and County	Complete
1.3	Bur Oak Accelerated Migration: Allemansrätt Wilderness Park	45°23'58.72"N	92°50'42.408"W	$78,646	Chisago	High quality mosaic of forest and wetland	Planting and Researching Three Ecotypes of Bur Oak	3		Municipal	Complete
	Spring Lake Regional Park	44° 42' 34.5234"	-93° 28' 19.8834"	$0	Scott	Wetland, Savanna, Woodland Habitat	Planting and Researching Three Ecotypes of Bur Oak	0		County	Not going forward
1.4	Bur Oak Accelerated Migration: Otter Lake	45° 07' 23.2"	-93° 02' 08.5"	$78,777	Ramsey	High quality mosaic of forest and wetland	Planting and Researching Three Ecotypes of Bur Oak	4		County	Complete
2.1	Fish Creek Open Space	44° 53' 46.7952"	-93° 0' 9.831"	$86,964	Ramsey	Prairie, Savanna, Woodland Habitat	Pollinator-Friendly Plugging and Monitoring Pollinators, Vegetation	0.5		Municipality and County	Complete
2.2	Pilot Knob Hill Open Space	44° 52' 52.2876"	-93° 10' 1.3902"	$21,892	Dakota	Prairie, Savanna Habitat	Pollinator-Friendly Plugging and Monitoring Pollinators, Soil N, Vegetation	0.5		Municipality	Complete
3.1	Central Corridor	44° 51' 53.6364"	-92° 54' 33.4866"	$74,515	Washington	Prairie and Savanna Habitat	Haying and Researching Effects on Vegetation, Soil N, Pollinators	22		Watershed District	Complete

NOTES: As a research, monitoring, and citizen science project, $/acre for restoration activities are not comparable to other restoration projects.

Accelerated Migration of Bur Oak Ecotypes for Climate Resilience

Final Report. July 18, 2018

Lee E. Frelich
Director, University of Minnesota Center for Forest Ecology

Ryan Toot
Graduate student, University of Minnesota Natural Resources Science and Management program

Acknowledgement
Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

Introduction

Climate change will affect future ecological restoration activities—different plants and ecotypes may be best suited for Minnesota's future climate than the current local ecotype and vegetation. Because of our fragmented environment and distance and rate at which species will need to travel to keep up with climate change, new plant species and ecotypes are unlikely to be able to get here on their own (Galatowitsch, Frelich and Phillips-Mao 2009). Invasive species with superior dispersal abilities could dominate future vegetation. Therefore, accelerated migration of neonative species and ecotypes may be needed. Trees, with their low natural rate of migration and slow life cycles, are especially in need of human assisted accelerated migration. Oaks are among the most important mast and habitat trees in Minnesota, and the foundation species in several of our native plant communities such as oak savanna and woodland. To maintain oak trees in Minnesota's future, the appropriate ecotype must be determined; this study will be a vanguard study to identify appropriate bur oak ecotypes for Minnesota's new climate.

Bur oak is intolerant of shade, casts low density shade, and is a poor competitor under conditions that allow mesic tree species like sugar maple, red oak and basswood to thrive, but is a good competitor on droughty sites or sites with frequent fire. It was historically abundant on savannas and open woodlands mixed with other oaks (red, white, black) with frequent fires that kept aggressive competitors at bay (Johnson 1990), it occurs as an occasional tree in northern hardwood stands (Curtis 1959; Frelich, Montgomery and Oleksyn 2015). The species can survive as grubs that are repeatedly top killed by fires (possibly for several centuries), but can sprout and become a tree if an interval of several years without a fire occurs (Curtis 1959). Due to development of thick bark at a relatively young age, the species can survive frequent surface fires, and is the most fire tolerant of all oak species in the Midwest (Frelich, Reich and Peterson 2015). Bur oak also occurs as riparian species in major river systems, occupying areas that are subject to short duration flooding events (2-3 weeks) just above the zone occupied by cottonwood, silver maple and black willow where floods are of long duration. Bur oak had high survivorship after 3-5 weeks of flooding, but growth was retarded compared to cottonwood and swamp white oak (Kabrick et al 2012).

Bur oak trees can survive for 200-400 years, and are used for long-term tree-ring chronologies; a chronology exists that spans years 912-2004 in the Midwest, with the possibility of eventually going back 10,000+ years using fossil wood preserved in sediments (Stambaugh and Guyette 2009). The species is very resistant to wind damage, due to low branching and low center of gravity, flexible wood, and low density crowns that don't provide much surface area for the wind to push on (Frelich and Ostuno 2012). The species is also less subject to road salt damage than other oaks, especially red oak (Singh and Stasolla 2016).

Perhaps the most important characteristic of bur oak that makes it a good species for a warmer future, is its resistance to heat waves and droughts. Trees are capable of obtaining most of their water from water tables 6-7 m below the surface (Chimner et al. 2014). Bur oak is more drought resistant than red oaks with lower mortality rates during an extreme drought (1987-1989) at Cedar Creek Ecosystem Science Reserve (Faber-Langendoen and Tester 1993). Tree-ring-based reconstructions of native savannas has shown that bur oak seedlings can become established during severe droughts, such as during the 1930s (Ziegler et al. 2008).

Even if the mesic northern hardwoods are wiped out across the Midwest by the combined effects of increasing temperatures, longer growing seasons, more droughts, storms, fires, invasive tree diseases and pests, and earthworm invasion, oaks will still be able to grow throughout much of the region (Frelich and Reich 2010). Increased fire in the future may help species like bur oak replace northern conifer and shade-tolerant northern hardwoods in a warming climate (He, Mladenoff and Gustafson 2002).

Conservation Issues

Relatively little ecologically intact bur oak savanna or woodland remains in the Midwest today (Nuzzo 1986). There is a lot of evidence for the oak and fire hypothesis, that oaks require fire to reproduce abundantly (Frelich et al 2015). Exclusion of fire by suppression and fragmentation of the landscape since the early 1900s, has allowed mesophication of oak forests (Nowacki and Abrams 2008). Mesophication results from a combination of fire exclusion, wetter summer climate in recent years, invasion by mesic hardwood species like maple that cast dense shade and keep the understory more moist, reinforcing fire exclusion. In some locations, changes in water table due to climate and landuse change favor invasion by tree species (e.g. elms) that prefer very wet conditions (Asbjornsen et al 2007). A few extremely dry, sandy sites are somewhat of an exception to the general rule that bur oak stands have been mesophied, although even on these sites, some woody encroachment has occurred (Dickie et al 2007, Peterson and Reich 2001).

Another issue of concern is invasion of bur oak savannas and woodlands by the exotic shrubs common buckthorn (*Rhamnus cathartica*), Tatarian honeysuckle (*Lonicera tatarica*), and others that follow European earthworm invasion (Frelich et al 2006). Indeed, there is a substantial two-way facilitation between European earthworms and buckthorn (Roth et al 2015). These invasive shrubs are more aggressive in bur oak stands as compared to other under oak species (Schulte et al 2011).

A third issue of concern for bur oak conservation is potential effects of genetic isolation of the remaining stands. However, evidence for this concern is mixed. Oaks in general have high rates of gene flow due to wind-dispersed pollen, and avian and mammal seed dispersal (Gerber et al. 2014). For bur oak, average pollination distance was found to be 42-70 meters within stands, with substantial proportions of pollination originating from outside of stands, well over 100 meters away 9Craft and Ashley 2010). Seed distribution is very good for a relatively large-seeded species, especially for northern ecotypes with small acorns that can be moved up to 2 km by Bluejays (Darely-Hill and Johnson (1981). Temperature and rainfall constrain acorn size, so that acorns are smaller in north and quite large in the south (Koenig et al. 2009). Bluejays probably cannot disperse acorns from bur oaks in Iowa and southward (due to acorns being too large to hold in their beaks), leading to concern that southern ecotypes will not be able to move northwards very fast on their own. In Illinois, half of all acorns fall straight down under the crown of parent tree, but some are dispersed 100-165 m (Dow and Ashley 1996). To sum up, there is some genetic connectivity among isolated bur oak stands (Craft and Ashley 2010) and no genetic structure was fund in isolated bur oak savanna remnants scattered over 160 km was found in Illinois (Craft and Ashley 2007), implying that adequate gene flow is occurring even when stand are several miles apart. However, more extreme isolation in bur oak remnants along the along the Minnesota River in southern Minnesota apparently has had some effect on gene flow among bur oak stands (Kittelson et al 2009). There is no evidence that proves that bur oak will be able to respond through natural movement of pollen and seeds, to the large geographical magnitude of shift in climate expected to occur over the next century in the Midwest.

Why plant bur oaks now?

The increasing desirability of restoring native vegetation, the suitability of bur oak for a future warmer climate in the Midwest, and the conservation problems related to fragmentation, lack of fire, invasive species, and climate change that is too rapid for most tree species to respond to, have all led to the great interest in planting oaks and learning about the success of planting techniques at this time. In addition, competition with herbaceous old field vegetation and limited mycrorrhizal infection more than 20 m from existing oak stands both limit bur oak invasion into fields from nearby forest stands (Dickie et al. 2007), and planting oaks can get around these difficulties.

Bur oak stands have been especially hard hit by land use conversion for agriculture, fire exclusion and invasion by native and exotic species (Marcum 2010, Schulte et al. 2011), At the same time, oaks are likely to fare better than mesic hardwood species with the future warming climate (Frelich, Montgomery and Oleksyn 2015). The niche of oak on the landscape—the proportion of sites where it can compete—will increase with a warmer climate, or with the restoration of fire (Frelich and Reich 2002). Climate is likely to change faster than rate at which this species can move (Iverson et al 2011).

Finally, although provenance trials (where seeds or seedlings from several locations are planted in a common garden) have been conducted for many tree species, a search of the literature (Johnson 1990 plus searches in USDA Forest Service TreeSearch and Web of Science) does not reveal any such trials for bur oak. This is probably because bur oak is mostly of ecological importance and historically has not been a big player economically in the forest industry. Therefore, this experiment (described in detail below) should yield valuable information about bur oak, one of the most ecologically important tree species in the Midwest.

Bur oak and climate projections

Climate envelope models attempt to predict where a given species of tree will grow under a future, warmer climate (Prasad et al 2007-ongoing, Iverson et al 2008). They do this by taking information on precipitation and temperature for the growing season (May-September) at the edges of the range, and projecting the new geographic locations where those same combinations of climatic variables would fall in the projected future climate.

The problem with bur oak is that there is little projected movement, because the range spans from the Gulf of Mexico in Texas to Lake Winnipeg in Manitoba, Canada (Figure 1). Therefore, the species shows little sensitivity to climatic warmth in the climate envelope model (Figure 2), and a 300-mile projected northward shift in climate (Figure 3) causes little projected change in places where bur oak is projected to grow well.

In reality, however, species like bur oak with very broad north-to-south ranges, have a gradient of ecotypes that are adapted to local climate, related to length of growing season and summer warmth. Acorn size in bur oak is one expression of this gradient (Koenig et al 2009). These adaptations include large acorns in warmer climates, more conservative leaf out times in warmer climates (i.e. trees wait for more growing degree days to accumulate in spring before leafing out in the south as compared to the north), greater

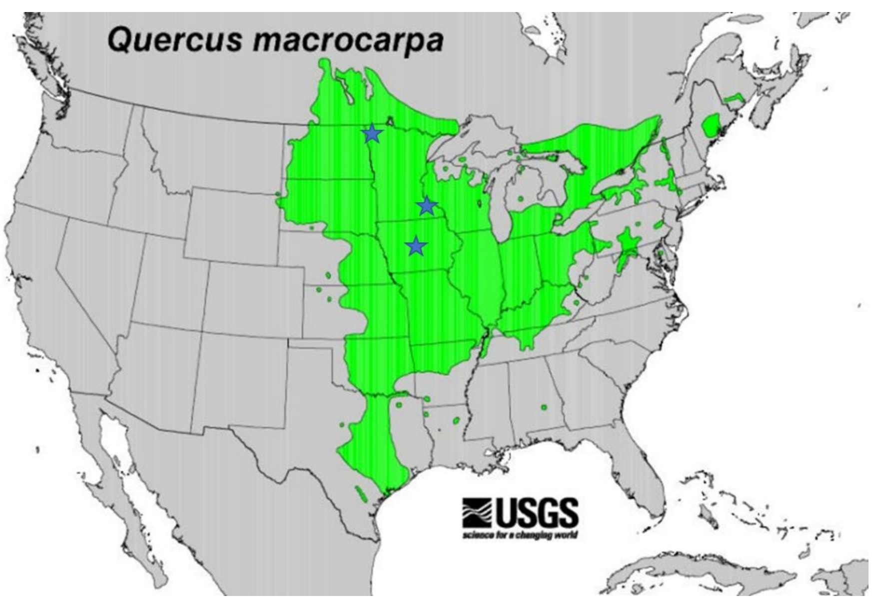

Figure 1. Range of bur oak. Stars show the north, central and southern seed source locations.

tree height in a warmer climate, more horizontal branching in a warmer climate, and earlier shedding of leaves in the north. Therefore, genetically fixed ecotypes arranged by latitude likely exist. However, compared to other tree species, very little research has been done on bur oak ecotypes. The current situation for Minnesota is that we are in the early phases of very large magnitude climate change, and are close to the northern edge of the range of bur oak, and thus, bur oak is expected to fare better in the future at the expense of other tree species, but unlikely to be able to respond on its own.

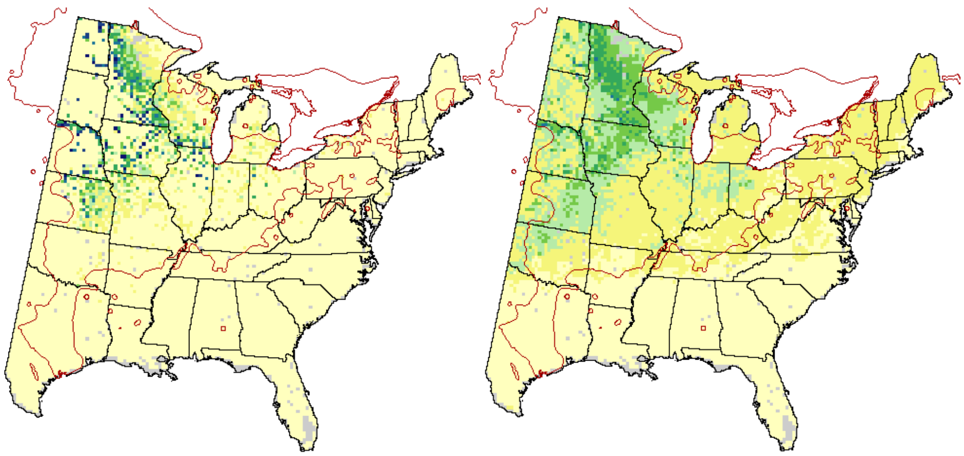

Figure 2. Current bur oak abundance based USDA Forest Service on inventory data (left) and projected bur oak abundance for a high (business as usual CO_2 emissions scenario, right). From Prasad et al 2007-ongoing.

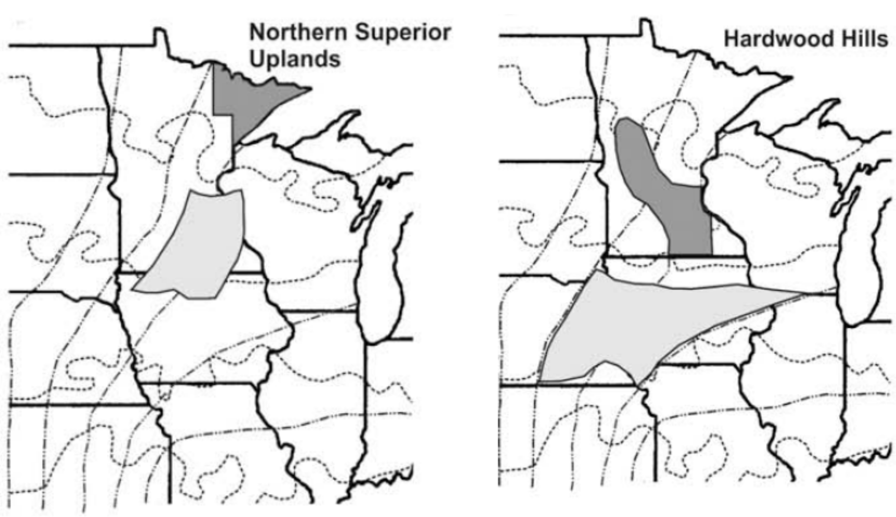

Figure 3. Projected future climate envelopes (light gray) for northeastern and south-central MN (dark gray), based on a business as usual scenario, from Galatowitsch, Frelich and Phillips-Mao, 2009.

Experimental design, acorn collection and seedling planting

The basic design is to plant bur oak seedlings of northern, central, and southern ecotypes in four common garden location in the Twin Cities Metro Area. The three ecotypes came from: Roseau in northwestern Minnesota, Rice County in south-central Minnesota, just south of the Twin Cities Metro Area, and Iowa, with the approximate centroid of the seeds included centered around Des Moines in the center of the state, at least 100 miles further south and likely averaging 200 miles further south than the Rice County seed source (stars in Figure 1). 5889 seedlings were planted (Table 1).

The experiment will tell us whether the local ecotype of bur oak still does better than those from Iowa (given the warming that has already occurred), or whether it is time to start switching to seed sources from further south (Figure 3, right). In addition, it will inform how bur oak in northern Minnesota will fare when the climate there becomes similar to the central seed source location, close to the Twin Cities Metro Area, since one part of the experiment involves planting acorns from northern Minnesota in the Metro Area (Figure 3, left). Thus, although not envisioned at the time the experiment originated, this experiment could inform the future of the Boundary Waters Canoe Area Wilderness, which is expected to convert to oak savanna due to shallow soils and projected warmer summers (Frelich and Reich 2010, Galatowitsch, Frelich and Phillips-Mao 2009).

Table 1. Bur oak seedlings planted by site and ecotype (provenance)

Site	Ecotype			
	Roseau (north)	Rice County (central)	Des Moines (south)	Totals
Allemansratt Wilderness Park	474	491	498	1463
Bald Eagle - Otter Lake Regional Park North	284	283	292	859
Bald Eagle - Otter Lake Regional Park South	589	583	588	1760
Fish Creek Natural Area	105	108	104	317
South Washington Central Corridor	517	498	475	1490
Total	1969	1963	1957	5889

Acorns of three different ecotypes were collected. Local ecotype acorns originated approximately 50 miles southwest of St. Paul; southern ecotype was from central Iowa near Des Moines and the northern provenance with climatic extremes of all types (cold, heat, drought) originated in northwestern Minnesota, near Roseau. Collection was done through Greening's network of acorn providers via paid collection followed by location verification for southern and northern ecotypes, and via Mn-DNR Forestry acorn purchase program for local ecotype . These acorns were custom grown using ecotype specific beds in a common nursery operation under identical conditions, at Mn-DNR's Badoura Nursery. At this nursery, leaves were painted according to DNR protocol using a different color for each ecotype.

Bur oak seedlings were planted at four old field sites in the suburban and exurban Twin Cities Metro Area. Site preparation at each site consisted of mowing the existing vegetation while dormant. Colored pin flags were used to mark the location of each planting with a spacing of approximately 9 feet. The pin flag colors correspond to seedling ecotype – orange for Des Moines, blue for Rice County, and white for Roseau. The ecotypes are randomly distributed throughout each site to mitigate the effects of local variations in topography and soil. The seedlings were planted on a range of dates by different crew combinations (Table 2). Before planting, the seedlings were kept in cool moist conditions by use of small plastic coolers, plastic bags, and a walk in plant cooler. During planting, seedlings were distributed to crew members in color coded buckets filled with moist straw. Colored flagging was used to aid recording of which date each seedling was planted. The stem of each seedling was painted the color corresponding to its ecotype. Seedlings were planted at the Allemansratt Wilderness Park and the Fish Creek Natural Area sites in a 2 foot diameter hole deep enough for the bare rootstock. Soil was then filled in around the roots, up to the root flare. The holes were dug by hand, often supplemented by a power auger. These seedlings were watered with approximately ½ gallon of water immediately after planting. Seedlings were planted at the Bald Eagle - Otter Lake Regional Park and the South Washington Central Corridor sites with a dibble bar. Multiple entries with the dibble bar were made for each seedling at perpendiculars to enable the roots to grow in all directions. The holes were then closed around the bare rootstock. These seedlings were not watered after planting. The seedlings at the Fish Creek site were mulched shortly after planting (Table 2) with woodchips. The other sites were mulched as stated in Table 2. All seedlings planted at Allemansratt, Otter Lake, and Fish Creek were protected from herbivory shortly after planting by securing a plastic mesh tube around the seedling on a bamboo stake.

Mulching with either plastic or organic materials such as straw has been shown to increase survival of planted bare root oak seedlings (Truax and Gagnon 1993). Tree tubes are being used in this experiment, which previous research has shown to increase the growth and survival of planted oak seedlings for conditions where there is little competing vegetation (Laliberté, Bouchard and Cogliastro 2008), and also reduced mortality caused by herbivores like deer and voles, which can be significant for oaks. Success rates 2-4 years post-planting of 60-90% for bare root bur oaks have been reported in the literature (Truax and Gagnon 1993, Cogliastro, Gagnon and Bouchard 1997, Laliberté, Cogliastro and Bouchard. 2008, Laliberté, Bouchard and Cogliastro 2008). Seedling root depth typically reaches 4.5 feet during the first growing season after planting (Johnson 1990), so that the seedlings become well established with ability to withstand drought, competition and top-kill by fires, despite the slow above-ground growth in the first few years.

Hypotheses to test

Hypothesis 1: Bur oak seedling growth will be positively related to initial seedling size (height) at time of planting, both across all provenances (seed origins) and within each provenance.

Rationale: Larger seedlings get more sunlight, have more stored energy and nutrients. Many studies show that absolute growth rate of seedlings and trees is directly related to initial size. Size of acorns very likely follows the latitudinal gradient (small in the north, large in the south), which is a very important factor in first and second year seedling size.

Hypothesis 2: Bur oak seedling growth will be negatively related to latitude of origin (northern MN seed source > Metro > Iowa), even if initial seedling size is taken into account.

Rationale: Almost all tree species show a pattern of slower growth towards the northern edge of their range, which is genetically fixed and remains when different seed sources are planted in a common garden experiment. Even if this pattern does not show up in absolute growth rate (due to confounding effects of initial acorn size being larger in the south), it could still be evident in relative growth rates, and/or a subset of southern seedlings that were relatively small for their provenance, and northern seedlings that were relatively large for their provenance, which are similar in size, that can be compared.

Hypothesis 3: Growth rates within each provenance will be the same among the four planting sites.
Rationale: The alternative hypothesis is that growth rates will differ at one or more sites, so that site must be taken into account as a factor when evaluating the other hypotheses. Spatial structure of oak seedling survival and growth rates in previous research in Quebec was related to soil characteristics, although acorn size and genetics also explain some of variation (Laliberté, Cogliastro and Bouchard. 2008). Bur oak height growth markedly different among soil types in a previous planting experiment that had 4-year survival of 60-90% in Quebec. Survival was highest on moraine ridges, stony and sandy soils (Cogliastro, Gagnon and Bouchard 1997). Moisture and light are two of the most important factors for growth of but oak seedlings (Wycoff et al 2012), and light is not a limiting factor on our open-field plating sites, so soil spatial variation in growth and mortality within and/or among sites is likely to be related to soil moisture.

Hypothesis 4: Timing of planting, relative to end of planting season will make a difference in growth; the later the planting date the slower the growth in the first season.

Rationale: Seedlings planted a few weeks earlier had more time for root establishment before soil freezing and will therefore be better able to grow faster during summer of 2017. If this hypothesis is true, then timing will have to be taken into account as a factor when evaluating the other hypotheses.

Study site details
Allemansratt Wilderness Park

The Allemansratt Wilderness Park planting site is located in Lindstrom, MN, at 45.400184 N, -92.837491 W. It is a previously grassy open field with some topography that dishes to the center to encompass a small low, wet area. The vegetation over most of the field consisted primarily of old field vegetation, dominated by non-native invasive smooth brome (*Bromus inermis*)prior to planting. The enclosed wet area is comprised mostly of reed canary grass, and was largely avoided for oak planting.

Bald Eagle - Otter Lake Regional Park

The planting sites at Bald Eagle - Otter Lake Regional Park are located at north site: 45.120856 N, -93.029561 W; south site 45.119068 N, -93.028645 W, in White Bear Lake, MN. Both sites were primarily open grassy fields, with non-native cool season grasses as the main components. Both sites also contain some mature trees. The north planting site is sloped to the southeast, and is bordered there by a wetland. The south planting site slopes to the southwest and is bordered there by a wetland. The other borders of both sites are comprised of mixed woodland.

Fish Creek Open Space

The Fish Creek Open Space planting site is located at 44.894462 N, -93.002963 W in Maplewood, MN. It was a grassy open field, sprayed and seeded to dry-mesic prairie with minimal native prairie establishment. It slopes gradually to the west. It is bordered on the south by and oak forest, and on the other three sides by reconstructed dry-mesic prairie. an

South Washington Central Corridor

The South Washington Central Corridor planting site (SWCC) is located at 44.862168 N, -92.911866 W in Woodbury, MN. It is a previously grassy field of reconstructed dry-mesic prairie. It slopes to the north and east. It is bordered on the south and west by farm fields, on the north by white oak plantings in mesic reconstructed prairie , and to the east a low grassy swale supporting a small woody component.

Table 2. Summary of planting and mulching details

Planting Site	Planting Date	Crews	Flagging Color/Area Descritiption	Method	Mulching Date	Crew	Type
Allemansratt Wilderness Park	10/29/16	Volunteers, GRG	Neon Green	2' D hole, watered	12/22/2016, and 3/16/17-3/27/17	GRG/VOL	Woodchips
	11/2/16	GRG, CCM	No Flagging				
	11/3/16	PRI, CCM	Pink				
	11/9/16	GRG, PRI	Yellow				
	11/10/16	GRG, PRI	Yellow				
Bald Eagle - Otter Lake Regional Park South	11/15/16	GRG, PRI	North to South on South Plot. Border was flagged	Dibble Bar, not watered	4/3/17-4/5/17	GRG/CCM	Tree Mats
	11/16/16	GRG, PRI	North to South on South Plot. Border was flagged				
	11/17/16	GRG, PRI, CCM	Plot Finished				
Bald Eagle - Otter Lake Regional Park North	11/17/16	GRG, PRI, CCM	South to north. Border flagged	Dibble Bar, not watered	4/3/17-4/5/17	GRG/CCM	Tree Mats
	11/22/16	GRG, PRI, CCM	North plot finished				
Fish Creek Natural Area	11/4/16	Volunteers, GRG	East to west, border flagged	2' D hole, watered	16-Nov-16	RCCF	Woodchips
	11/7/16	GRG	East to west, border flagged		21-Nov-16	RCCF	
	11/8/16	GRG	East to west, plot finished		21-Nov-16	RCCF	
South Washington Central Corridor	11/23/16	PRI	Southwest to East. Border was flagged	Dibble Bar, not watered	n/a	n/a	None
	11/24/16	MNL	Plot finished				

GRG - Great River Greening Crew VOL – Great River Greening Volunteers

CCM - Conservation Corps of Minnesota

PRI - Prairie Restorations, Inc.

MNL - Minnesota Native Landscapes, Inc.

RCCF - Ramsey County Correctional Facility figure 4: Allemansratt bur oak plantings by ecotype

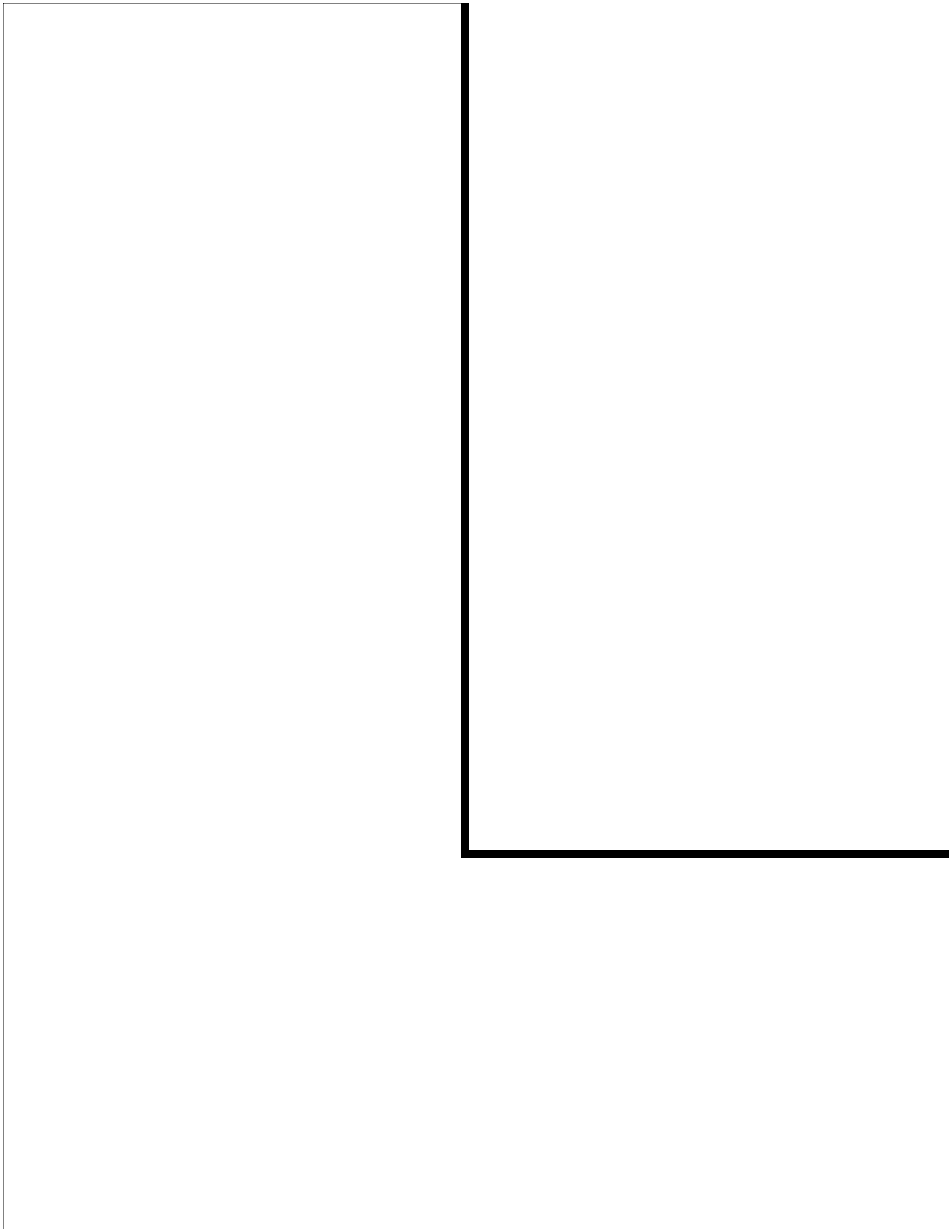

figure 5: Otter Lake North bur oak plantings by ecotype

figure 6: Otter Lake South bur oak plantings by ecotype

figure 7: South Washington Central Corridor bur oak plantings by ecotype

Fish Creek Natural Area Plantings

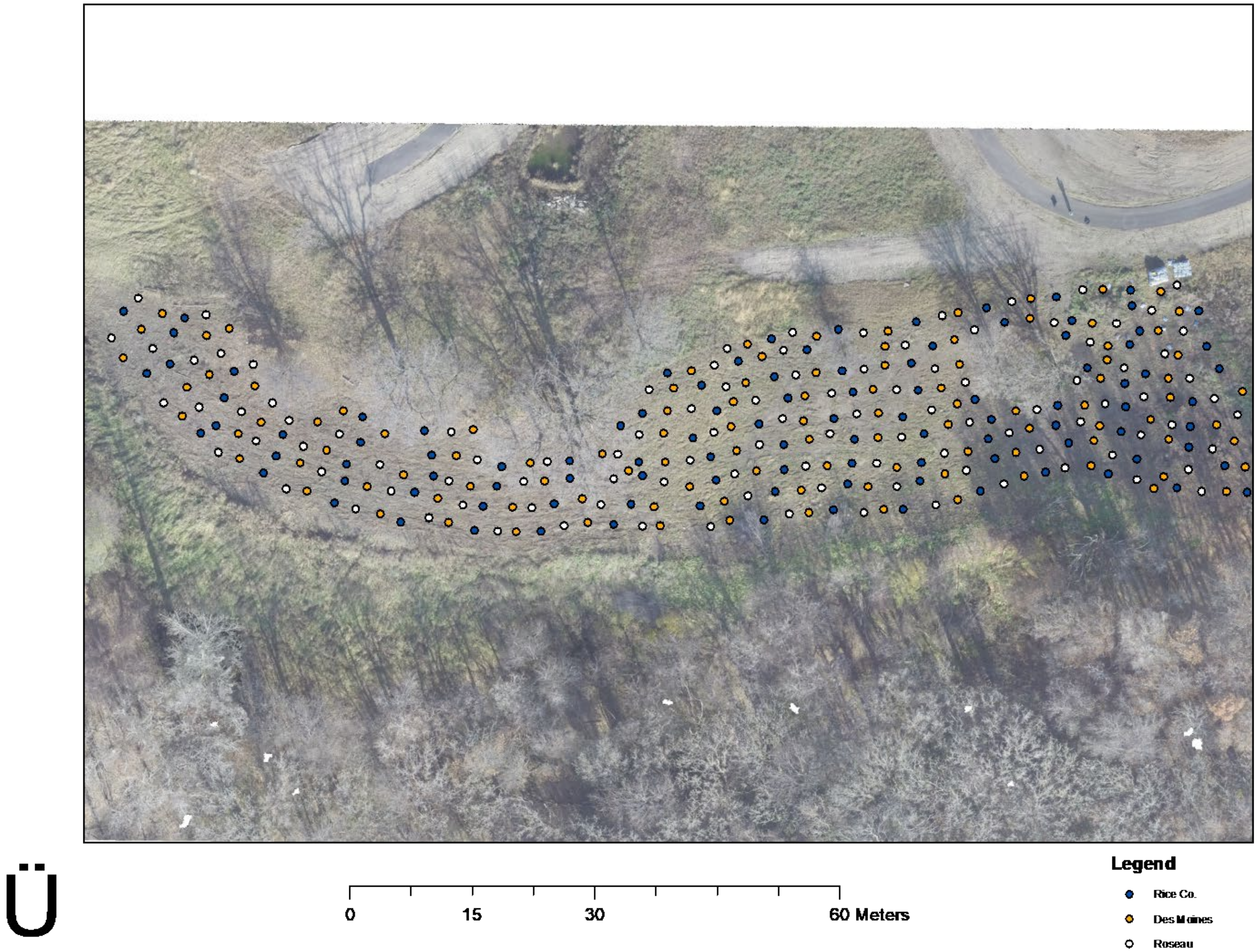

figure 8: Fish Creek bur oak plantings by ecotype

2017 Maintenance, data collection, methods and analysis:

Allemansratt
Data collection and maintenance

The height of the Allemansratt seedlings was measured in December 2016 and March 2017. Summary statistics are shown in Table 3. A small number of seedlings (12) had been browsed between planting and measurement. The heights of these seedlings are included in the summary table. In addition, there were 2 seedlings whose ecotype was misrecorded. These seedlings have been left out of the summary table, but will be kept in the database and updated after measurement during the 2017-2018 dormant season. The seedlings were mulched with woodchips during the 2016-2017 dormant season. The mesh tubes currently remain on the seedlings at the Allemansratt site. A perimeter fence was constructed around the Allemansratt plantings starting 10/23/2017 and completed on 11/20/17 to prevent ungulate herbivory.

Methods and data analysis

Analysis of variance (ANOVA) was performed on the 2016-2017 dormant season mean height of the seedlings to detect statistically significant differences between ecotypes at Allemansratt. The ANOVA tests the null hypothesis that mean height is equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t test was subsequently performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height differed significantly from another. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown).

Results
Based on the results of the ANOVA, the null hypothesis can be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that all three ecotypes differed from one another at a significance level < 0.001.

Table 3 : Allemansratt planted seedling height summary statistics and significance

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	474	18.0 (a)	7.0	0.3
Rice Co.	491	15.0 (b)	4.8	0.2
Des Moines	498	20.5 (c)	6.5	0.3

(a) (b) (c) indicate significant differences

Otter Lake North
Data collection and maintenance

Otter Lake North seedlings were measured in April and May of 2017. Summary statistics are shown in Table 4. Some seedlings had begun growing by the time they were measured for the 2016-2017 dormant season. However, the new growth was clearly distinguishable from the older growth, and the measurements reflect the height of the seedling during the 2016-2017 dormant season. A small number of seedlings (33) had been browsed, and some stems had been damaged by rodents between planting and measurement. The heights of these seedlings are included in the summary table. In addition, there were 2 seedlings whose ecotype was misrecorded. These seedlings have been left out of the summary table, but will be kept in the database and updated after measurement during the 2017-2018 dormant season.. The majority of the tree tubes at Otter Lake North were removed after measurements, with the exception of the seedlings measured on the first day at the site. It was later discovered that seedlings were being browsed at the site, so the remaining tubes were left on, and currently still remain on the seedlings. A perimeter fence was constructed around the Otter Lake North plantings starting 11/29/2017 and completed on 12/5/2017 to prevent ungulate herbivory.

Methods and data analysis

ANOVA was performed on the 2016-2017 dormant season mean height of the seedlings to detect statistically significant differences between ecotypes at Otter Lake North. The ANOVA tests the null hypothesis that the mean height is equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t test was subsequently performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height differed significantly from another. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown).

Results

Based on the results of the ANOVA, the null hypothesis can be rejected at significance < 0.001. Inspection of the QQ and residuals plots confirm sufficient normality of the data. The pairwise t test shows that the Des Moines ecotype differs from both the Roseau and the Rice County ecotypes at a significance level of <0.001. The Rice County and Roseau ecotypes do not significantly differ from one another.

Table 4: Otter Lake North planted seedling height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard deviation (cm)	Standard error
Roseau	284	17.4 (a)	7.0	0.4
Rice Co.	283	17.3 (a)	5.3	0.3
Des Moines	292	22.6 (b)	8.4	0.5

(a) (b) (c) indicate significant differences

Otter Lake South

Data collection and maintenance

Otter Lake South seedlings were measured in April and May of 2017. Summary statistics are shown in Table 5. As with the Otter Lake North site, some seedlings had begun growing by the time they were measured for the 2016-2017 dormant period. As before, the new growth was clearly distinguishable from the older growth, and the measurements reflect the height of the seedling during the 2016-2017 dormant period. A small number of seedlings (58) had been browsed between planting and measurement, and some stems had been damaged by rodents between planting and measurement. The heights of these seedlings are still included in the summary table. In addition, there were 3 seedlings whose ecotype was misrecorded. These seedlings have been left out of the summary table, but will be kept in the database and updated upon measurement during the 2017-2018 dormant period. Stem diameter at ground level was measured on a random sample of 323 seedlings. These summary statistics are shown in table 6. The mesh tree tubes at Otter Lake South were removed in May 2017 due to concern about the seedlings intertwining with the mesh, making the tubes being difficult to remove in the future.

Browse on the seedlings at the site was noticed shortly after removal. A perimeter fence was constructed around the Otter Lake South plantings starting 11/29/2017 and completed on 12/5/2017 to prevent ungulate herbivory.

Methods and data analysis

Analysis of variance (ANOVA) was performed on the 2016-2017 dormant season mean heights and the mean ground level diameters of the seedlings to detect statistically significant differences between ecotypes at Otter Lake South. The ANOVA tests the null hypothesis that the means are equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t test was subsequently performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height and diameter differed significantly from one another. Normality of the data was assessed with a QQ plot and a residuals plot (not shown).

Results

Based on the results of the ANOVA, the null hypotheses regarding 2016-2017 dormant season height and the null hypothesis regarding diameter can both be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that the three ecotypes' mean height differed from one another at a significance level < 0.001. The mean diameter of the Des Moines seedlings differed significantly from the Rice County seedlings at a significance < 0.001, and from the Roseau seedlings at a significance of < 0.05. The mean diameters of the Roseau and Rice county seedlings did not differ significantly from one another.

Table 5: Otter Lake South planted seedling height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	589	19.0 (a)	7.9	0.3
Rice Co.	583	16.5 (b)	5.2	0.2
Des Moines	588	23.5 (c)	8.2	0.3

(a) (b) (c) indicate significant differences

Table 6: Otter Lake South planted seedling diameter summary statistics

Ecotype	Seedlings	Mean (mm)	Standard Deviation (mm)	Standard Error
Roseau	106	6.1 (a)	1.8	0.2
Rice Co.	110	5.9 (a)	1.4	0.1
Des Moines	107	6.8 (b)	1.9	0.2

(a) (b) (c) indicate significant differences

Fish Creek

Data collection and maintenance

Fish Creek seedlings were measured in October and November in 2017. Height data was collected in 2017 using a tablet with a georeferenced pdf file and its associated attribute file. The files were created using the drone imagery created in 2016.

For the 2018-2018 dormant season, the measurement was made from the highest point on the seedling, regardless of whether that point was live or dead tissue. The measurement was made plumb to the ground surface level at the base of the seedling without manipulating the seedling.

This is in contrast to the first season measurements, for which the seedling length was measured. This affects the growth calculation because many seedlings were not planted and/or are not growing perfectly plumb. This biases the growth calculations lower than true growth to a degree varying by both seedling angle and length. Because the seedlings are relatively small and because the analysis entails a very robust data set being analyzed among ecotypes rather than analyzing absolute growth, this inconsistency does not pose a serious problem. The method change was made to ensure that in the future the measurement can remain consistent. When the seedlings become more rigid and taller, measuring length will not be feasible, but measuring height will be.

The seedlings were mulched during the 2016-2017 dormant season. At the time of 2017 data collection nearly all tubes at Fish Creek had been removed. Removal occurred in May of 2017, due to concern about seedlings entwining in the mesh and being difficult to remove in the future. At that time it was thought that herbivory would not be a problem due to the abundance of other vegetation for ungulate grazing and browsing. Unfortunately, browsing at the Fish Creek site during the 2017 growing season was fairly heavy, as evidenced by the number of seedlings used for the growth calculations. In addition to there was a small amount of rodent damage to some stems. A perimeter fence was constructed around the Fish Creek plantings starting 9/25/2017 and completed on 11/24/2017 to prevent ungulate herbivory.

Methods and data analysis

Table 7 shows the summary statistics from the 2016-2017 dormant season height measurements. Table 8 shows the summary statistics from the 2017-2018 dormant season measurements for all seedlings >0 cm. The growth for each seedling is calculated by subtracting the 2016-2017 height measurement from the 2017-2018 height, and is shown in table 9. Growth is calculated for only those seedlings whose main stem had not been obviously browsed or broken.

ANOVA was performed on the 2016-2017 dormant season height of each seedling to detect statistically significant differences between ecotypes at Fish Creek. The ANOVA tests the null hypothesis that the mean height is equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t test was subsequently performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height differed significantly from one another. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown). ANOVA was also performed on the calculated 2017 growth. A pairwise t test was also performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height growth differed significantly from one another. Again, the assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown).

Results

Based on the results of the ANOVA, the null hypothesis on 2016-2017 dormant season mean height can be rejected at significance < 0.001. Inspection of the QQ and residuals plots confirm sufficient normality of the data. The pairwise t test shows that the Rice County ecotypes' 2016-2017 dormant season mean height differed from that of both the Roseau and Des Moines ecotypes at a significance level < 0.001. The Roseau and Des Moines 2016-2017 dormant season mean heights are not significantly different. The null hypothesis regarding 2017 growth can be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that the Des Moines 2017 mean growth differs from that of the Roseau ecotype at a significance of <0.01, and from the Rice County 2017 mean growth at a significance of <0.1. The Rice County and Roseau seedlings' mean growth differed significantly from each other at a significance level of < 0.001.

Table 7: Fish Creek 2016-2017 dormant season height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	105	21.0 (a)	6.6	0.6
Rice Co.	108	16.7 (b)	4.4	0.4
Des Moines	104	22.7 (a)	6.6	0.7

(a) (b) (c) indicate significant differences

Table 8: Fish Creek 2017-2018 dormant season height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	95	20.9	10.3	1.1
Rice Co.	102	12.8	5.9	0.6
Des Moines	101	20.5	8.8	0.9

Table 9: Fish Creek 2017 seedling height growth summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	50	1.7 (a)	7.4	1.0
Rice Co.	66	-4.1 (b)	4.7	0.6
Des Moines	57	-1.8 (c)	4.9	0.7

(a) (b) (c) indicate significant differences

South Washington Central Corridor
Data collection and maintenance

Both the 2016-2017 and 2017-2018 dormant season height measurements were made during 2017, the former, during the months of April and May, the latter during the months of November and December. In June of 2017, some of the seedlings had begun to grow, but the new growth was clearly distinguishable from the prior year's growth. In these cases, the measurements reflect the height of the seedling during the 2016-2017 dormancy season. Measurement techniques remained consistent across sites during each dormant season, such that the 2016-2017 dormant season measurements at South Washington Central Corridor (SWCC) were seedling length, while the 2017-2018 measurements were height, as described for the Fish Creek site. Those implications apply to this site. At SWCC it was possible to infer which seedlings survived planting, and which did not. This was noted and used to exclude dead seedlings from analysis.

Approximately 75% of the tree tubes were removed at SWCC during measurement in May and June. The tree cages on the trees measured in April remained on the seedlings through the 2017 growing season, and were removed during the 2017-2018 dormant season measurements. There was little browse at this site, and a small amount of rodent damage to the stems of some seedlings.

A total of 15 Roseau seedlings, 135 Rice County seedlings, and 26 Des Moines seedlings appeared to have no new growth since planting or were not found at the time of 2017-2018 dormant measurement.

Methods and data analysis

Table 10 shows the summary statistics from the 2016-2017 dormant season measurements. Table 11 shows the summary statistics from the 2017-2018 dormant season measurements for all seedlings >0 cm that were found to be alive, excluding one seedling whose height was misrecorded.

Table 10: SWCC 2016-2017 dormant season height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	517	17.6 (a)	7.4	0.3
Rice Co.	498	18.4 (a)	4.8	0.2
Des Moines	475	22.9 (b)	7.1	0.3

(a) (b) (c) indicate significant differences

Table 11: SWCC 2017-2018 dormant season height summary statistics

Ecotype	Seedlings	Mean (cm)	Standard Deviation (cm)	Standard Error
Roseau	465	23.8	9.0	0.4
Rice Co.	318	18.3	4.8	0.3
Des Moines	410	25.2	10.7	0.5

Height growth for 2017 was calculated for seedlings that were not were browsed or broken, and had tissue grown in 2017. In some cases the main stem tissue of the seedling was dead above a certain point and was subsequently broken, but the seedling was alive and growing at a lesser height. These are also excluded from the growth calculation. The summary statistics of the 2017 growth are shown in table 12.

ANOVA was performed on the 2016-2017 dormant season mean height to detect statistically significant differences between ecotypes at SWCC. The ANOVA tests the null hypothesis that the mean height is equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t test was subsequently performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height differed significantly from one another. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown). ANOVA was also performed for the calculated 2017 growth. A pairwise t test was again performed using Bonferroni's p-adjustment method, to determine which ecotypes' mean height growth differed significantly from another. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown).

Results

Based on the results of the ANOVA, the null hypothesis regarding 2016-2017 dormant season mean height can be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that the Roseau seedlings' 2016-2017 dormant season mean height differed from both the Des Moines and Rice County ecotypes at a significance level of <0.001. The Rice County and Roseau seedlings' 2016-2017 mean height did not differ significantly from eachother. The null hypothesis regarding 2017 mean height growth can be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that 2017 mean height growth of the Roseau seedlings differed from both the Rice County seedlings and the Des Moines seedlings at a significance of <0.001, and the Rice County and Des Moines seedlings' 2017 mean height growth differed significantly from one another at a significance of <0.01.

Table 12: SWCC 2017 height growth summary statistics

Ecotype	Seedlings	Mean growth (cm)	Standard Deviation (cm)	Standard Error
Roseau	449	5.8 (a)	4.6	0.2
Rice Co.	310	0.6 (b)	3.5	0.2
Des Moines	395	2.2 (c)	5.4	0.3

(a) (b) (c) indicate significant differences

Discussion

It is too early to draw conclusions from the analysis presented here, but the following is a comment on the preliminary results. The mean height growth for the Rice County seedlings at SWCC was significantly lower than that of both the Roseau ecotype and the Des Moines ecotype in 2017. In addition, the mortality rate seems to be higher. There could be many reasons for this result, all of which should be addressed further. One reason could be that the seed source in Rice County was less diverse and/or genetically inferior than the other two seed sources. One would expect that the planted seedling height of the Rice County seedlings to be greater than that of Roseau and less than Des Moines because of the growing season lengths being longest in the south and shortest in the north. Longer growing seasons provide additional energy that can be stored in the acorn and subsequently utilized by the seedling. But in SWCC , the Rice county seedlings' initial height did not differ significantly from the Roseau seedlings, at Allemansratt, Otter Lake South, and Fish Creek they had the lowest mean height. In addition, the Rice County seedling heights were the least variable. This may support that reasoning.

Regardless of these somewhat unexpected results, the seedlings should continue to be measured in the coming decade and beyond to expand upon this research. The value of this research lies in the long term data and analysis, as trees are long lived species, and the first years after planting are likely to be more stochastic or unpredictable due to planting shock than years following.
It is noteworthy that some of the growth numbers are negative and relatively large in magnitude. This could be caused by a few different issues. The measurement method change is part of this, as well the possibility of a large stem being broken off and not visible, with a new stem being measured. Measurement or recording error is also possible. In that case, it will become evident upon inspecting data from the 2018-2019 dormant season, and can subsequently be corrected.

2018 Maintenance, data collection and analysis:

Allemansratt

Data collection and maintenance

A random sample of Allemansratt seedlings outside a 10 meter buffer around mature trees and a 5 meter buffer around a large patch of dense grass were visited in May 2018. The sampled seedlings, totaling 284, are shown in figure 9. 11 of these seedlings were not found. The heights of 91 Rice county seedlings, 91 Des Moines seedlings, and 86 Roseau seedlings were measured and recorded. The herbivory protection cages were removed from all of the seedlings in April during measurement. For these 2017-2018 dormant season measurements, height is from the ground level to the highest point on the seedling, regardless of whether that point was live or dead tissue. The measurement was made plumb to the ground surface level at the base of the seedling without manipulating the seedling. This is in contrast to the 2016-2017 dormant season measurements, for which the seedling length was measured. This affects the growth calculation because many seedlings were not planted and/or are not growing perfectly plumb. This biases the growth calculations lower than true growth to a degree varying by both seedling angle and length. Because the seedlings are relatively small and because the analysis is between ecotypes rather than absolute growth, this inconsistency does not pose a serious problem. The method change was made to ensure that in the future the measurement can remain consistent. When the seedlings become more rigid and taller, measuring length will not be feasible, but measuring height will be.

Methods and data analysis

5 of the measured seedlings had been mowed down and were not included in this year's analysis. 32 of the measured seedlings were browsed and were included in the analysis. Height growth during 2017 was calculated for all included seedlings. The summary statistics of the 2017 growth are shown in table 13. ANOVA was performed on the 2017 mean height growth of the seedlings to detect statistically significant differences between ecotypes at Allemansratt. The ANOVA tests the null hypothesis that the mean height growth is equal across ecotypes, the alternative hypothesis being that they are not equal. A pairwise t-test with Bonferonni's adjustment was used to determine the significant differences between each pair of ecotypes. The assumption of normally distributed data was assessed with a QQ plot and a residuals plot (not shown). ANOVA was performed within each ecotype to test the null hypothesis that growth is equal across planting dates.

Results

The results of the ANOVA indicate the null hypothesis regarding 2017 mean height growth can be rejected at significance < 0.001. Inspection of the QQ and residuals plot confirm sufficient normality of the data. The pairwise t test shows that 2017 mean height growth of the Roseau seedlings differed from both the Rice County seedlings and the Des Moines seedlings at a significance of <0.001, and the Rice County and Des Moines seedlings' 2017 mean height growth did not differ significantly from one another. The results of the ANOVA regarding plant dates indicates that the null hypothesis cannot be rejected at a significance <0.1. There is no evidence to support that the different planting dates have an effect on the growth of the seedlings.

Table 13: Allemansratt 2017 growth summary statistics

Ecotype	Seedlings	Mean growth (cm)	Standard Error
Roseau	91	8.6 (a)	0.74
Rice Co.	91	2.6 (b)	0.6
Des Moines	86	8.1 (a)	0.9

(a) (b) (c) indicate significant differences

Discussion

The mean height growth for the Rice County seedlings was less than that of both the Roseau ecotype and the Des Moines ecotype in 2017 at Allemansratt. Although the analysis addresses only one year's growth in the field, the result is surprising and statistically significant. Hypothesis 2 posited that the growth of the Rice County seedlings would be greater than that of Roseau and less than Des Moines because of the growing season lengths being longest in the south and shortest in the north. There could be many reasons for this discrepancy. It is possible that the non-native ecotypes benefit from a lack of well-adapted enemies compared to the relatively local Rice County ecotype, as in the enemy-release hypothesis. It is also possible that the seed source in Rice County is diverse and/or genetically inferior than the other two seed sources.

The seedlings should continue to be measured in the coming decade and beyond to expand upon this research. The value of this research lies in the long term data and analysis, as trees are long lived species, and the first years after planting are likely to be more stochastic or unpredictable due to planting shock than years following.

Otter Lake North

Data collection and maintenance

All Otter Lake North seedlings outside a buffer region around mature trees and forest and inside the fenced exclosure were visited in May 2018. These seedlings, totaling 319, are shown in figure 10. Of these seedlings, 36 were clearly dead, or not found. The heights of 89 Roseau, 97 Rice County, and 97 Des Moines seedlings were measured and recorded. A small number of remaining tree tubes at Otter Lake North were removed after measurements. For the 2017-2018 dormant season measurements, height is from the ground level to the highest point on the seedling, regardless of whether that point was live or dead tissue. The measurement was made plumb to the ground surface level at the base of the seedling without manipulating the seedling. This is in contrast to the 2016-2017 dormant season measurements, for which the seedling length was measured. This affects the growth calculation because many seedlings were not planted and/or are not growing perfectly plumb. This biases the growth calculations lower than true growth to a degree varying by both seedling angle and length. Because the seedlings are relatively small and because the analysis is between ecotypes rather than absolute growth, this inconsistency does not pose a serious problem. The method change was made to ensure that in the future the measurement can remain consistent. When the seedlings become more rigid and taller, measuring length will not be feasible, but measuring height will be.

Methods and data analysis

Of the measured seedlings, many 44% had been browsed. Summary statistics of the height growth for each ecotype are shown in table 14. ANOVA was performed on the 2017 mean height growth of the seedlings to detect statistically significant differences between ecotypes at Otter Lake North. The ANOVA tests the null hypothesis that the mean height growth is equal across ecotypes, the alternative hypothesis being that they are not equal.

Based on the results of the ANOVA, the null hypothesis cannot be rejected at significance < 0.1. The Rice County, Des Moines, and Roseau ecotypes do not significantly differ from one another in mean height growth during 2017.

Table 14: Otter Lake North planted seedling height summary statistics

Ecotype	Seedlings	Mean Growth (cm)	Standard deviation (cm)
Roseau	89	0.1 (a)	7.0
Rice Co.	97	-1.6 (a)	5.3
Des Moines	97	-1.5 (a)	7.0

(a) (b) (c) indicate significant differences

Discussion

Heavy browse at this site complicates interpretation of the data and the analysis shouldn't be interpreted closely at this point. It is possible for any of the seedlings to have been browsed and subsequently continued growing before the end of the season, rendering evidence of the disturbance difficult or impossible to discern during dormant season measuring.

Otter Lake South

Data collection and maintenance

A random sample of Otter Lake South seedlings outside a 10 meter buffer around mature trees were visited in April and May 2018. The sampled seedlings, totaling 318, are shown in figure 11. 21 of the visited seedlings were missing or clearly dead. The height and ground-level diameter of 97 Roseau, 101 Rice County, and 100 Des Moines seedlings were measured. For the 2017-2018 dormant season measurements, height is from the ground level to the highest point on the seedling, regardless of whether that point was live or dead tissue. The measurement was made plumb to the ground surface level at the base of the seedling without manipulating the seedling. This is in contrast to the 2016-2017 dormant season measurements, for which the seedling length was measured. This affects the growth calculation because many seedlings were not planted and/or are not growing perfectly plumb. This biases the growth calculations lower than true growth to a degree varying by both seedling angle and length. Because the seedlings are relatively small and because the analysis is between ecotypes rather than absolute growth, this inconsistency does not pose a serious problem. The method change was made to ensure that in the future the measurement can remain consistent. When the seedlings become more rigid and taller, measuring length will not be feasible, but measuring height will be.

Methods and data analysis

A large number of seedlings (238 or 75%) had been browsed. Summary statistics of height growth for each ecotype are shown in table 15. Analysis of variance (ANOVA) was performed on the 2017 season mean height growth. The ANOVA tests the null hypothesis that the means are equal across ecotypes, the alternative hypothesis being that they are not equal. Summary statistics of diameter for each ecotype are shown in table 16. ANOVA was also performed on the mean seedling diameter of each ecotype. No analysis was done on diameter growth as the overlap between the sample measured last season and this season did not result in a dataset robust enough for analysis.

Based on the results of the ANOVA, the null hypothesis regarding height growth cannot be rejected at significance < 0.1. The results of the ANOVA indicate that the null hypothesis regarding seedling diameter cannot be rejected at a significance <0.01.

Table 15: Otter Lake South seedling height growth summary statistics

Ecotype	Seedlings	Mean growth (cm)	Standard Error
Roseau	104	-3.5 (a)	0.7
Rice Co.	105	-4.3 (a)	0.5
Des Moines	109	-5.4 (a)	0.6

(a) (b) (c) indicate significant differences

Table 16: Otter Lake South 2017-2018 dormant diameter statistics

Ecotype	Seedlings	Mean diameter (cm)	Standard Error
Roseau	91	0.6 (a)	0.74
Rice Co.	91	0.6 (a)	0.6
Des Moines	86	0.6 (a)	0.9

(a) (b) (c) indicate significant differences

Discussion

Heavy browse at this site complicates interpretation of the data and the analysis shouldn't be interpreted closely at this point. It is possible for any of the seedlings to have been browsed and subsequently continued growing before the end of the season, rendering evidence of the disturbance difficult or impossible to discern during the dormant season measuring.

2018 Seedlings Measured Maps

figure 9: Allemansratt randomly sampled bur oak seedlings by ecotype

figure 10: Otter Lake North measured bur oak seedlings by ecotype

Otter Lake South Sample

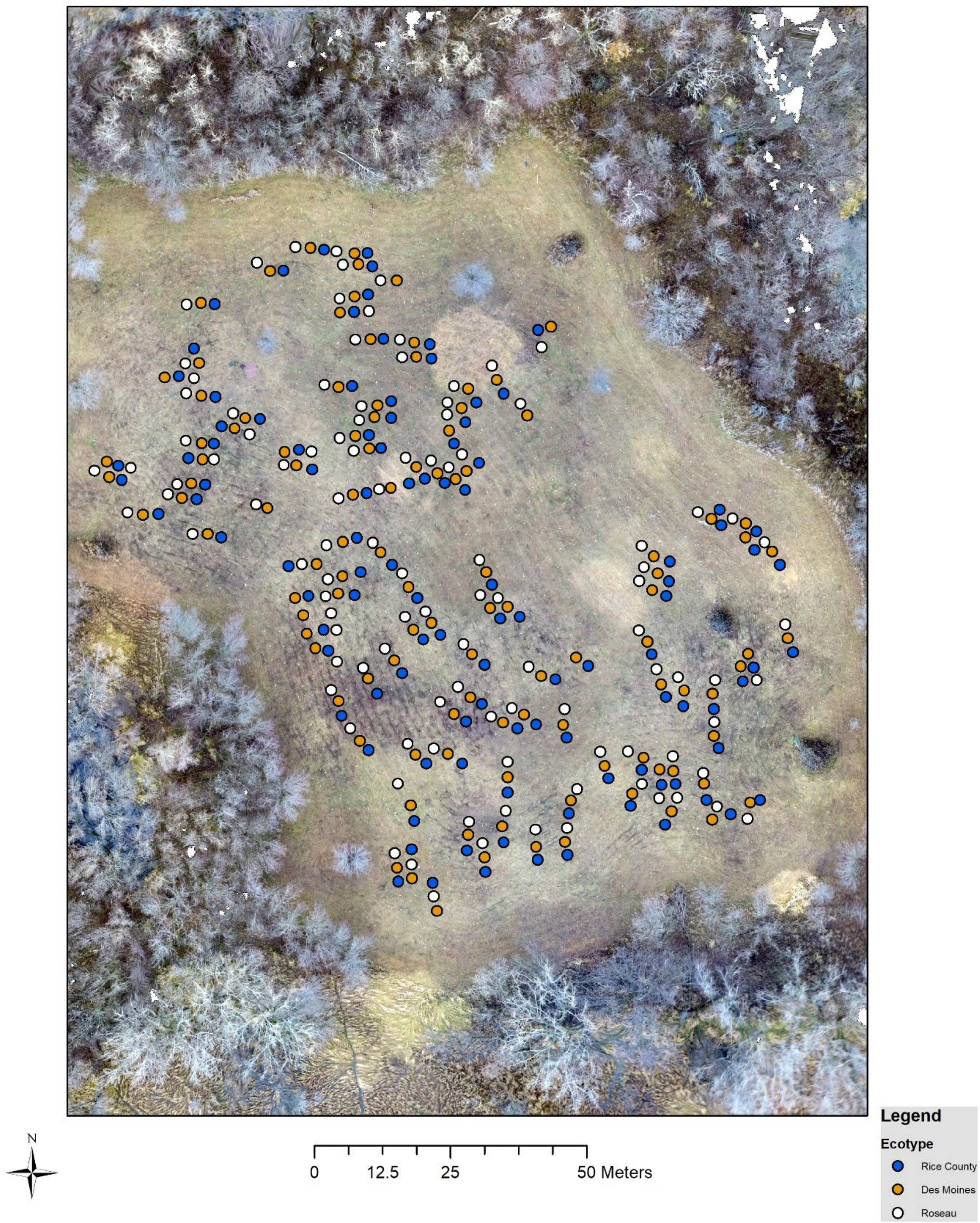

figure 11: Otter Lake South randomly sampled bur oak seedlings by ecotype

Summary and Conclusions, 7/18/2018

Hypothesis #1 was partially addressed using planted seedling height as a proxy for acorn size. Unexpectedly, the Rice County seedlings were the smallest at Allemansratt, Otter Lake South, and Fish Creek. They were not significantly different from the Roseau seedlings at Otter Lake North and at SWCC. The reason for this is unclear, but it could be due to genetics.

To date, Hypothesis #2 has been addressed at each site. At the two sites without significant browse pressure, mean height growth for the Rice County seedlings was significantly less than that of both the Roseau ecotype and the Des Moines ecotype in 2017. Although the analysis addresses only one year's growth in the field, the result is surprising and statistically significant if both cases. Hypothesis 2 posited that the growth of the Rice County seedlings would be greater than that of Roseau and less than Des Moines because of the growing season lengths being longest in the south and shortest in the north. There could be many reasons for this discrepancy. It is possible that the non-native ecotypes benefit from a lack of well-adapted enemies compared to the relatively local Rice County ecotype, as in the enemy-release hypothesis. It is also possible that the seed source in Rice County is diverse and/or genetically inferior to the other two seed sources.

Hypothesis #4 was addressed at Allemansratt, which had the largest differences in planting dates, but found no significant results.

Hypothesis #3 is not addressed in this report as the conditions and maintenance at each site were different enough such that the results would not be meaningful at this time.

Mortality is reported only for SWCC where data is available. It not analyzed or discussed thoroughly in this report as meaningful results won't be obtained for another 2 to 4 years.

The results, discussion, and conclusions presented here are preliminary. Data collected in the next few years will be used in more meaningful analysis and presented at that time.

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Citizen Engagement for Pollinator Monitoring: 2015-2017 Bumble Bee Monitoring Summary

Pilot Knob Hill, Mendota Heights, MN

Prepared by: Sarah Foltz Jordan & Pamela Herou, Xerces Society, June 2018

Funded by: Minnesota Environment and Natural Resources Trust Fund (ENRTF)
Partners: The Xerces Society, Great River Greening, and University of MN Bee Squad (Elaine Evans)

The Endangered rusty-patched bumble bee (*Bombus affinis*), detected at Pilot Knob during this project. Photo by Sarah Foltz Jordan, Xerces Society.

Methods

- Bumble bee monitoring occurred once per month during the time of peak bumble bee abundance in Minnesota (July, August, and September) for three consecutive years (2015, 2016, 2017).
- Monitoring methods followed those used by the University of MN Bee Squad, in which volunteers are trained to collect bumble bees from flowers and bring them back to a central location for expert identification. Volunteers were encouraged to scout a variety of flowers, including natives and non-natives. Following identification, bees were marked with a dot on the top of thorax and then released (this approach ensures that the same bee is not captured/counted more than once). See Appendix 1 for detailed protocol.
- Surveys (including a short training session) took place for ~2.5 hours.
- For each bumble bee, the species, sex, and floral association was recorded.
- Flowering plants in the survey area (both native and non-native) that were *in bloom at the time of the survey* were also recorded.

Results

Abundance, Diversity, and Rare Species Detections:

Over the course of three years and nine surveys, 806 bumble bees were identified and released. Our first year of surveys revealed seven species of bumble bees; the following year, two additional species were observed, and the third year, one more species was added. In total, ten different species were observed at the site, including both rare and common species. The relative abundance of these species is shown in Figure 1.

Throughout the study, three rare species were detected in very low numbers at the site, most notably, *Bombus affinis* (the rusty patched bumble bee), which was recently listed as Federally Endangered under the Endangered Species Act by the Fish and Wildlife Service. Only one individual was encountered in our surveys, a female worker foraging on bee balm (*Monarda fistulosa*) in July of 2016. *Bombus fervidus* and *B. pensylvanicus* were also encountered in very low numbers (four and twelve individuals, respectively) during our surveys; both of these species are listed Vulnerable to extinction by the IUCN, and as Species of Greatest Conservation need in the state of MN, based on range declines and severe relative abundance declines in recent years (Hatfield et al. 2015; MNDNR 2015).

Bombus impatiens (the common eastern bumble bee) was the most abundant species at the site (Figure 1). This species is apparently secure (not at risk of extinction) and increasing in relative abundance across its range (Hatfield et al. 2015). Similarly, the next three most abundant species (*B. auricomus, B. bimaculatus,* and *B. griseocollis*) are fairly common across their ranges and not known to be at risk of extinction (Hatfield et al. 2015).

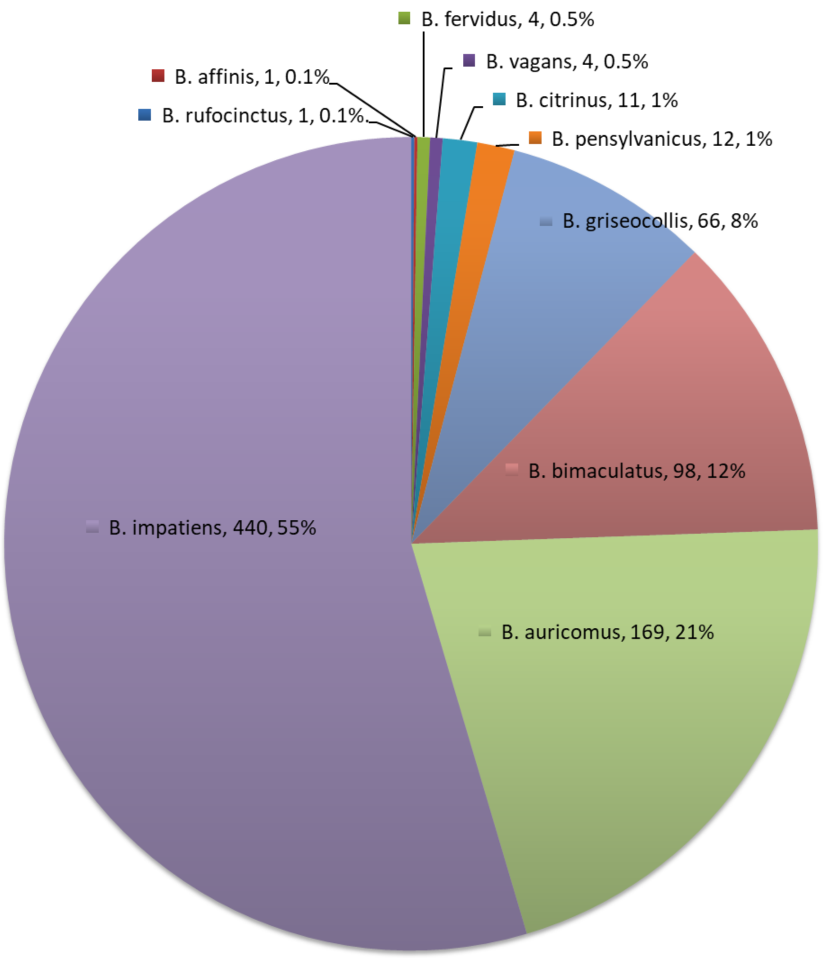

Figure 1. Relative abundance of ten bumble bee species over the 3-year survey period (2015- 2017). The species name in the graph is followed by (1) the number of individuals of that species observed (total abundance) and (2) the percentage of that species in the observed bumble bee population (relative abundance).

One cuckoo bee species, *Bombus citrinus*, was observed throughout the study. This is among the most common of the cuckoo bees in Minnesota, likely because it cleptoparasitizes *Bombus impatiens*, one of the most abundant bees in the region (and also at this site). Cuckoo bees, in general, are often a signal of ecosystem heath, since they can be highly specific in terms of the bee hosts that they will cleptoparasitize.

Floral Associations:

Floral association data revealed interesting seasonal floral visitation trends by bumble bees at the site.

In July, the vast majority (93%) of bumble bees were visiting bee balm (*Monarda fistulosa*), a well-known bumble bee plant (Figure 2).

In August, native field thistle (*Cirsium discolor*) was visited by bumble bees over twice as much as any other plant, despite numerous other high quality forage plants in bloom at that time. This plant is unfortunately rarely included in seed mixes due to general distaste for thistles, combined with low availability of seed (Eckberg et al. 2017). Our findings regarding the relative attractiveness of this plant to bumble bees are very useful in encouraging consumers and the native seed industry to prioritize planting and propagating this plant, along with other native thistles.

In September, New England aster (*Symphyotrichum novae-angliae*) was the most visited plant over all (3 years of September surveys combined (Figure 2)). However, the most visited September flower varied by year: in 2015, New England aster (*Symphyotrichum novae-angliae*) was the most visited; in 2016, Canada goldenrod (*Solidago canadensis*), and in 2017, showy goldenrod (*Solidago speciosa*). This variability was likely an artefact of slight differences in plant phenology during the time of our surveys. For example, our 2017 September survey occurred a bit later than the other years, and showy goldenrod was the only flower in peak bloom at the time (the other goldenrods and asters were slightly past peak bloom). This finding suggests that when designing seed mixes and plantings, it is often important to include multiple species within a given plant genus (and certainly within bloom time categories) in an effort to fill subtle niches in bloom time and food availability for bees.

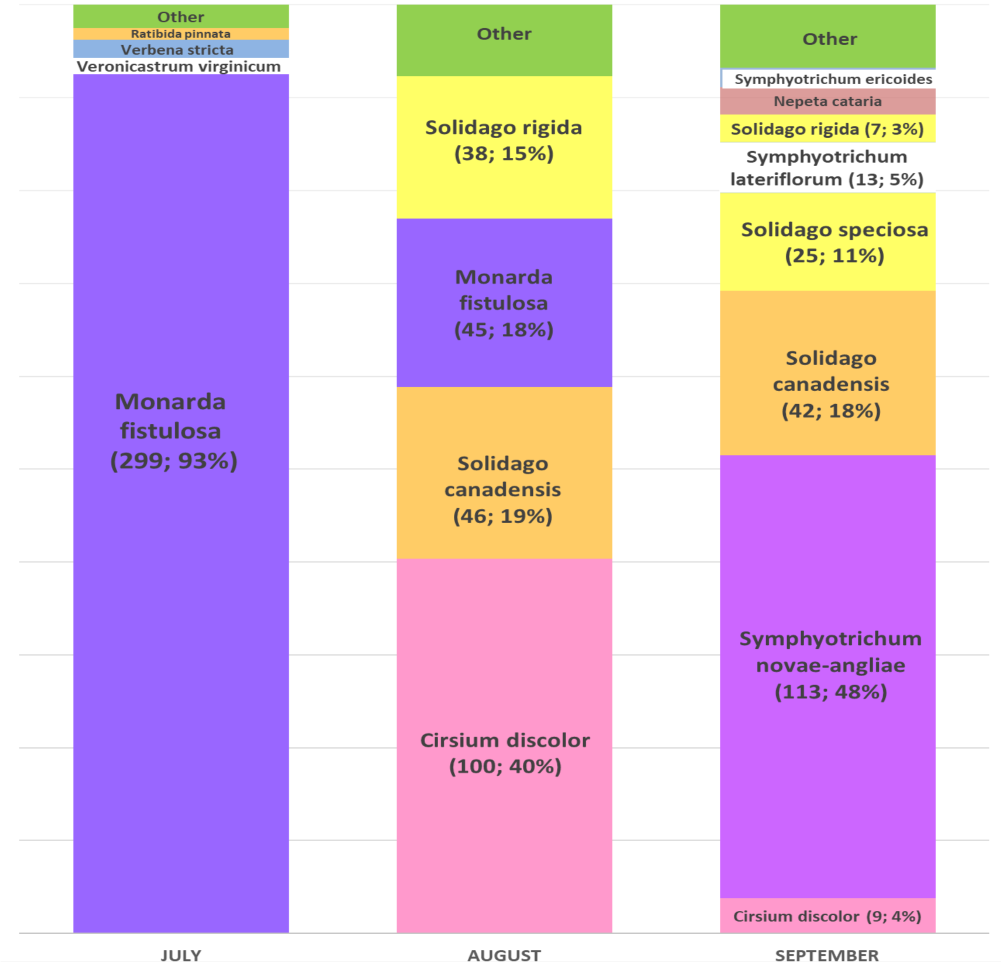

Figure 2. Floral associations of 806 bumble bee species observed over the 3-year survey period, divided by month (July, August, and September). The species names in the graph are followed by (1) the number of bumble bee floral associations observed on the plant, and (2) the percentage of total floral associations that occurred on that plant in that month. Approximate bloom color of the flower is reflected in the color choices used in the graph. Plants with less than 4 occurrences were combined into the "other" category.

With regard to rare species floral associations, the only individual we observed of *Bombus affinis* was detected on *Monarda fistulosa,* a plant well-known to be highly attractive to and supportive of bumble bees. *Bombus fervidus* was observed on *Cirsium discolor* (3 individuals) and *Monarda fistulosa* (1 individual). *Bombus penysylvanicus* was observed on *Monarda fistulosa* (11 individuals), and *Cirsium discolor* (1 individual). *Bombus rufocinctus*, very rare at Pilot Knob although fairly common in general, was detected only on *Veronicastrum virginicum*- a shallow-nectary plant that is well-suited for the shorter mouthparts of this bee.

Seasonal Variability:

Seasonal changes in the bumble bee community were observed as follows: In July, *Bombus auricomus* and *B. bimaculatus* were consistently the most abundant bumble bees observed at the site. In August, *Bombus impatiens* was typically the most abundant, although *B. auricomus* surpassed *B. impatiens* in numbers in August 2016. In September, *Bombus impatiens* was consistently the most abundant bee by far; many other bees had tapered off in activity at that time.

With regard to rare species detections, *Bombus affinis* was only detected once in our surveys, in July. Both *Bombus fervidus* and *B. penysylvanicus* were observed in low numbers in both in July and August.
On average, bumble bee species richness was highest in August, intermediate in July, and lowest in September. This suggests that if future studies are limited to conducting only one survey during the

growing season, August would likely yield the highest number of species at the site. No species were encountered in September surveys that had not already been detected in July or August.

The seasonality findings discussed above are more or less consistent with what is reported about the seasonality of these species in the literature (Williams et al. 2014).

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Appendix 1. University of MN Bumble Bee Survey Protocol

1. Before each survey, explains rules for catching bumble bees to volunteers to reduce chance of damage. Explain that they may find the endangered rusty patch bumble bee which is protected by federal law. We have a permit allowing us to do this activity. Without permit, it is recommended to not handle bumble bees. You could be liable to fines if you accidentally damage an endangered bumble bee without this permit. STEPS FOR PARTICIPANTS 1. Capture bees while on flowers. Place cup around bee. Hold cup upside down. Check to make sure bee is at top of cup before sealing lid. 2. Bring back to survey leader within 5 minutes of capture. Place bee on ice if it will be more than 5 minutes before you can ID mark and release.
2. Use data collection sheets for recording data. Feel free to adapt for your own use but please collect all the same data. If plant is unknown, take photo if possible, but sometimes volunteers aren't sure what flower they collection from, so you can also have a catch all UNKNOWN for plant id. With the exception of *Bombus affinis*, mark all bumble bees with an orange dot prior to release, to avoid recapturing and recording the same bee multiple times.
3. Photograph any B. affinis, B. terricola, or unusual or unexpected bumble bee species. Also photo any tentative IDs and note on data sheet. Note PhotoFileID (file name).
4. Snap a photo of your data sheet at the end of each survey date (just incase). I will only need these from you if data doesn't get entered here.
5. Enter survey information (date, time, location, etc) into "CollectionCodes" sheet.
6. Enter bumble bee data on "BumbleBeeData" sheet using appropriate CollectionCode
7. Ensure that a minimum of 3 surveys are completed over the growing season, and that a minimum of 200 bees are observed & recorded during this period (all survey dates, combined)

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

2015 *o8f*

Enhancing Restoration Techniques *and Citizen Engagement* for Pollinator Conservation

Photo: Sarah Foltz Jordan, Xerces Society

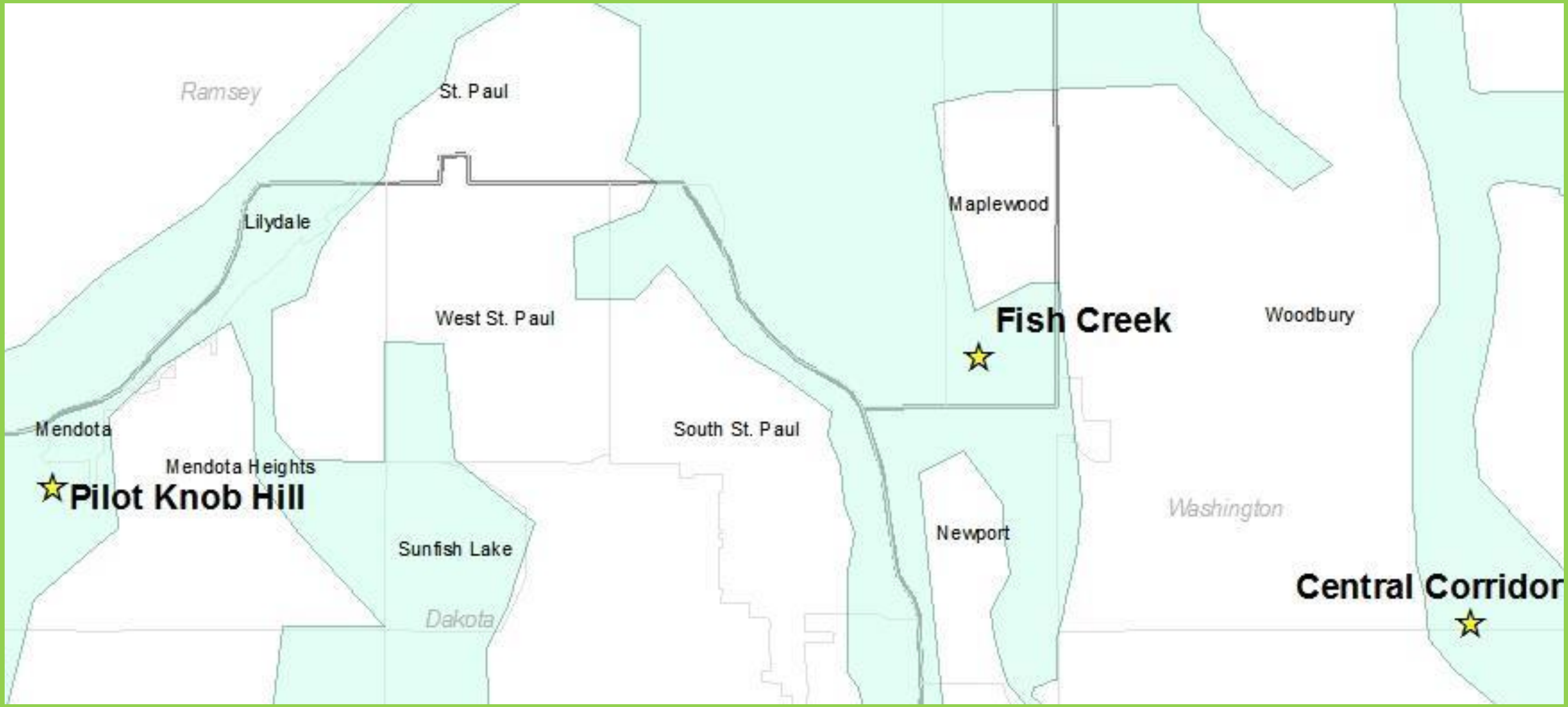
GREAT RIVER GREENING

Maplewood

XERCES SOCIETY for Invertebrate Conservation

Three Metro Sites

- Prairie sites within Metro Conservation Corridors
- Each varies on:
  - Restoration/mgmt. phase and activities
  - Pollinator monitoring program including community engagement



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Pilot Knob Hill

- 24 ac Prairie / Savanna site restored in four phases
- Forb rich site

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Pilot Knob Hill

- Conducted 3 of 9 bumble bee surveys
- Trained volunteers in bumble bee life history, conservation issues, and ID
- Collected species-level data on bumble bee population and floral visitation
- 423 bumble bees of 7 species
- One IUCN “Vulnerable” species (*Bombus fervidus*)
- Over 400 floral associations including high % of observations on native thistles in August
- Volunteers enhanced pollinator ‘mowed habitat’

Photo: Sarah Foltz Jordan, Xerces Society

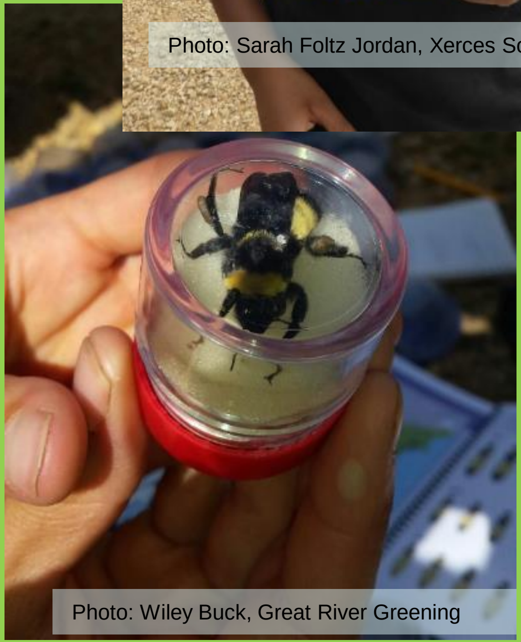
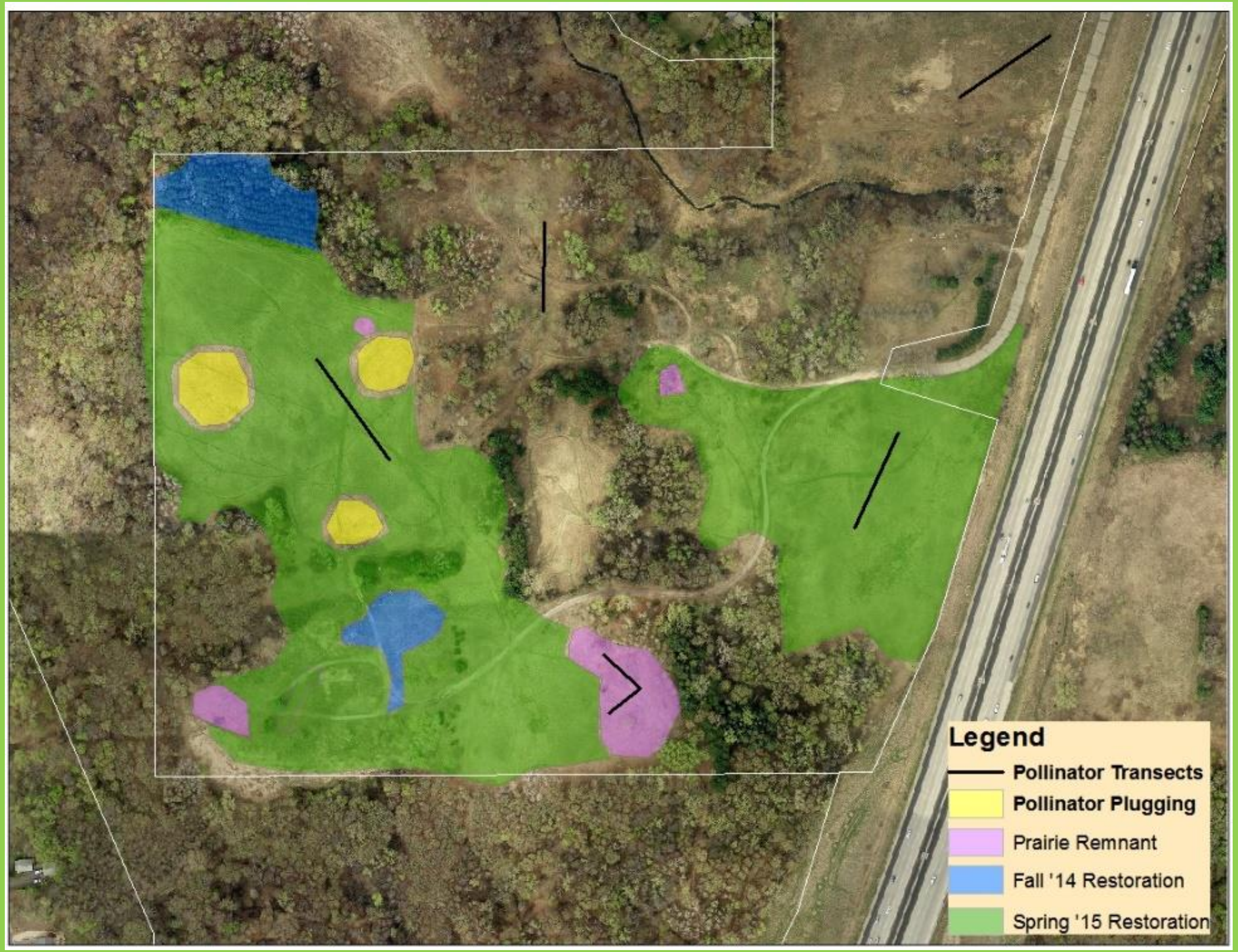


Photo: Wiley Buck, Great River Greening

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Fish Creek

- 70ac site with prairie, savanna, woodland restoration
- Small high quality prairie remnant as refugia



Fish Creek Restoration

- 20 acres prairie seeded in 2014-15
- Plant species diversity
  - Enhanced: 11 grasses, 37 forbs

- Trust Fund plugging
  - Focus on species that aren't in the seed mix
  - Planted by school volunteers
  - With plugs: 11 grasses, 49 forbs

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

CLEAN WATER LAND & LEGACY AMENDMENT

Photos: Maplewood Nature Center

Fish Creek School Groups: Goal 800 kids

- Fall 2015 we had 100+ 4th and 6th graders at the site, Spring
- Classroom session & field sessions on pollinators
- Kids engaged in restoration process by planting native plugs

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Fish Creek Adult Education

- Fall 2015 Xerces Society Staff led the first ‘Become a Bee Monitor’ program for 25 adults
  - Day 1: ID training included practice with photos, pinned specimens, and live bees
  - Day 2: Participants practiced monitoring transects and collecting data at Fish Creek

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Photos: The Xerces Society and Maplewood Nature Center

Native Bee Monitoring Guide

- Developed by Xerces Society under this grant
- Printed draft for first workshop
- Observation-based "group-level" ID
  - 10 bee morpho-groups (groups of related species that look alike)
  - No collection or curation
- Monitoring protocol
  - Adapted from bee monitoring protocol developed Xerces and UC-Berkley for citizen scientists
  - Data analysis showed this type of data is effective at detecting anges in bee abundance and ness

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

https://www.youtube.com/watch?v=aXT1DZEHsMk

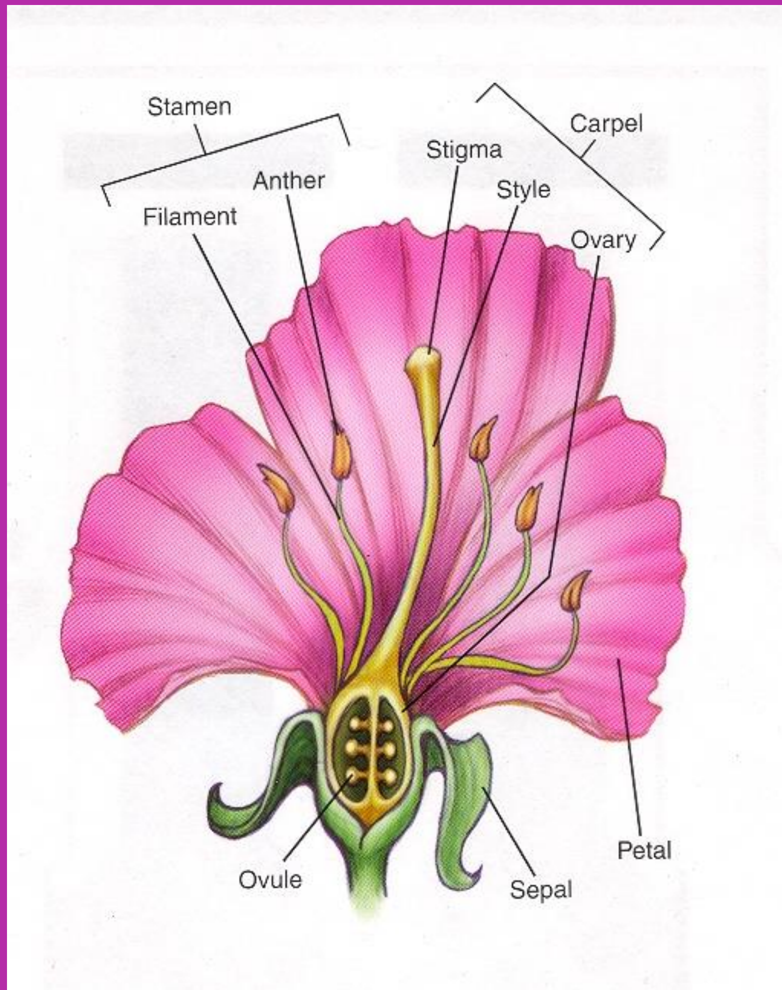
Why do we need pollinators?

We need pollinators to pollinate flowers so we can grow foods like:

chocolate, oranges, bananas, apples, cucumbers, vanilla, cashews, almonds, beans, tomatoes, pumpkins, tomatoes, avocadoes, blueberries, strawberries, mangos, raspberries. . . and many more!!!

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

What is Pollination?



Moving of pollen from the male flower parts to the female flower parts of the same kind of plant.

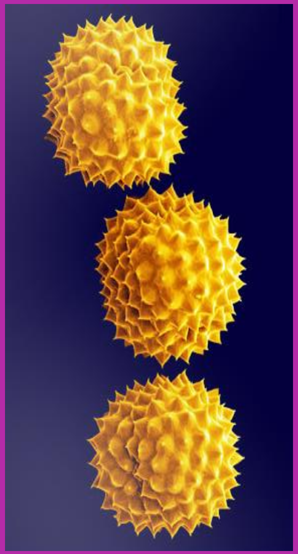
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Honey bee: our most famous bee from Europe!

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Meet some Minnesota Native Bees

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND



Bumble bees collect pollen and nectar for their colony.

- Nectar = Energy
- Pollen = protein, fats, vitamins

In the Process they transport pollen for plants.

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Green Sweat Bee

ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND

Photo by Sarah Foltz Jordan- Xerces Society

Striped Hairy Belly Bee

This group includes
- Leaf Cutter bees,
- Small Resin bees,
- Carder bees,
- Mason bees

They carry pollen on the underside of their abdomen.

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Leaf Cutter Bee

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

- Females cut out circles and oval shapes from tree leaves to line their tunnels that are rolled up like tunnels and tucked into the cavity.
- They carry pollen on thick hairs on the underside of their abdomen.



ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Leaf Cutter Bee (*Megachile spp*.)

A Minnesota native bee…

Solitary females work on their own to build a nest in cavities (holes) in trees, logs, rocks, etc., or some species nest in the ground.

- They leave a ball of pollen for the larva to eat after it hatches.
- The female does not guard the nest, and dies soon after laying her eggs.

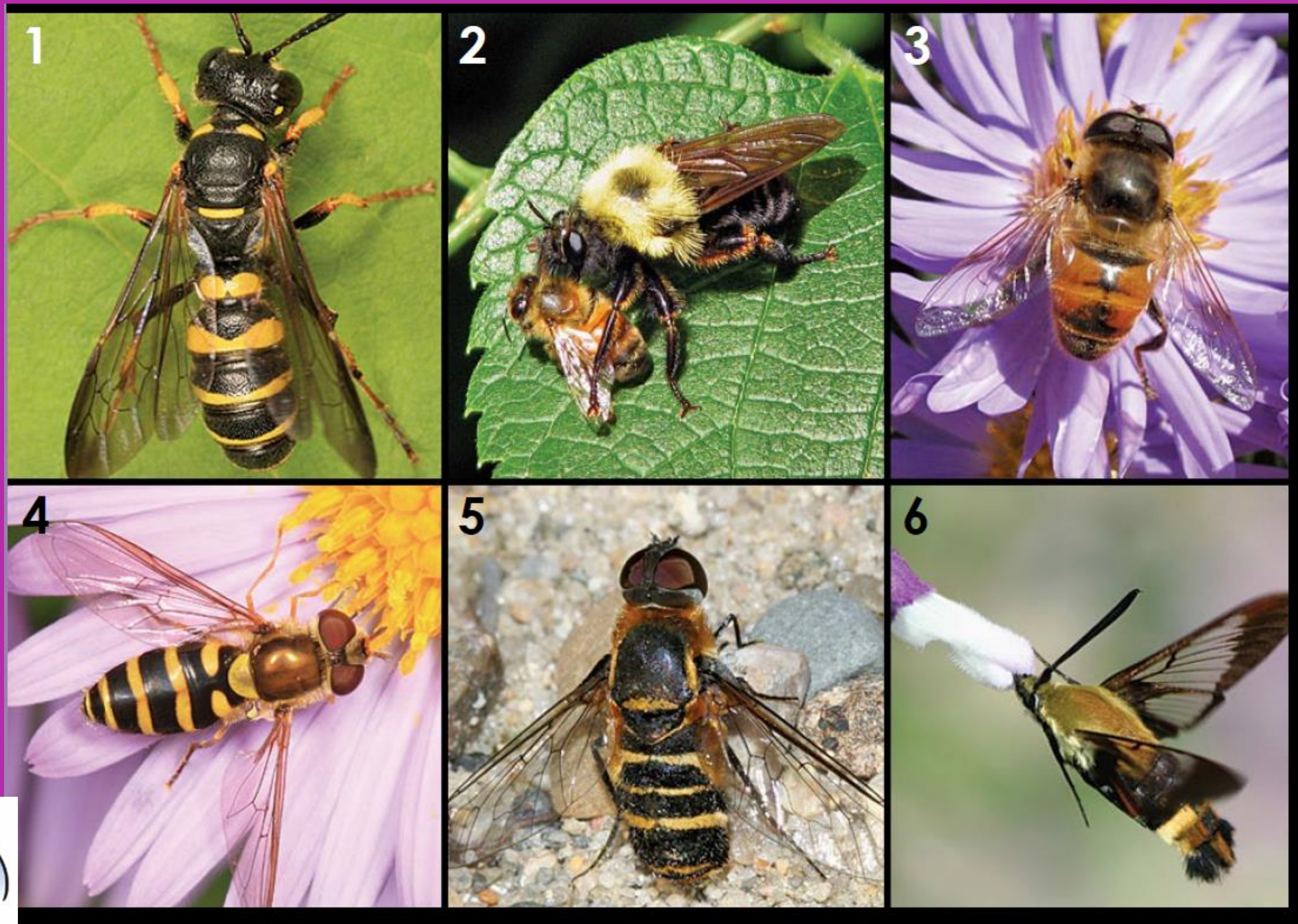
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

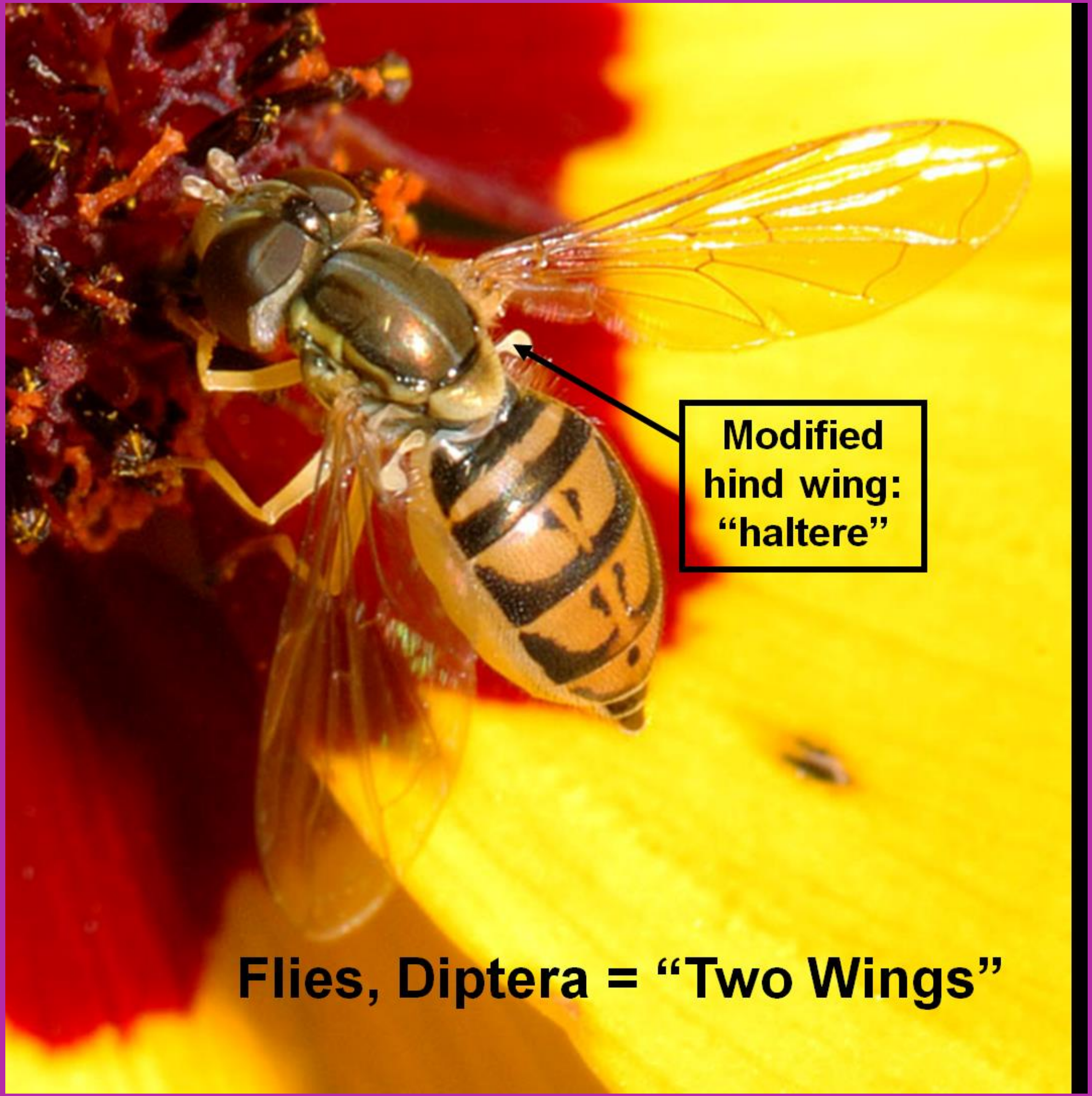
Ceratina, or yellow-faced bee

Photo by Sarah Foltz Jordan- Xerces Society

“Wanna-Bees” Bee Look-alikes



ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND


Modified
hind wing:
“haltere”
Flies, Diptera = “Two Wings”

Other Pollinators- Beetle

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Mosquito

Clear-Wing Moth

ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND

Pollinators are in Trouble

- There are fewer natural spaces and these spaces are broken into smaller areas
- Invasive species out-compete
- Pesticides
- Diseases

ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND

Rusty-patched Bumble Bee

How Can We Help Pollinators?

Provide Habitat!

- Plant more sources of food for pollinators
- Provide places for pollinators to nest in
- Don’t use pesticides.

ENVIRONMENT
AND NATURAL RESOURCES
TRUST FUND

Plant flowers with different colors, shapes, sizes and bloom times.

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Prescribed Haying for Pollinators and Prairie: Pollinator Monitoring Summary: 2015-2017

South Washington Conservation Corridor

Prepared by: Sarah Foltz Jordan & Pamela Herou, Xerces Society, June 2018
Funded by: Minnesota Environment and Natural Resources Trust Fund (ENRTF)
Partners: The Xerces Society & Great River Greening

A green sweat bee (*Augochlorini*) observed on butterfly milkweed at South Washington during this project. Photo by Sarah Foltz Jordan, Xerces Society.

Methods:

- 6 plots (each ~5 acres) were established, 3 treatments and 3 controls.
- Within each of these plots, two monitoring transects were established.
- All transects were 300 ft. long, running N-S.
- All transects were at least 50 ft. from an edge (75 or 100 ft. when possible).
- The 2 transects within each plot were at least 100 ft. from each other (usually 200 ft. except in one smaller plot (ES) where that wasn't possible).
- Transects were monitored once/per month from May to September, with visits spaced at least 3 (usually 4) weeks apart. Monthly monitoring typically took place in the last week of the month.
- Monitoring followed the protocol presented in the Xerces Society Upper Midwest Citizen Science Native Bee Monitoring Guide (Foltz Jordan, Lee-Mader, and Vaughan 2016).
- All floral visitors were recorded & identified to the highest taxonomic level without collection (usually genus).
- When possible, photographic “vouchers” were taken.
- Specimen vouchers were collected for select bumble bees that require microscopic examination for species level identification.
- All floral associations were recorded for each insect visitor.
- All blooming species in transect were recorded (whether or not there were floral visitors using them).

For further details on methods and survey protocol, see the Xerces Society Upper Midwest Citizen Science Native Bee Monitoring Guide (Foltz Jordan, Lee-Mader, and Vaughan 2016).

Results:

3-Year Relative Abundance and Diversity:

A total of 3,759 floral visitors were observed on flowers during the three years of season-long monitoring at this site, including 1,039 native bees. Honey bees, bumble bees, soldier beetles, hover flies, paper wasps, and monarchs were the most abundant pollinator groups present (Figure 1). Native bees comprised 55% of the total bees present, 29% of the pollinators, and were represented by 12 different groups. Six groups of pollinating flies were observed; thirteen species of butterflies; eleven groups of wasps, seven groups of flower visiting beetles were observed; and five groups of predatory and herbaceous flower-visiting bugs.

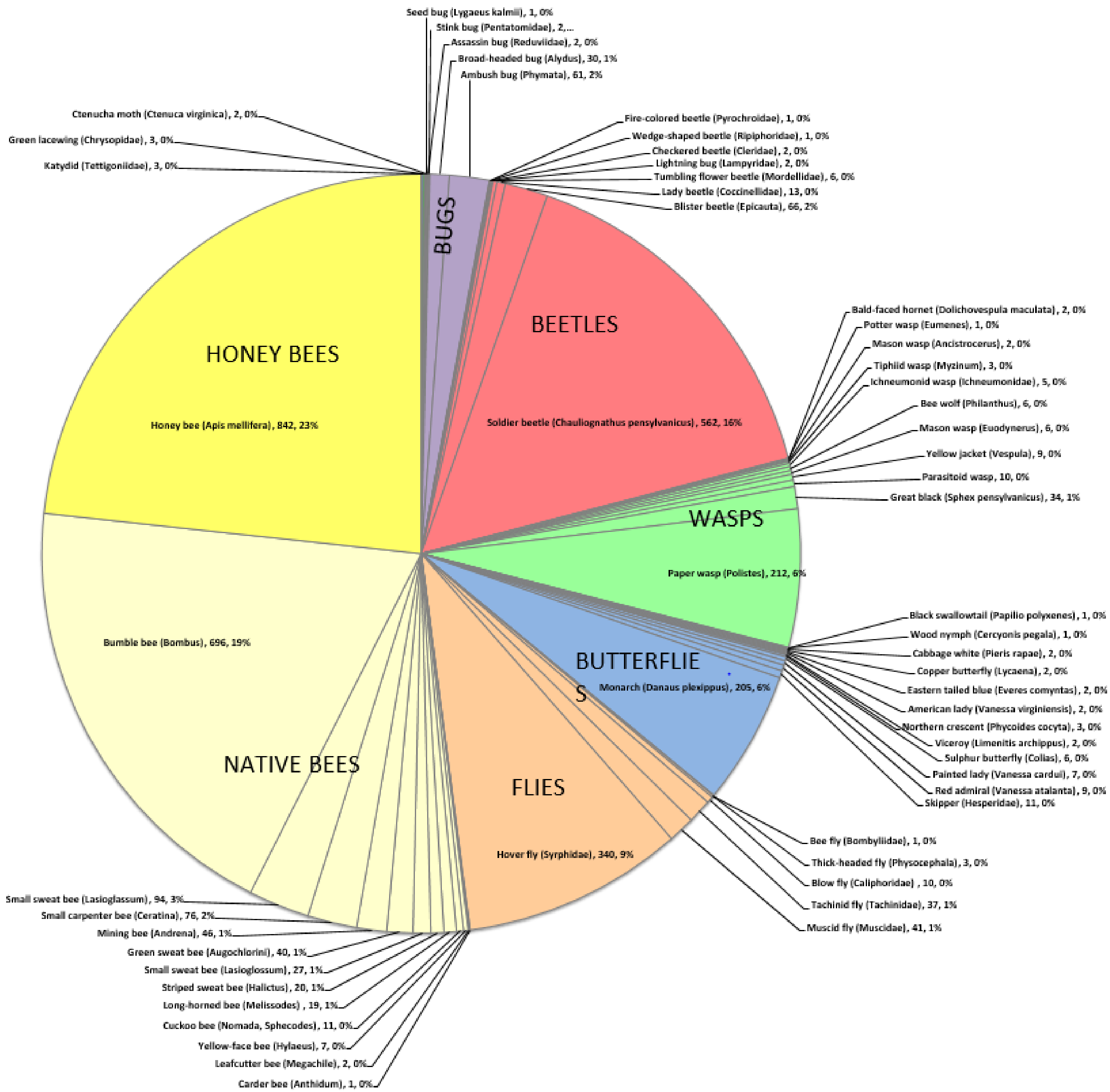


Figure 1. Relative abundance of insect floral visitors at South Washington Conservation Corridor over the three-year study period (all seasons and years combined).

Seasonal Variation in Abundance and Diversity of Pollinator Groups:

Pollinator abundance varied greatly by month, with the highest abundance of native bees observed in July, and the lowest in September (Figure 2). The highest abundance of floral visitors as a whole (including honey bees, and non-bee pollinators) was observed in August (Figure 2).

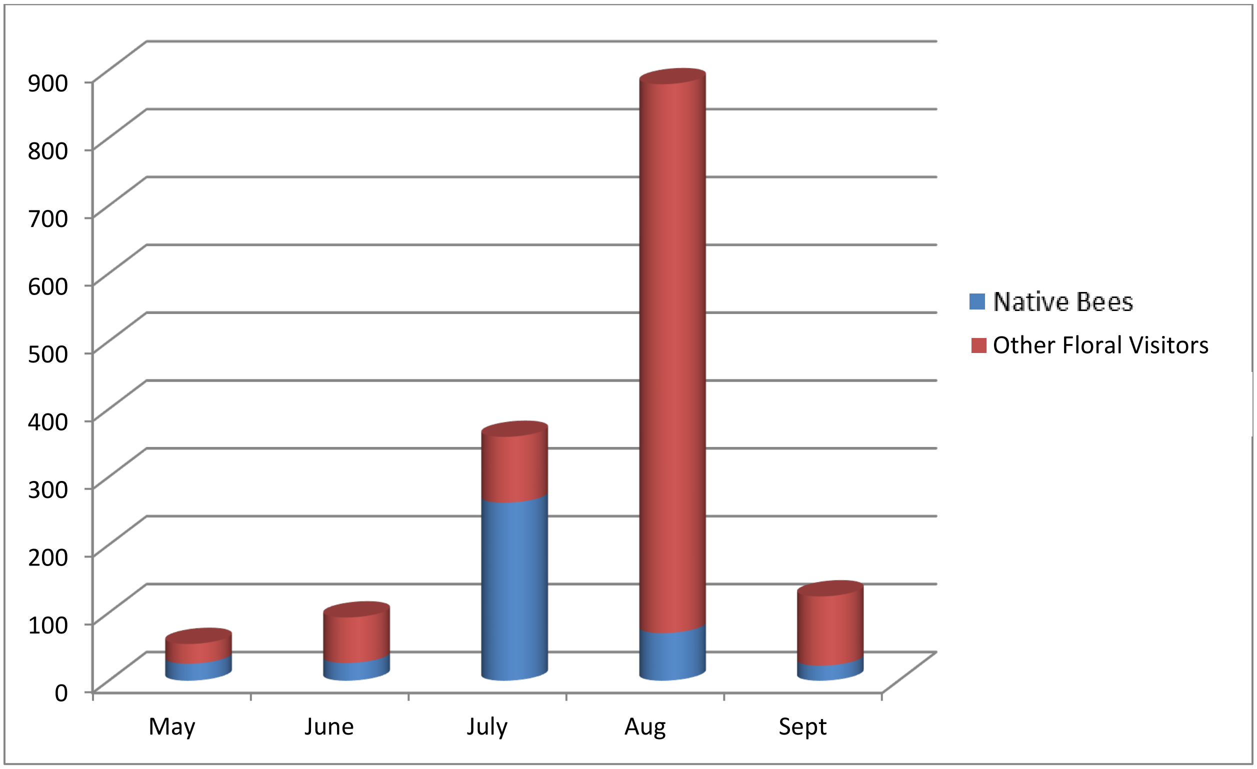
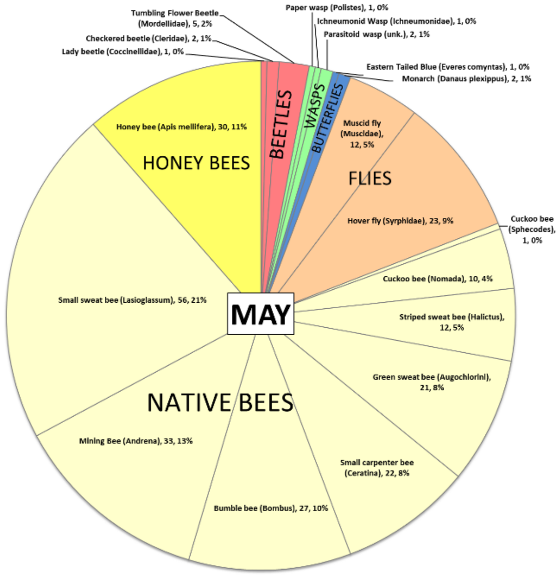
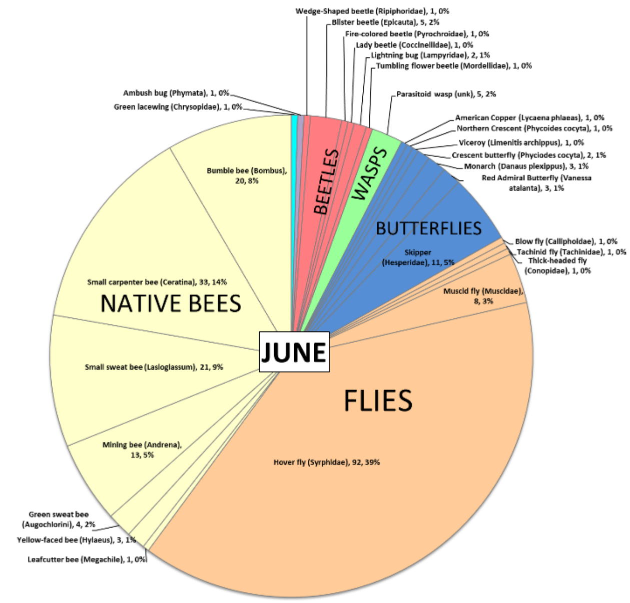
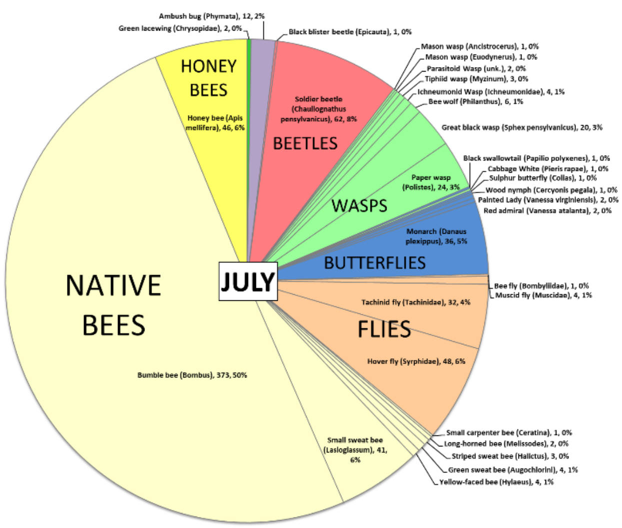


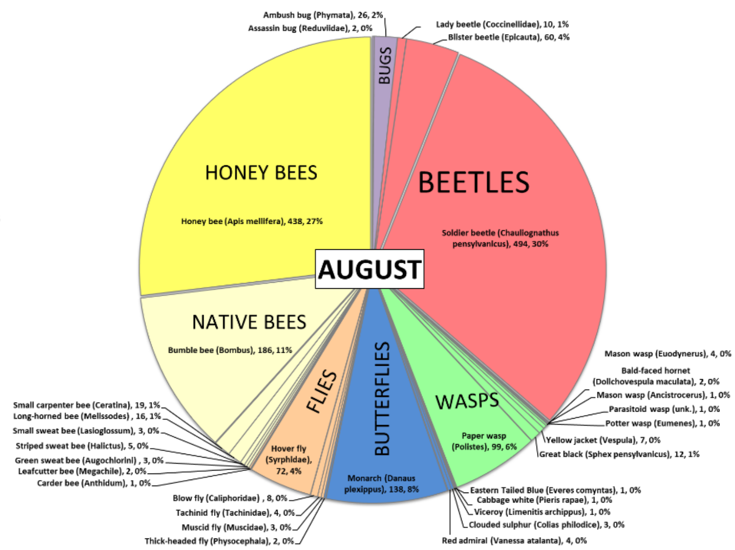
Figure 2. Total abundance of floral visitors by month, showing highest abundance of native bees in July, and of floral visitors as a whole in August. *(Note: this graph is based on 2015 data, but is reflective of findings in 2016 and 2017, also).*

Pollinator assemblages also varied greatly by month (Figure 3, May through September). In May, native bees (mostly small sweat bees) were the most abundant group, followed by flies and honey bees. In June, the majority of pollinators were hoverflies, followed by native bees (mostly small carpenter bees) and butterflies (mostly skippers). Honey bees were absent in June, and bumble bee numbers were low, despite high abundance of both of these groups in both May and July. This suggests that floral resources favored by these bees were lacking in the survey transects at this time (see Floral Associations summary, below). In July, native pollinators (primarily bumble bees) were the most abundant group, followed by flies (primarily hover flies and tachinids), with fairly even abundance of the other floral visitor groups. In August, soldier beetles were the most abundant group followed by honey bees; bumble bees, monarchs, and paper wasps were also well-represented. In September, honey bees were by far the most abundant group, followed by hover flies, native bees (primarily bumble bees), and wasps (primarily paper wasps) (Figure 3).


MAY
Tumbling Flower Beetle (Mordellidae), 5, 2%
Checkered beetle (Cleridae), 2, 1%
Lady beetle (Coccinellidae), 1, 0%
Paper wasp (Polistes), 1, 0%
Ichneumonid Wasp (Ichneumonidae), 1, 0%
Parasitoid wasp (unk.), 2, 1%
Eastern Tailed Blue (Everes comyntas), 1, 0%
Monarch (Danaus plexippus), 2, 1%
BEETLES
WASPS
BUTTERFLIES
Honey bee (Apis mellifera), 30, 11%
HONEY BEES
Muscid fly (Muscidae), 12, 5%
FLIES
Hover fly (Syrphidae), 23, 9%
Cuckoo bee (Sphecodes), 1, 0%
Cuckoo bee (Nomada), 10, 4%
Small sweat bee (Lasioglassum), 56, 21%
Striped sweat bee (Halictus), 12, 5%
Green sweat bee (Augochlorini), 21, 8%
NATIVE BEES
Mining Bee (Andrena), 33, 13%
Small carpenter bee (Ceratina), 22, 8%
Bumble bee (Bombus), 27, 10%


JUNE
Wedge-Shaped beetle (Ripiphoridae), 1, 0%
Blister beetle (Epicauta), 5, 2%
Fire-colored beetle (Pyrochroidae), 1, 0%
Lady beetle (Coccinellidae), 1, 0%
Lightning bug (Lampyridae), 2, 1%
Tumbling flower beetle (Mordellidae), 1, 0%
Ambush bug (Phymata), 1, 0%
Green lacewing (Chrysopidae), 1, 0%
Parasitoid wasp (unk), 5, 2%
American Copper (Lycaena phlaeas), 1, 0%
Northern Crescent (Phycoides cocyta), 1, 0%
Viceroy (Limenitis archippus), 1, 0%
Crescent butterfly (Phyciodes cocyta), 2, 1%
Monarch (Danaus plexippus), 3, 1%
Red Admiral Butterfly (Vanessa atalanta), 3, 1%
Bumble bee (Bombus), 20, 8%
BEETLES
WASPS
BUTTERFLIES
Skipper (Hesperidae), 11, 5%
Blow fly (Calliphoidae), 1, 0%
Tachinid fly (Tachinidae), 1, 0%
Thick-headed fly (Conopidae), 1, 0%
Small carpenter bee (Ceratina), 33, 14%
NATIVE BEES
Muscid fly (Muscidae), 8, 3%
Small sweat bee (Lasioglassum), 21, 9%
FLIES
Mining bee (Andrena), 13, 5%
Hover fly (Syrphidae), 92, 39%
Green sweat bee (Augochlorini), 4, 2%
Yellow-faced bee (Hylaeus), 3, 1%
Leafcutter bee (Megachile), 1, 0%


JULY
Ambush bug (Phymata), 12, 2%
Green lacewing (Chrysopidae), 2, 0%
Black blister beetle (Epicauta), 1, 0%
Mason wasp (Ancistrocerus), 1, 0%
Mason wasp (Euodynerus), 1, 0%
Parasitoid Wasp (unk.), 2, 0%
Tiphiid wasp (Myzinum), 3, 0%
Ichneumonid Wasp (Ichneumonidae), 4, 1%
Bee wolf (Philanthus), 6, 1%
Great black wasp (Sphex pensylvanicus), 20, 3%
HONEY BEES
Honey bee (Apis mellifera), 46, 6%
Soldier beetle (Chauliognathus pensylvanicus), 62, 8%
BEETLES
Black swallowtail (Papilio polyxenes), 1, 0%
Cabbage White (Pieris rapae), 1, 0%
Sulphur butterfly (Colias), 1, 0%
Wood nymph (Cercyonis pegala), 1, 0%
Painted Lady (Vanessa virginiensis), 2, 0%
Red admiral (Vanessa atalanta), 2, 0%
Paper wasp (Polistes), 24, 3%
WASPS
Monarch (Danaus plexippus), 36, 5%
BUTTERFLIES
NATIVE BEES
Bee fly (Bombyliidae), 1, 0%
Muscid fly (Muscidae), 4, 1%
Tachinid fly (Tachinidae), 32, 4%
FLIES
Hover fly (Syrphidae), 48, 6%
Bumble bee (Bombus), 373, 50%
Small carpenter bee (Ceratina), 1, 0%
Long-horned bee (Melissodes), 2, 0%
Striped sweat bee (Halictus), 3, 0%
Green sweat bee (Augochlorini), 4, 1%
Yellow-faced bee (Hylaeus), 4, 1%
Small sweat bee (Lasioglassum), 41, 6%


AUGUST
Ambush bug (Phymata), 26, 2%
Assassin bug (Reduviidae), 2, 0%
Lady beetle (Coccinellidae), 10, 1%
Blister beetle (Epicauta), 60, 4%
BUGS
HONEY BEES
BEETLES
Honey bee (Apis mellifera), 438, 27%
Soldier beetle (Chauliognathus pensylvanicus), 494, 30%
NATIVE BEES
Bumble bee (Bombus), 186, 11%
Mason wasp (Euodynerus), 4, 0%
Bald-faced hornet (Dolichovespula maculata), 2, 0%
Mason wasp (Ancistrocerus), 1, 0%
Parasitoid wasp (unk.), 1, 0%
Potter wasp (Eumenes), 1, 0%
Yellow jacket (Vespula), 7, 0%
Great black (Sphex pensylvanicus), 12, 1%
FLIES
BUTTERFLIES
WASPS
Paper wasp (Polistes), 99, 6%
Small carpenter bee (Ceratina), 19, 1%
Long-horned bee (Melissodes), 16, 1%
Small sweat bee (Lasioglossum), 3, 0%
Striped sweat bee (Halictus), 5, 0%
Green sweat bee (Augochlorini), 3, 0%
Leafcutter bee (Megachile), 2, 0%
Carder bee (Anthidium), 1, 0%
Hover fly (Syrphidae), 72, 4%
Monarch (Danaus plexippus), 138, 8%
Eastern Tailed Blue (Everes comyntas), 1, 0%
Cabbage white (Pieris rapae), 1, 0%
Viceroy (Limenitis archippus), 1, 0%
Clouded sulphur (Colias philodice), 3, 0%
Red admiral (Vanessa atalanta), 4, 0%
Blow fly (Caliphoridae), 8, 0%
Tachinid fly (Tachinidae), 4, 0%
Muscid fly (Muscidae), 3, 0%
Thick-headed fly (Physocephala), 2, 0%

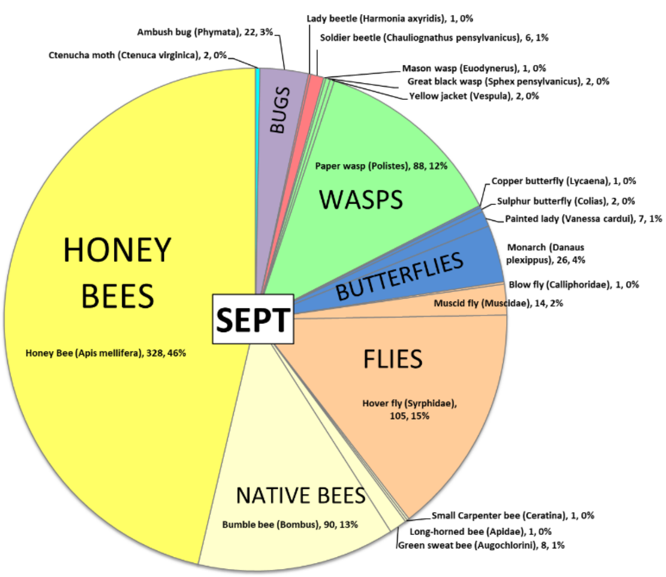

SEPT
Lady beetle (Harmonia axyridis), 1, 0%
Ambush bug (Phymata), 22, 3%
Soldier beetle (Chauliognathus pensylvanicus), 6, 1%
Ctenucha moth (Ctenuca virginica), 2, 0%
Mason wasp (Euodynerus), 1, 0%
Great black wasp (Sphex pensylvanicus), 2, 0%
Yellow jacket (Vespula), 2, 0%
BUGS
Paper wasp (Polistes), 88, 12%
WASPS
Copper butterfly (Lycaena), 1, 0%
Sulphur butterfly (Colias), 2, 0%
Painted lady (Vanessa cardui), 7, 1%
HONEY BEES
Monarch (Danaus plexippus), 26, 4%
BUTTERFLIES
Blow fly (Calliphoridae), 1, 0%
Muscid fly (Muscidae), 14, 2%
Honey Bee (Apis mellifera), 328, 46%
FLIES
Hover fly (Syrphidae), 105, 15%
NATIVE BEES
Bumble bee (Bombus), 90, 13%
Small Carpenter bee (Ceratina), 1, 0%
Long-horned bee (Apidae), 1, 0%
Green sweat bee (Augochlorini), 8, 1%

Figure 3. Assemblages of floral visitors by month (all years combined). Graphs were grouped together on this page to help visualize changes in floral visitor assemblages by month. For larger versions of each of these graphs, see Appendix.

Floral Associations of Native Bees and other Pollinators:

May: A total of 269 pollinators were observed on flowers during this monitoring period (Figure 2). Native bees (including small sweat bees, mining bees, bumble bees, and a diversity of other bee groups) were the most abundant floral visitors present (Figure 3). Native bees comprised 86% of the bees, and 69% of the pollinators. The majority of floral visits in May were on golden Alexanders (*Zizia aurea*) (188) and wild lupine (*Lupinus perennis*) (73). The lupine was most attractive to honey bees and bumble bees, while the golden Alexanders was frequented by a diversity of small native bees, including small sweat bees (*Lasioglossum*), small carpenter bees (*Ceratina*), mining bees (*Andrena*), sweat bees (*Halictus*), and cuckoo bees (*Nomada* & *Sphecodes*). A diversity of flies and wasps were also especially common on golden Alexanders at this time.

June: A total of 250 insects were observed on flowers during this monitoring period (Figure 2). Hover flies were the most abundant pollinator present, and small carpenter bees (*Ceratina*) were the most abundant bee group present (Figure 3). Native bees comprised 100% of the bees, and 40% of the pollinators. No honey bees and few bumble bees were present during this time period. Floral visits by native bees, hover flies, and other insects were fairly evenly divided between a number of native and non-native plants (Table 1). Native blooms were relatively limited during this time period, calling our attention to a bloom gap that should be addressed by interseeding or plugging additional forbs that bloom during this period (see bumble bee section, below).

Table 1. June floral visits by native bees, hover flies, and other insects primarily occurred on the following native and exotic plants (2015-2017). Foraging resources (and bumble bee visits) were very limited during this monitoring period.

Scientific Name	Common Name	Status	# Visits
Potentilla arguta	Prairie cinquefoil	Native	33
Achillea millefolium	Yarrow	Native	26
Securigera varia	Crown vetch	Exotic	22
Coreopsis palmata	Prairie coreopsis	Native	22
Tradescantia occidentalis	Prairie spiderwort	Native	19
Erigeron sp.	Fleabane	Unclear	17
Berteroa incana	Hoary alyssum	Exotic	16
Trifolium pratense	Red clover	Exotic	14
Heliopsis helianthoides	Early sunflower	Native	10
Medicago sativa	Alfalfa	Exotic	10

July: A total of 853 insects were observed on flowers during this monitoring period (Figure 2). Native bees comprised 90% of the bees, and 58% of the pollinators. The majority of visits during this time period were on *Monarda fistulosa* (436), *Pycnanthemum virginianum* (151), *Agastache foeniculum* (100), and *Ratibida pinnata* (72). Bumble bees were the most abundant bee group at this time (Figure 3), and were primarily observed on *M. fistulosa.*

August: A total of 1674 insects were observed on flowers during this monitoring period (Figure 2). Native bees comprised 35% of the bees, and 14% of the floral visitors. Soldier beetles were the most abundant floral visitor (Figure 3), the vast majority of which were visiting *Solidago rigida*. Honey bees (*Apis mellifera*) were the most abundant bee group present, followed by bumble bees (Figure 3). *Solidago rigida* hosted the most insect visitors (1077), followed by *S. canadensis* (228), *S. speciosa* (154), *Liatris ligulistylis* (52), *S. nemoralis* (48), and *Cirsium discolor* (29).

<u>September</u>: A total of 712 insects were observed on flowers during this monitoring period (Figure 2). Native bees comprised 23% of the bees, and 14% of the floral visitors. Honey bees (*Apis mellifera*) were the most abundant bee group present, followed by hoverflies, bumble bees (*Bombus*), and paper wasps (*Polistes*) (Figure 3). The majority of floral visits were to *Solidago speciosa* (381), *Symphyotrichum ericoides* (171) and *S. novae-angliae* (99), and *S. laeve* (32).

Bumble Bee Community Structure:

A total of 697 bumble bees representing ten different species were observed during all surveys (monthly May through September over 3 years) (Figure 4). Representative photographs were taken of all species at the site.

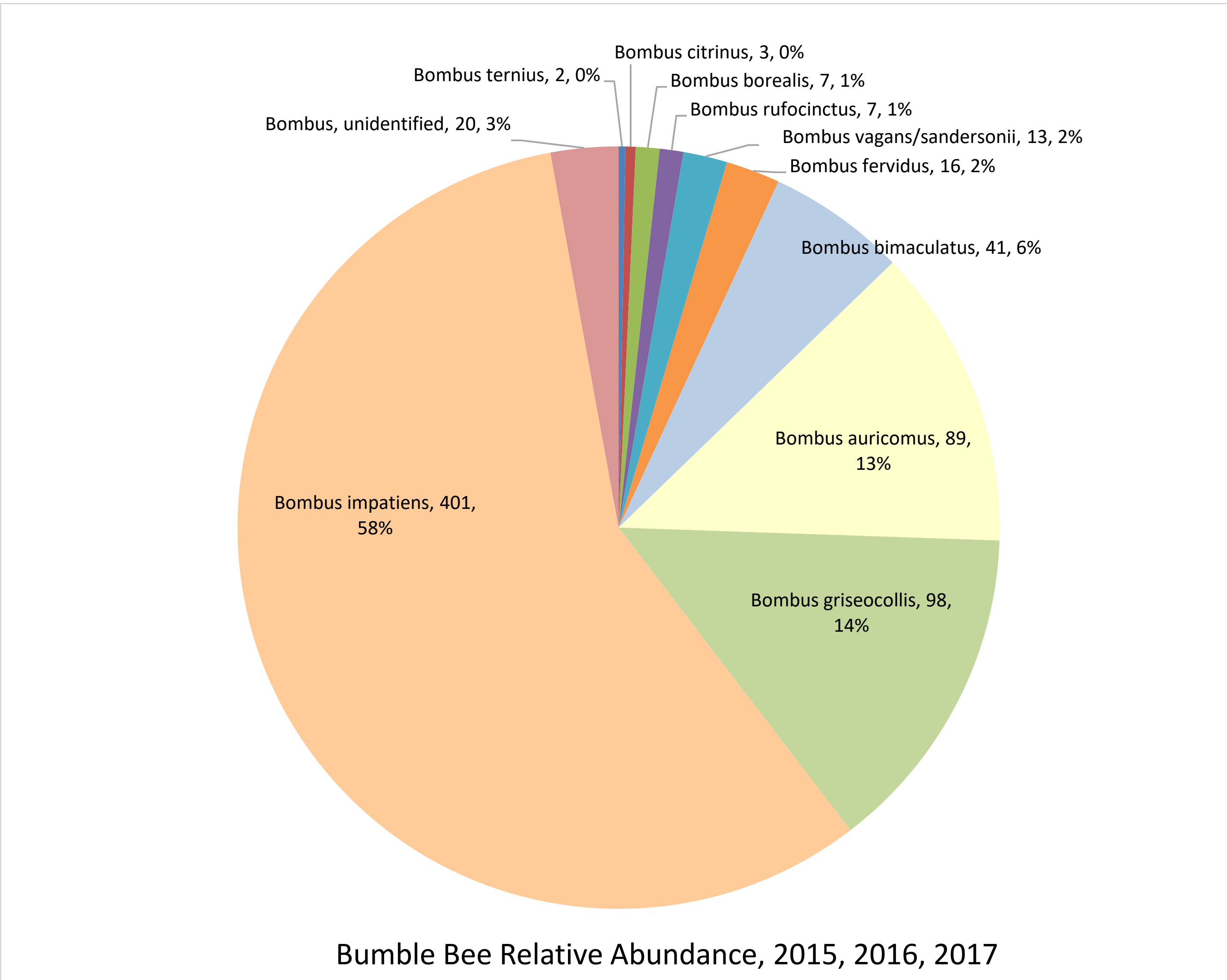


Figure 4. Relative abundance of bumble bees at South Washington (Central Corridor) in 2015, 2016, and 2017. The number of observed individuals of each species is listed after the species name. **Bombus vagans* (common) and *B. sandersoni* (relatively rare) are difficult to distinguish without microscopic examination. One individual of this morphotype was collected, examined microscopically, and determined to be *B. vagans*. As such, it is likely (but not certain) that the other individuals of this morphotype also represent *B. vagans*. Similarly, *B. auricomus* (common) is very similar to *B. pensylvanicus* (very rare); numerous individuals of this morphotype were examined in hand, and all were determined to be *B. auricomus.* We will continue to look for *B. pensylvanicus* at the site, but currently do not have evidence of this species' presence.

A total of 689 floral associations were recorded, representing interactions between ten different bumble bee species and 33 different flowers. The plant species found to support the highest number of bumble bee visits are shown in Table 2.

Table 2. Flowers visited by bumble bees during the course of our 3 years of surveys, monthly May through September. The "other" category is composed of 21 plant species for which four or less bumble bee visits were recorded: *Astragalus canadensis, Boltonia asteroides, Cirsium discolor, Coronilla varia, Dalea candida, Echinacea purpurea, Helenium autumnale, Lespedeza leptostachya, Liatris ligulistylis, Mimulus glabratus, Mimulus ringens, Ratibida pinnata, Rudbeckia hirta, Scrophularia lancelolata, Solidago nemoralis, Symphyotrichum sericeum, Tradescantia occidentalis, Trifolium pratense, Verbena stricta,* and *Zizia aurea*.

Flower Species	Predominant Bloom Time	# Visits
Monarda fistulosa	July	331
Solidago rigida	September	94
Solidago speciosa	August, Sept	77
Solidago canadensis	August	40
Lupinus perennis	May	23
Agastache foeniculum	July	20
Symphyotrichum novae-angliae	September	18
Symphyotrichum ericoides	September	13
Symphyotricum laeve	September	12
Securigera varia	June	9
Dalea purpurea	July	7
Pycnanthemum virginianum	July	7
Other (species with 4 or less visits)	-	21
Total		**689**

It should be noted that *Cirsium discolor* was also found to be highly attractive to bumble bees during late August. Although poorly represented in our transects, this plant was abundant in dense patches outside of our transect areas. We did not attempt to quantify bumble bee visits to *C. discolor* in these areas, however, during a 15 minute-observation of one dense patch of blooming *C. discolor* in August 2013, it was noted that nearly every bloom had one or more bumble bee visitors at any given moment. In contrast, bumble bees were relatively sparse in our transects this same day (just 62 bumble bees were observed during our August 2013 survey compared to 233 during the July survey), presumably due to the higher attractiveness of the *C. discolor* patches relative to the *Solidago* blooming in our transects. Attempts to better quantify the use of *C. discolor* by *Bombus* and other pollinators are underway at other sites.

In general, June observations of bumble bees over the 3 years were lower than expected (based on May bumble bee abundance) across the site, presumably due to low forage availability at that time.

Table 3. Bumble bee observations per month, over 3 years (a few of these observations were in flight or on the ground, not on flowers).

May	27
June	20
July	373
August	187
September	90

Across all years, only 16 bumble bee were observed on flowers in June, visiting just four species *(Scrophularia lanceolata, Secuigera varia, Tradescantia occidentalis, Trifolium pretense*). This finding suggests that there may be a gap in bumble bee floral resources (particularly natives) post-*Lupinus/Zizia* bloom (late May), and pre-*Monarda /Agastache* bloom (July). Plants with potential to fill or partially fill this bloom gap include (but are not limited to): additional spiderwort (*Tradescantia* spp.), additional figwort (*Scrophularia* spp.), prairie phlox, upland white goldenrod, common milkweed, butterfly weed, smooth/foxglove penstemon (but nativity remains uncertain), slender penstemon, yarrow, flat-topped aster (wet areas), *Coreopsis* spp., fireweed, *Rosa* spp., and native loosestrife (wet areas).

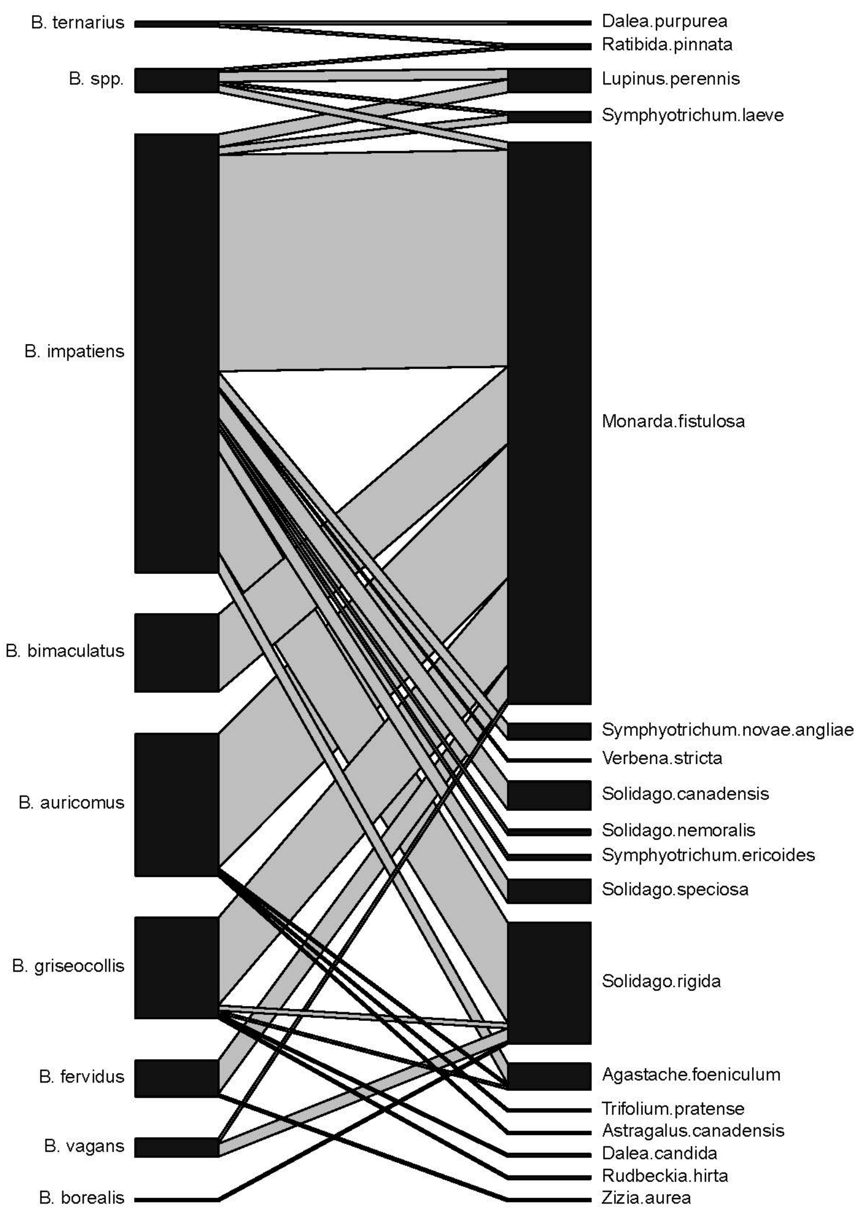


Figure 5. Floral associations of bumble bees at South Washington (Central Corridor) in 2015. Although the majority of bumble bee observations were on *Monarda fistulosa*, a few species (*B. ternarius, B. borealis,* and *B. vagans*) were detected only (or primarily) on other plant species (namely, *Solidago rigida, Dalea purpurea,* and *Ratibida pinnata*).

Monarch Nectar Plant Associations:

Nectaring associations of adult monarchs are presented below. *Solidago rigida* was the most-visited plant by adult monarchs (67 visits, 35%), followed by *Liatris ligulistylis* (56 visits, 29%) and *Syphyotrichum novae-angliae* (19 visits, 10%) (Figure 6). Although three *Liatris* species are common on site (*L. aspera, L. pycnostachya,* and *L. ligulistylis*), the latter was by far the most attractive to monarchs (Figure 6).

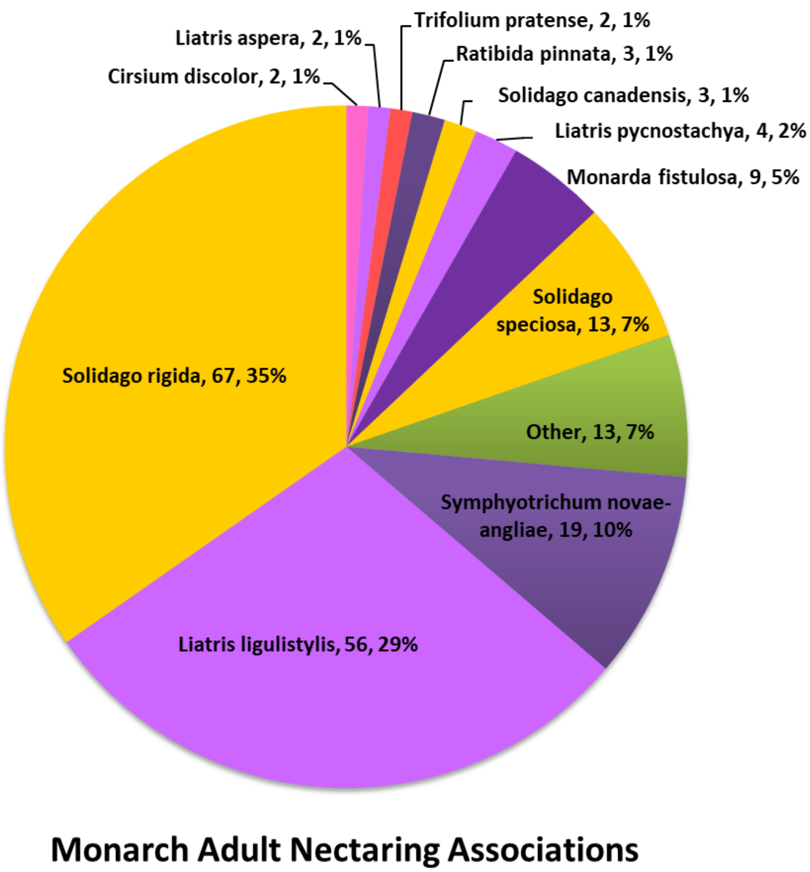


Figure 6. Floral associations of nectaring adult monarchs at South Washington over the three-year monitoring period. The colors in the graph roughly approximate the flower color. Additional plant species that were documented with nectaring monarchs on only one occasion were combined into the “other” category. The majority of these observations occurred in late August, followed by late September.

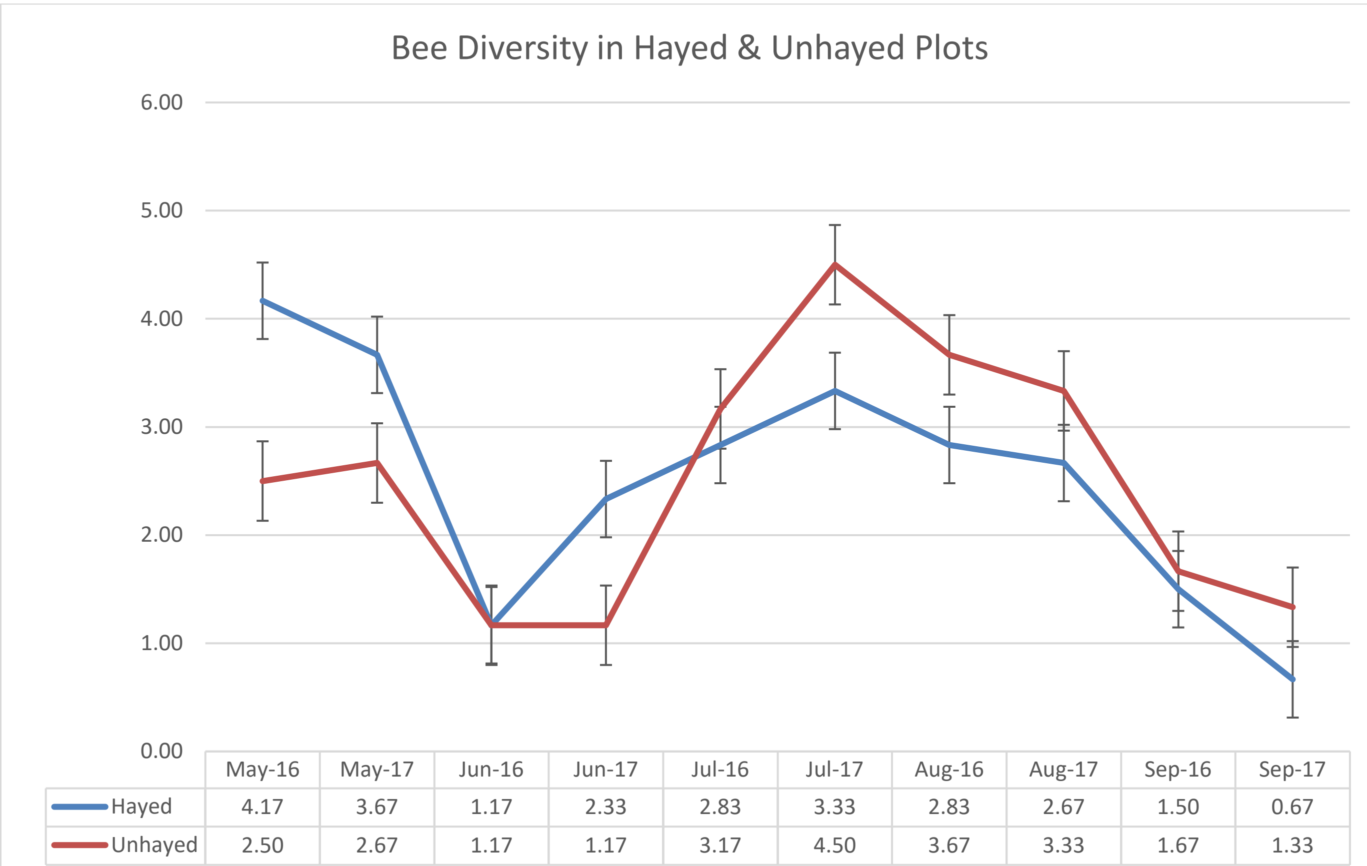
Monitoring Implications:

In this study, our surveys were conducted monthly from May to September, typically the last week of the month. Native bees exhibited the highest diversity in May and August (8 genera represented), compared to other months, especially September. Native bees also had the highest *relative abundance* in May (69%), relative to other flower visitors (Figure 3). The greatest *total abundance* of native bees was observed in July, followed by August (Figure 2). June revealed low numbers, but moderate diversity, of native bees (7 groups represented, including one not seen in other months). By late September, relative abundance of native bees had tapered down to 14%, and no new bee groups/genera were detected at that time. **These findings suggest that May, June, July, and August should be prioritized for native bee monitoring, due to the highest diversity, abundance, and relative abundance of native bees on flowers at these times.** If funding/time is limited, September monitoring could be omitted in this region, unless monarchs, honey bees, or other groups are considered priority for the study (Figure 3).

Impact of Haying on Native Bee Abundance and Diversity:

One of the objectives of this study was to examine potential impacts of haying on native bees. To do this, we calculated the mean abundance and diversity values for hayed and for unhayed transects on each survey date following the fall 2015 haying, and performed two-tailed paired T-tests to evaluate differences. We also examined abundance differences specifically in cavity nesting bees, since these bees are likely to be the most negatively impacted by haying due to removal of nest sites.

Bee diversity in hayed vs. unhayed plots (all months / years combined) was not significantly different (p = 0.5). However, on our May survey dates, bee diversity was consistently higher in hayed plots (p = .018), Figure 7).

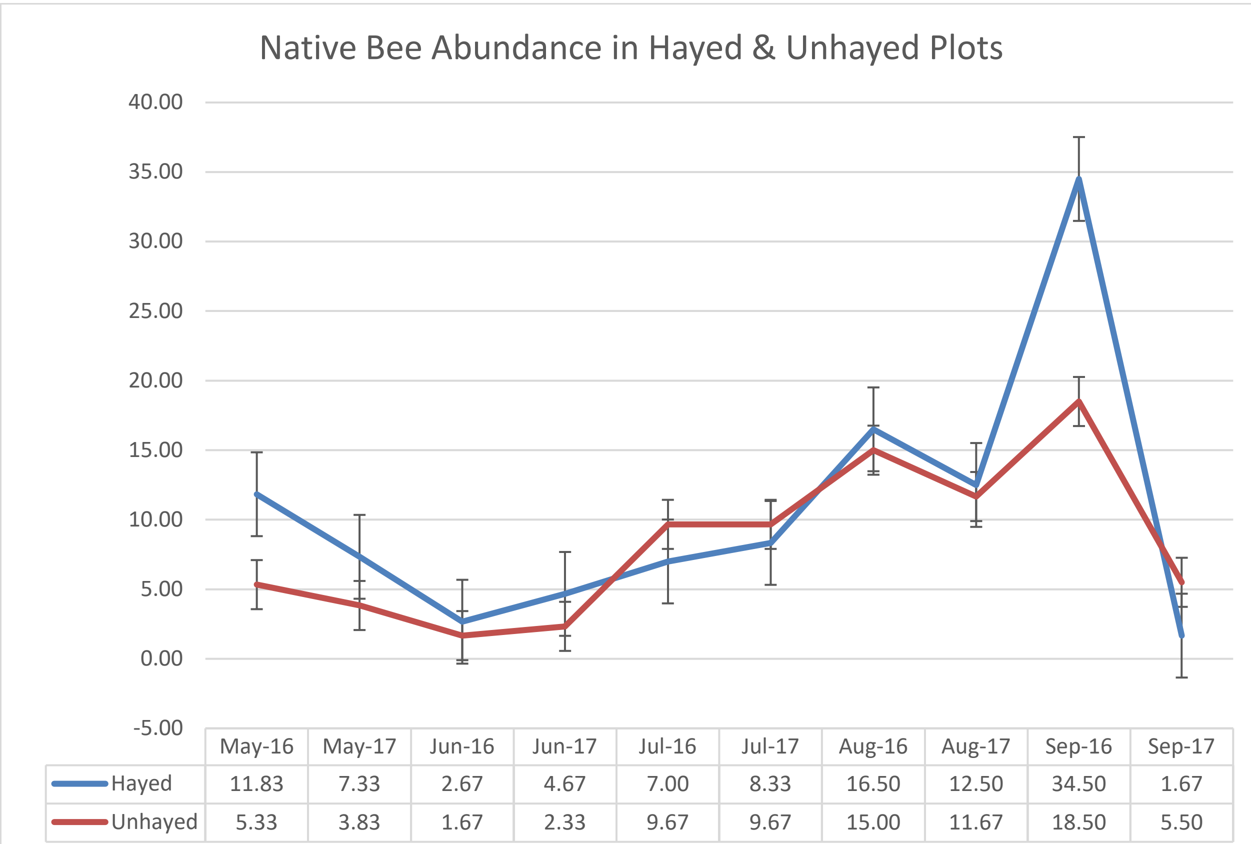


	May-16	May-17	Jun-16	Jun-17	Jul-16	Jul-17	Aug-16	Aug-17	Sep-16	Sep-17
Hayed	4.17	3.67	1.17	2.33	2.83	3.33	2.83	2.67	1.50	0.67
Unhayed	2.50	2.67	1.17	1.17	3.17	4.50	3.67	3.33	1.67	1.33

Figure 7. Average bee diversity in hayed vs. unhayed transects. Hayed transects had significantly higher diversity in May, consistent across years.

Similarly, bee abundance in hayed vs. unhayed plots (all months / years combined) was not significantly different (p = 0.21). However, on our May survey dates, bee abundance was higher in hayed plots, although significance was not consistent across all survey years (p = .09), Figure 8). Higher abundance and diversity of bees in hayed plots in May was likely driven by increased wildflower bloom, and/or increased visibility of wildflowers in the hayed plots at that time, since the grass canopy and thatch had been removed.

Bee abundance was also higher in hayed plots in September of the first study year, although this was not consistent across both years.



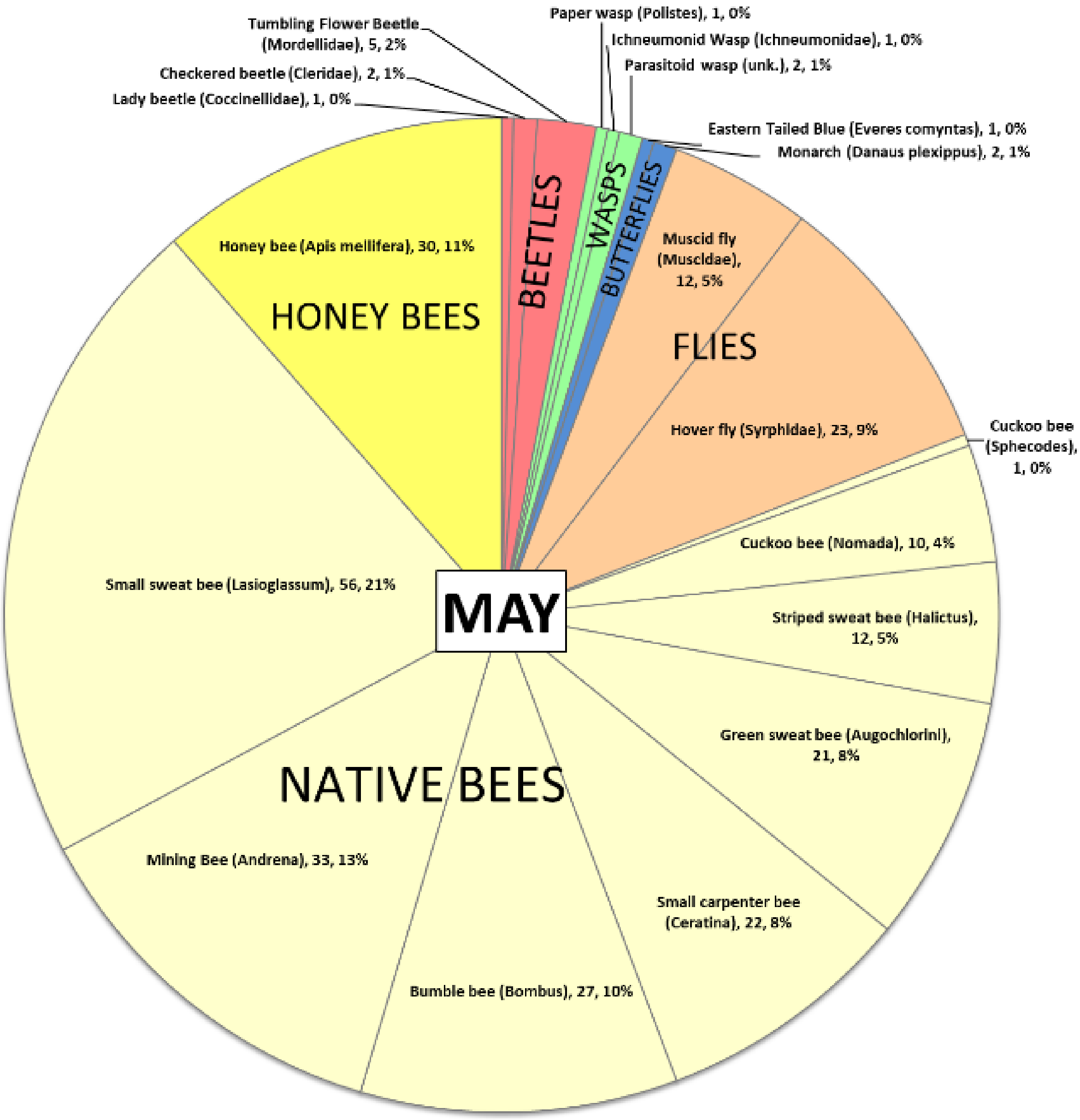
	May-16	May-17	Jun-16	Jun-17	Jul-16	Jul-17	Aug-16	Aug-17	Sep-16	Sep-17
Hayed	11.83	7.33	2.67	4.67	7.00	8.33	16.50	12.50	34.50	1.67
Unhayed	5.33	3.83	1.67	2.33	9.67	9.67	15.00	11.67	18.50	5.50

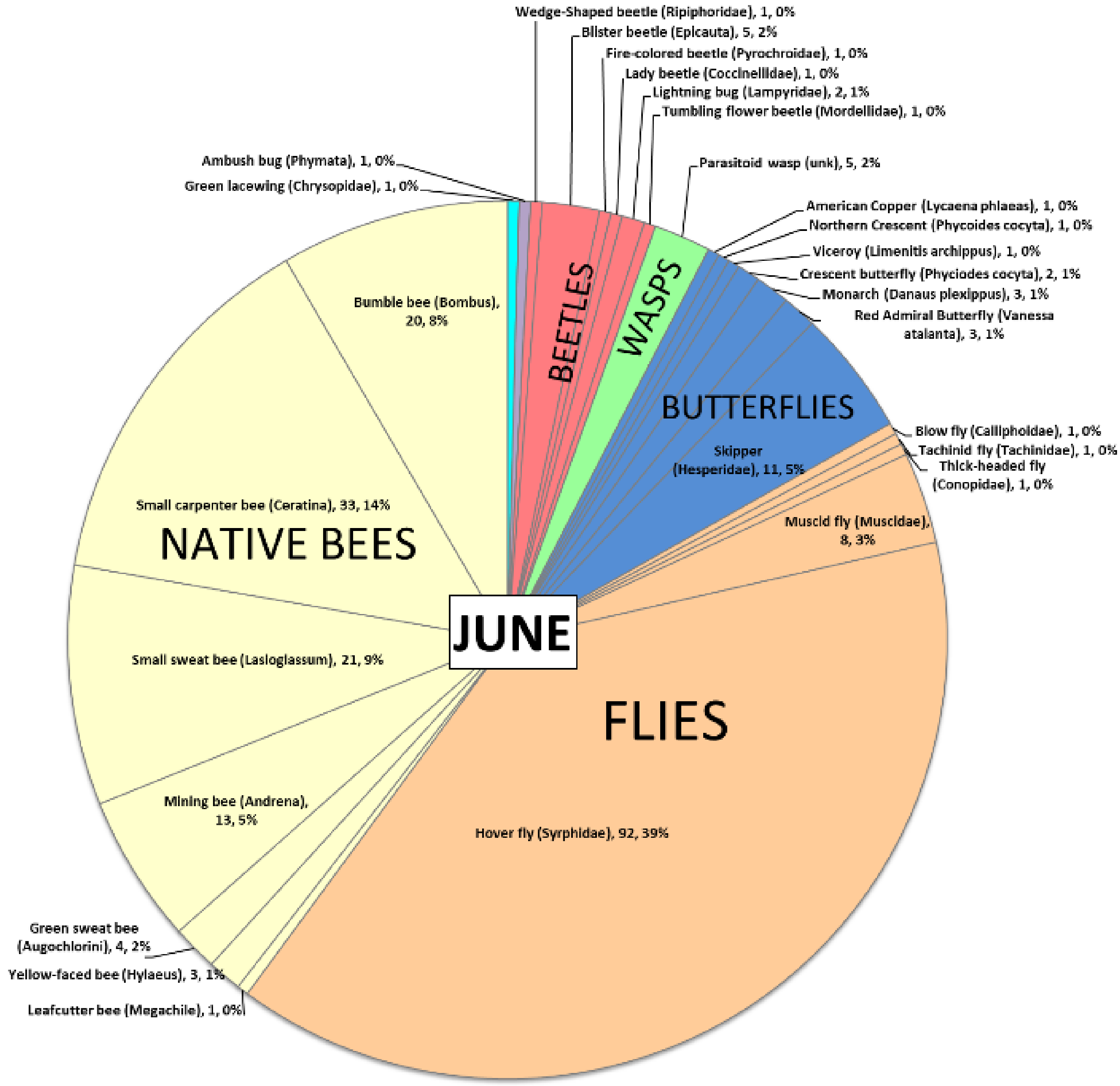
Figure 8. Average bee abundance in hayed vs. unhayed transects.

Cavity-nesting bee abundance was not significantly different in hayed vs. unhayed plots (all months/years combined) (p = 0.5).

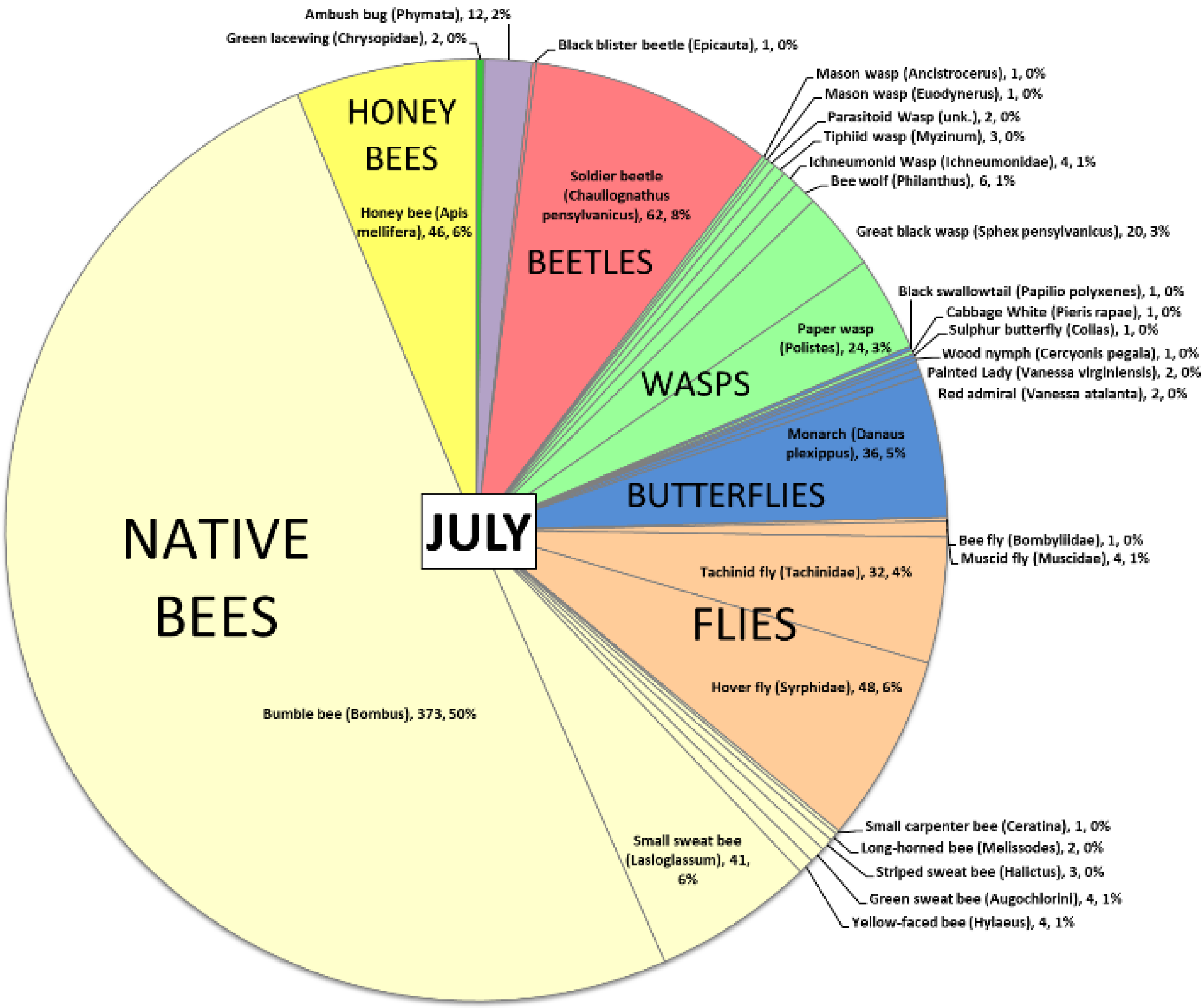
Appendix:

Larger versions of graphs shown in Figure 3 in the text, showing assemblages of floral visitors by month (all years combined).

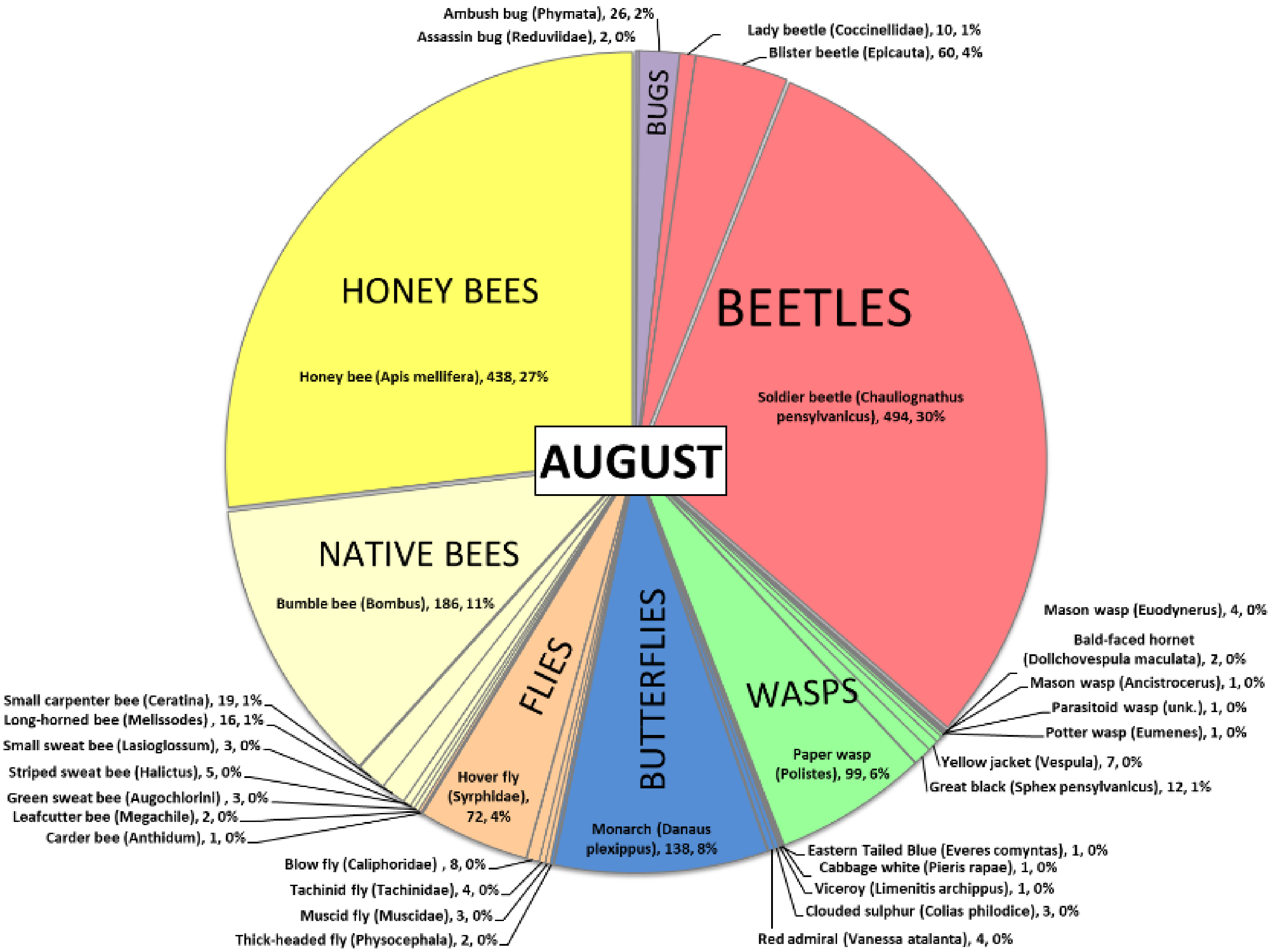

Tumbling Flower Beetle (Mordellidae), 5, 2%
Checkered beetle (Cleridae), 2, 1%
Lady beetle (Coccinellidae), 1, 0%
Paper wasp (Polistes), 1, 0%
Ichneumonid Wasp (Ichneumonidae), 1, 0%
Parasitoid wasp (unk.), 2, 1%
Eastern Tailed Blue (Everes comyntas), 1, 0%
Monarch (Danaus plexippus), 2, 1%
BEETLES
WASPS
BUTTERFLIES
Muscid fly (Muscidae), 12, 5%
FLIES
Hover fly (Syrphidae), 23, 9%
Cuckoo bee (Sphecodes), 1, 0%
Honey bee (Apis mellifera), 30, 11%
HONEY BEES
Cuckoo bee (Nomada), 10, 4%
Small sweat bee (Lasioglassum), 56, 21%
MAY
Striped sweat bee (Halictus), 12, 5%
Green sweat bee (Augochlorini), 21, 8%
NATIVE BEES
Mining Bee (Andrena), 33, 13%
Small carpenter bee (Ceratina), 22, 8%
Bumble bee (Bombus), 27, 10%

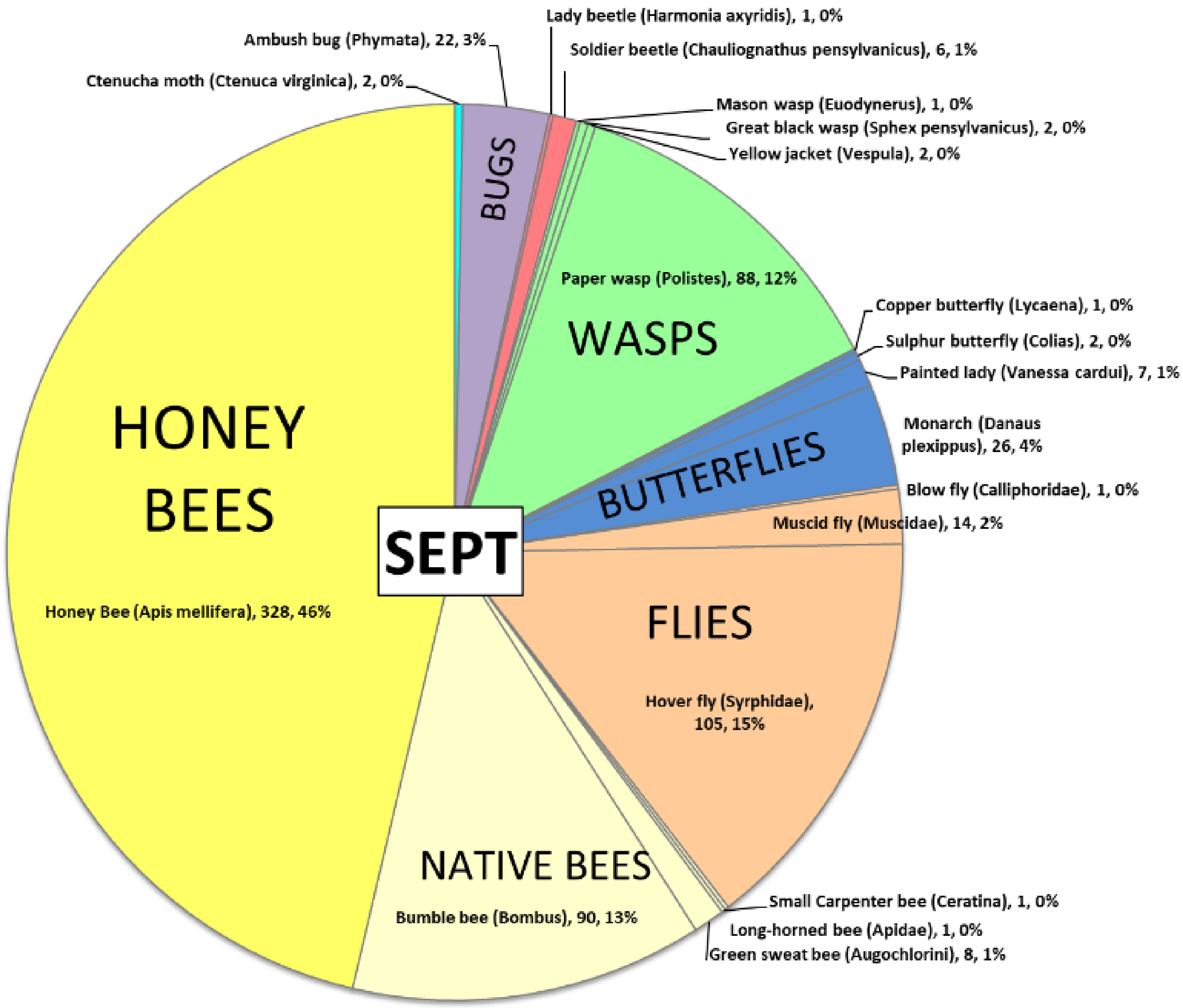


Wedge-Shaped beetle (Ripiphoridae), 1, 0%
Blister beetle (Epicauta), 5, 2%
Fire-colored beetle (Pyrochroidae), 1, 0%
Lady beetle (Coccinellidae), 1, 0%
Lightning bug (Lampyridae), 2, 1%
Tumbling flower beetle (Mordellidae), 1, 0%
Parasitoid wasp (unk), 5, 2%
Ambush bug (Phymata), 1, 0%
Green lacewing (Chrysopidae), 1, 0%
American Copper (Lycaena phlaeas), 1, 0%
Northern Crescent (Phycoides cocyta), 1, 0%
Viceroy (Limenitis archippus), 1, 0%
Crescent butterfly (Phyciodes cocyta), 2, 1%
Monarch (Danaus plexippus), 3, 1%
Red Admiral Butterfly (Vanessa atalanta), 3, 1%
BEETLES
WASPS
BUTTERFLIES
Bumble bee (Bombus), 20, 8%
Skipper (Hesperidae), 11, 5%
Blow fly (Calliphoidae), 1, 0%
Tachinid fly (Tachinidae), 1, 0%
Thick-headed fly (Conopidae), 1, 0%
Muscid fly (Muscidae), 8, 3%
Small carpenter bee (Ceratina), 33, 14%
NATIVE BEES
JUNE
Small sweat bee (Lasioglossum), 21, 9%
FLIES
Mining bee (Andrena), 13, 5%
Hover fly (Syrphidae), 92, 39%
Green sweat bee (Augochlorini), 4, 2%
Yellow-faced bee (Hylaeus), 3, 1%
Leafcutter bee (Megachile), 1, 0%



Ambush bug (Phymata), 12, 2%
Green lacewing (Chrysopidae), 2, 0%
Black blister beetle (Epicauta), 1, 0%
Mason wasp (Ancistrocerus), 1, 0%
Mason wasp (Euodynerus), 1, 0%
Parasitoid Wasp (unk.), 2, 0%
Tiphiid wasp (Myzinum), 3, 0%
Ichneumonid Wasp (Ichneumonidae), 4, 1%
Bee wolf (Philanthus), 6, 1%
Great black wasp (Sphex pensylvanicus), 20, 3%
Black swallowtail (Papilio polyxenes), 1, 0%
Cabbage White (Pieris rapae), 1, 0%
Sulphur butterfly (Colias), 1, 0%
Wood nymph (Cercyonis pegala), 1, 0%
Painted Lady (Vanessa virginiensis), 2, 0%
Red admiral (Vanessa atalanta), 2, 0%
Bee fly (Bombyliidae), 1, 0%
Muscid fly (Muscidae), 4, 1%
Small carpenter bee (Ceratina), 1, 0%
Long-horned bee (Melissodes), 2, 0%
Striped sweat bee (Halictus), 3, 0%
Green sweat bee (Augochlorini), 4, 1%
Yellow-faced bee (Hylaeus), 4, 1%
HONEY BEES
Honey bee (Apis mellifera), 46, 6%
Soldier beetle (Chauliognathus pensylvanicus), 62, 8%
BEETLES
WASPS
Paper wasp (Polistes), 24, 3%
Monarch (Danaus plexippus), 36, 5%
BUTTERFLIES
JULY
NATIVE BEES
Tachinid fly (Tachinidae), 32, 4%
FLIES
Hover fly (Syrphidae), 48, 6%
Bumble bee (Bombus), 373, 50%
Small sweat bee (Lasioglossum), 41, 6%


Ambush bug (Phymata), 26, 2%
Assassin bug (Reduviidae), 2, 0%
Lady beetle (Coccinellidae), 10, 1%
Blister beetle (Epicauta), 60, 4%
BUGS
HONEY BEES
Honey bee (Apis mellifera), 438, 27%
BEETLES
Soldier beetle (Chauliognathus pensylvanicus), 494, 30%
AUGUST
NATIVE BEES
Bumble bee (Bombus), 186, 11%
FLIES
BUTTERFLIES
WASPS
Mason wasp (Euodynerus), 4, 0%
Bald-faced hornet (Dolichovespula maculata), 2, 0%
Mason wasp (Ancistrocerus), 1, 0%
Parasitoid wasp (unk.), 1, 0%
Potter wasp (Eumenes), 1, 0%
Yellow jacket (Vespula), 7, 0%
Great black (Sphex pensylvanicus), 12, 1%
Paper wasp (Polistes), 99, 6%
Small carpenter bee (Ceratina), 19, 1%
Long-horned bee (Melissodes) , 16, 1%
Small sweat bee (Lasioglossum), 3, 0%
Striped sweat bee (Halictus), 5, 0%
Green sweat bee (Augochlorini) , 3, 0%
Leafcutter bee (Megachile), 2, 0%
Carder bee (Anthidum), 1, 0%
Hover fly (Syrphidae), 72, 4%
Monarch (Danaus plexippus), 138, 8%
Blow fly (Caliphoridae) , 8, 0%
Tachinid fly (Tachinidae), 4, 0%
Muscid fly (Muscidae), 3, 0%
Thick-headed fly (Physocephala), 2, 0%
Eastern Tailed Blue (Everes comyntas), 1, 0%
Cabbage white (Pieris rapae), 1, 0%
Viceroy (Limenitis archippus), 1, 0%
Clouded sulphur (Colias philodice), 3, 0%
Red admiral (Vanessa atalanta), 4, 0%


Lady beetle (Harmonia axyridis), 1, 0%
Ambush bug (Phymata), 22, 3%
Soldier beetle (Chauliognathus pensylvanicus), 6, 1%
Ctenucha moth (Ctenuca virginica), 2, 0%
Mason wasp (Euodynerus), 1, 0%
Great black wasp (Sphex pensylvanicus), 2, 0%
Yellow jacket (Vespula), 2, 0%
BUGS
Paper wasp (Polistes), 88, 12%
WASPS
Copper butterfly (Lycaena), 1, 0%
Sulphur butterfly (Colias), 2, 0%
Painted lady (Vanessa cardui), 7, 1%
HONEY BEES
Monarch (Danaus plexippus), 26, 4%
BUTTERFLIES
Blow fly (Calliphoridae), 1, 0%
Muscid fly (Muscidae), 14, 2%
SEPT
Honey Bee (Apis mellifera), 328, 46%
FLIES
Hover fly (Syrphidae), 105, 15%
NATIVE BEES
Small Carpenter bee (Ceratina), 1, 0%
Bumble bee (Bombus), 90, 13%
Long-horned bee (Apidae), 1, 0%
Green sweat bee (Augochlorini), 8, 1%

Response of vegetation and soil nitrogen to haying in a restored prairie

Final Report. August 9, 2018

Eric Ogdahl, Ecologist. Great River Greening

Acknowledgement

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Introduction

Prairie ecosystems are adapted to frequent disturbances, such as fire, grazing, or drought, which help remove thatch buildup and undesirable vegetation (e.g., woody species or non-native invasive forbs and legumes) and promote high-diversity plant communities. These high-diversity plant communities can in turn support a high diversity of fauna, especially pollinators. Increasingly, however, as Minnesota's original prairie landscape continues to be fragmented with housing developments and agriculture, employing necessary disturbance regimes such as prescribed fire or grazing can become impractical.

Haying has been proposed as a novel disturbance regime in prairies, as it can remove periodic thatch buildup and has potential to remove excess soil nutrients, which can otherwise promote weedy and undesirable vegetation. Our study sought to evaluate the response of vegetation and soil nitrogen to haying in a restored prairie in the east metropolitan area of Minnesota. Specifically, we assessed changes in vegetation cover (percent coverage of forbs, legumes, graminoids, litter, bare ground, woody species, and blooms of forbs and legumes), forb species richness, and soil nitrogen after two years of repeated haying in comparison to control units without haying.

Since floral variables alone give an incomplete assessment of the effectiveness of prescribed haying as a prairie management technique, another component of this study, led by Xerces, examined pollinator abundance, diversity, and floral interactions in hayed and control plots. Anticipated benefits of haying to pollinators include higher diversity and abundance of forbs during the spring season when nectar and pollen is most limited; lower abundance of nitrophilic forb species; higher forb-to-grass ratio; and reduced thatch/easier access to soil for ground nesting bees.

Methods

Site Description and Study Design—South Washington Conservation Corridor is an 84-acre restored prairie located in Washington County, Minnesota. The physical conditions of the site consist of rolling topography formed by ice block deposits from the last glaciation and underlain by sand and gravel outwash deposits (EOR 2002). Soils consist primarily of moderately well to well-drained silt loam. Prior to the study, all plots had been seeded with 128 prairie-adapted species native to Minnesota, including 38 graminoid and 90 forb species. Study units ranging from 2.5 to 5 acres were assigned to alternating control and hay treatments (Figure 1).

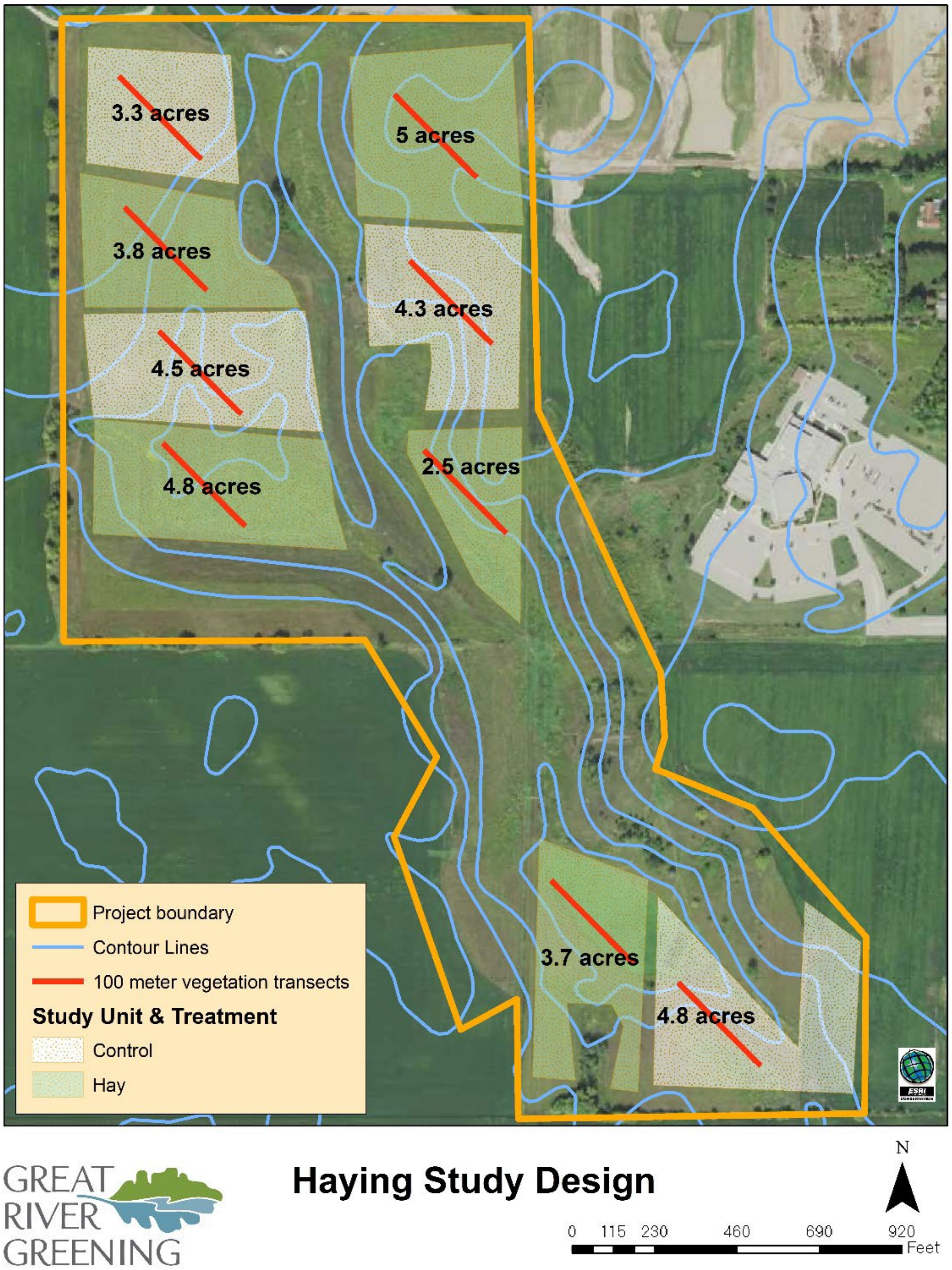

Figure 1 Haying Study Layout and Design

Haying—Hayed units were hayed by Strohfus Stock Farm, LLC in October 10, 2015, early November 2016, and October 18, 2017. Vegetation was cut to a height of 11 cm (4.25 in).

Vegetation and Soil Surveys—Using GIS software (ArcMap 10.5.1, ESRI 2017), a 100 m transect was mapped out along the longest part of each study unit (Figure 1). All transects were located at least 10 meters from the edge of the unit to avoid edge effects. A 20 x 50 cm quadrat was systematically placed along the transects at 0 m, 20 m, 40 m, 60 m, 80 m, and 100 m. In each quadrat, vegetation coverage was estimated based on the following categories: percent cover of graminoids, woody species, forbs (vegetative and blooms), legumes, bare ground, and litter. Vegetation cover was recorded using an 8-point scale (0%, 1%, 3%, 16%, 38%, 63%, 85%, and 96%) per Daubenmire (1959). Additionally, all forbs and legumes (blooming and non-blooming) were recorded to species in each quadrat.

In addition to recording vegetation cover, soil subsamples were collected from the center of each quadrat. Subsamples were collected to a depth of 15 cm (6 in) and composited by transect. Vegetation and soil samples were collected during June, July, and September of 2017, with additional soil samples collected in December of 2016.

Soil Total Nitrogen Analyses—Soil samples were submitted to the University of Minnesota Soil Testing Lab for Total Nitrogen analyses, described by the UMN as follows (UMN 2018):

> This technique uses a LECO FP-528 Nitrogen Analyzer to determine total N in soil materials. A 250-300 mg sample is weighed into a capsule and dropped into an 850°C furnace purged with O_2 gas. The combustion products of CO_2, H_2O and NO_x are filtered, cooled by a thermoelectric cooler to condense most of the water, and collected in a large ballast. A 3 cc aliquot of the ballast combustion products is integrated into a He carrier stream and passed through: 1.) a hot copper column where the O_2 is removed and the NO_x gasses are converted to N_2 and 2.) a reagent tube which scrubs the $CO_2$and remaining H_2O from the stream. The N_2 content is then measured by a thermal conductivity cell against a He background and the result displayed as weight percentage of nitrogen.

Statistical Analyses—Linear mixed effects models were used to examine the effects of treatment (haying vs. no haying) and survey month on soil total nitrogen and forb bloom coverage. Haying treatment and month were included as fixed effects and tested for significance and interaction via Wald's Chi-square test; plot number was included as a random effect. Similar models were used to determine the effects of treatment on functional group canopy coverage (e.g. forbs and graminoids), except survey month was considered a repeated measure and therefore included as a random effect. For all models, where main effects were significant at the 0.05 level, Tukey's honestly significant difference (HSD) for multiple comparisons was used to test for differences among means at a 0.05 significance level. All statistical analyses were performed in R (R Development Core Team 2008).

Results and Discussion

Bloom coverage—We found no significant effect of haying on bloom coverage, nor a significant interaction between haying and month. However, month significantly affected bloom coverage ($p < 0.001$, Figure 1), with September having a significantly higher bloom coverage than June and July; June and July were not significantly different. While significant, the difference in bloom coverage between September and the other two months was minimal, with September, on average, showing a difference in bloom coverage by 2.57% and 3% over June and July, respectively. Nonetheless, the higher bloom coverage observed in September may be due to the presence of a variety of later-blooming forbs, such as species in the goldenrod (*Solidago*) and *Symphyotrichum* genera [e.g., New-England Aster (*Symphyotrichum novae-angliae*)], on the site.

While no differences were observed between haying treatments, future, earlier surveys may show higher bloom coverages in hayed plots. Observationally, certain hayed plots during May 2018 appeared to have higher coverage of lupine (*Lupinus perrenis*) blooms compared to control plots (Figure 2).

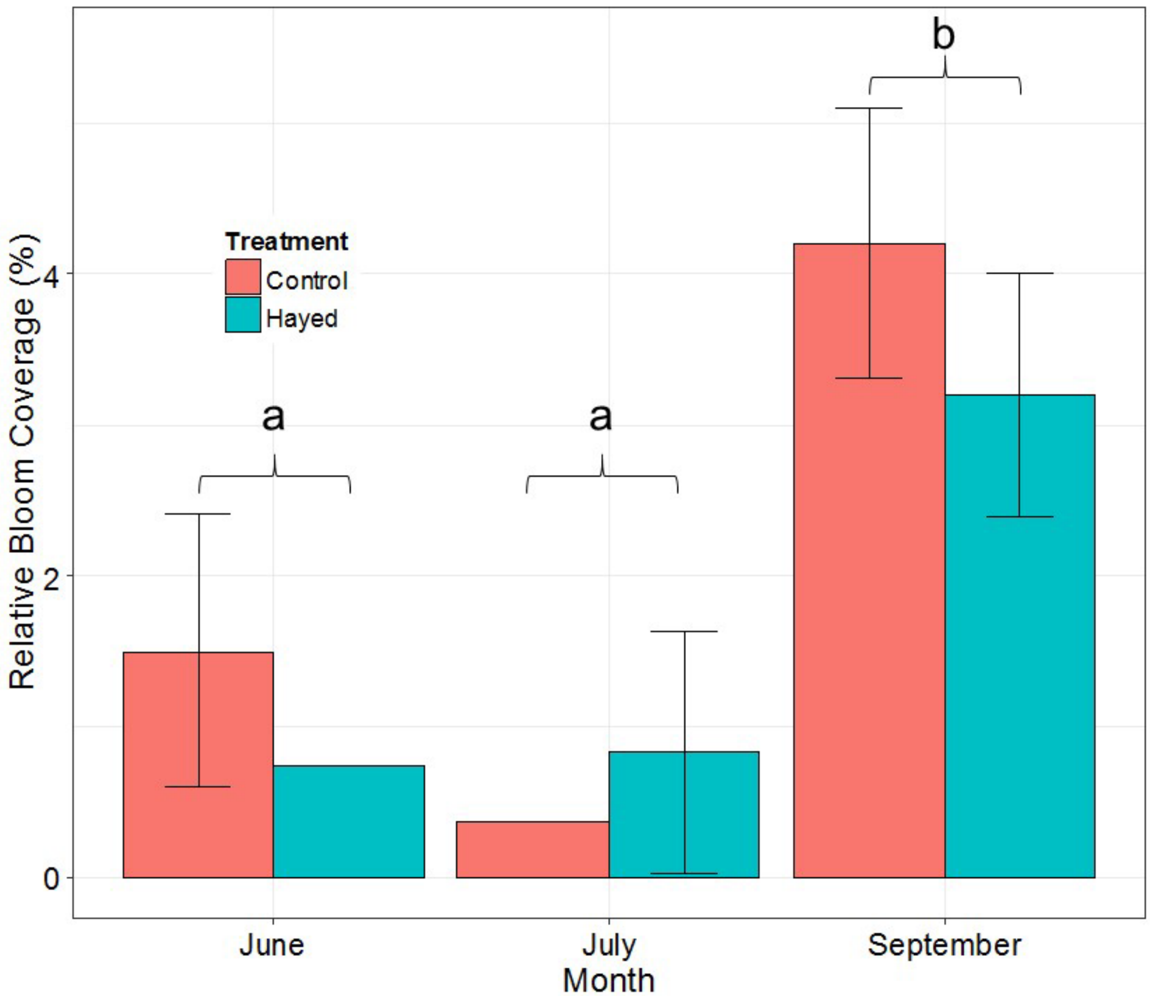

Figure 2 Mean bloom coverage by haying treatment and month. Error bars denote standard error. Different letters above error bars denote significant differences among month as determined by Tukey's HSD test.

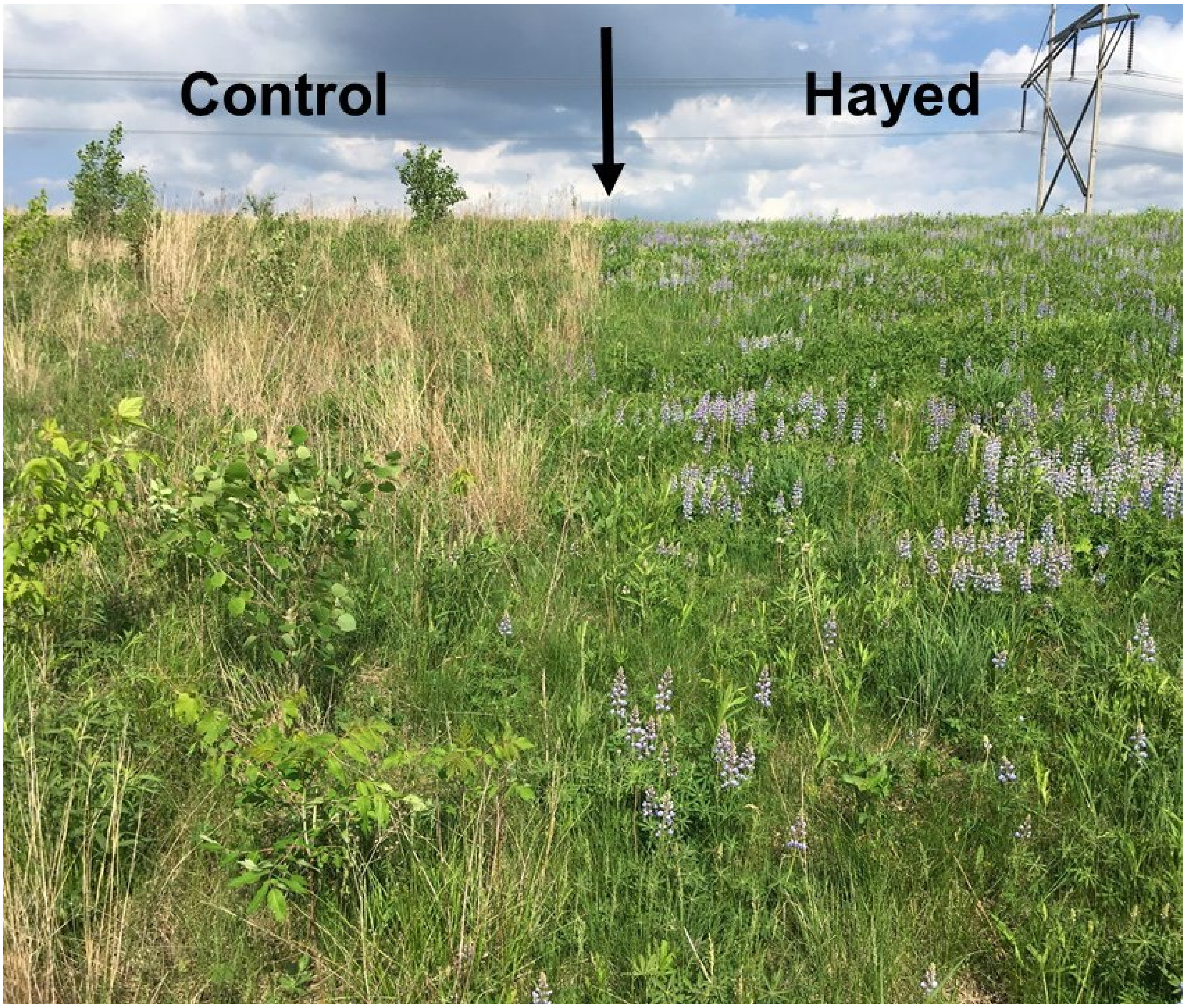

*Figure 3 Lupine (*Lupinus perennis*) blooms in control vs. hayed plots in May 2018.*

Forb and legume species richness

Treatment had a significant effect on forb and legume species richness (P = 0.004998). However, the difference between treatments was slight, with hayed units having, on average, one more species than unhayed units. Furthermore, when native vs. non-native species were considered separately, no significant difference between native species in hayed and unhayed units was identified. This is mainly due to slightly more non-native red and white clover (*Trifolium pretense* and *T. repens*, respectively) being recorded in hayed units.

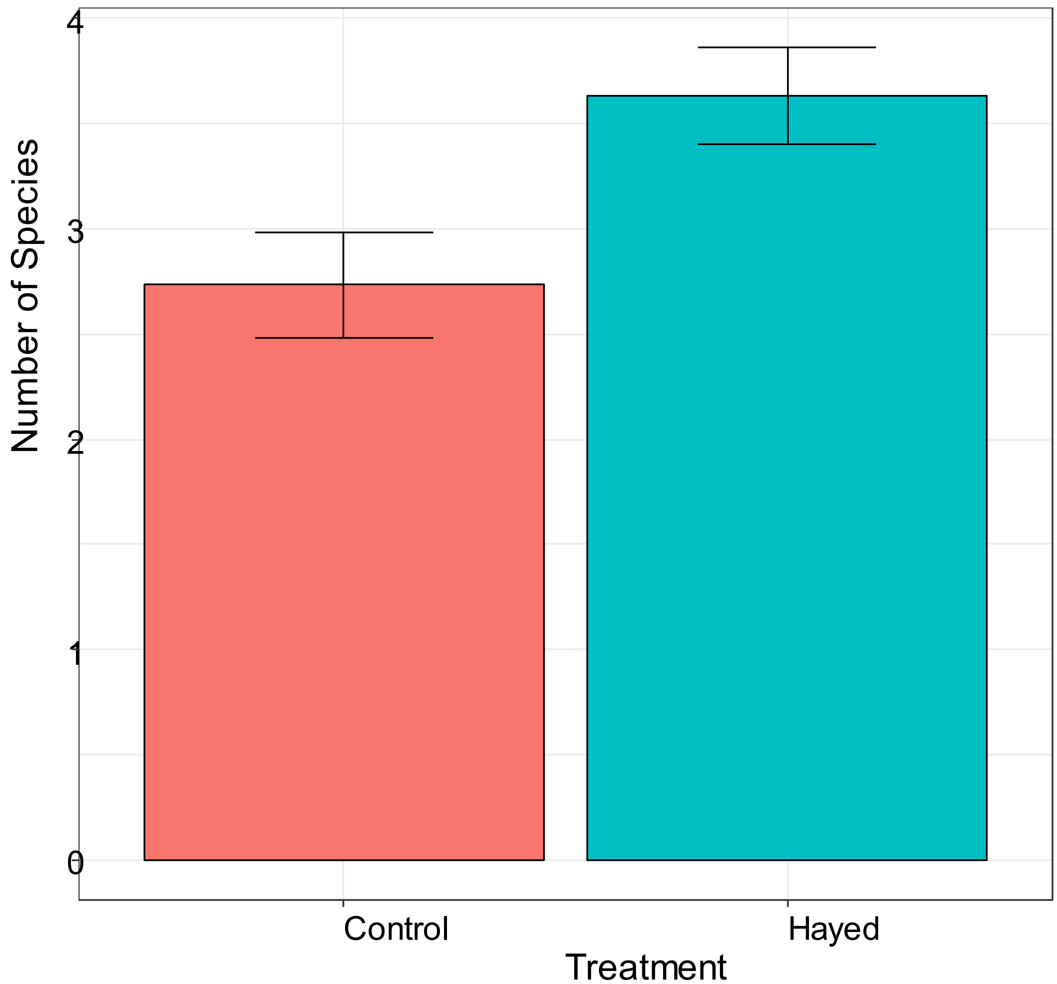

Figure 4 Mean number of species in control and hayed units. Error bars denote standard error.

Functional group coverage

We found no significant difference in canopy coverage between treatments for litter, graminoids, legumes, or bare ground (Figure 4). Although not depicted in Figure 4, bare ground coverage averaged 0.25% and 0.52% for control and hayed units, respectively. Forb coverage was significantly different between control and hayed units ($P = 0.0012$), with hayed units on average having 17.5% greater coverage than control units. The ratios of forb coverage to grass coverage in control and hayed units were also compared (Figure 6). Ratios were significantly different between treatments ($P = 0.041$), wherein hayed units on average had a 5.3-fold greater ratio of forbs to grasses than control units.

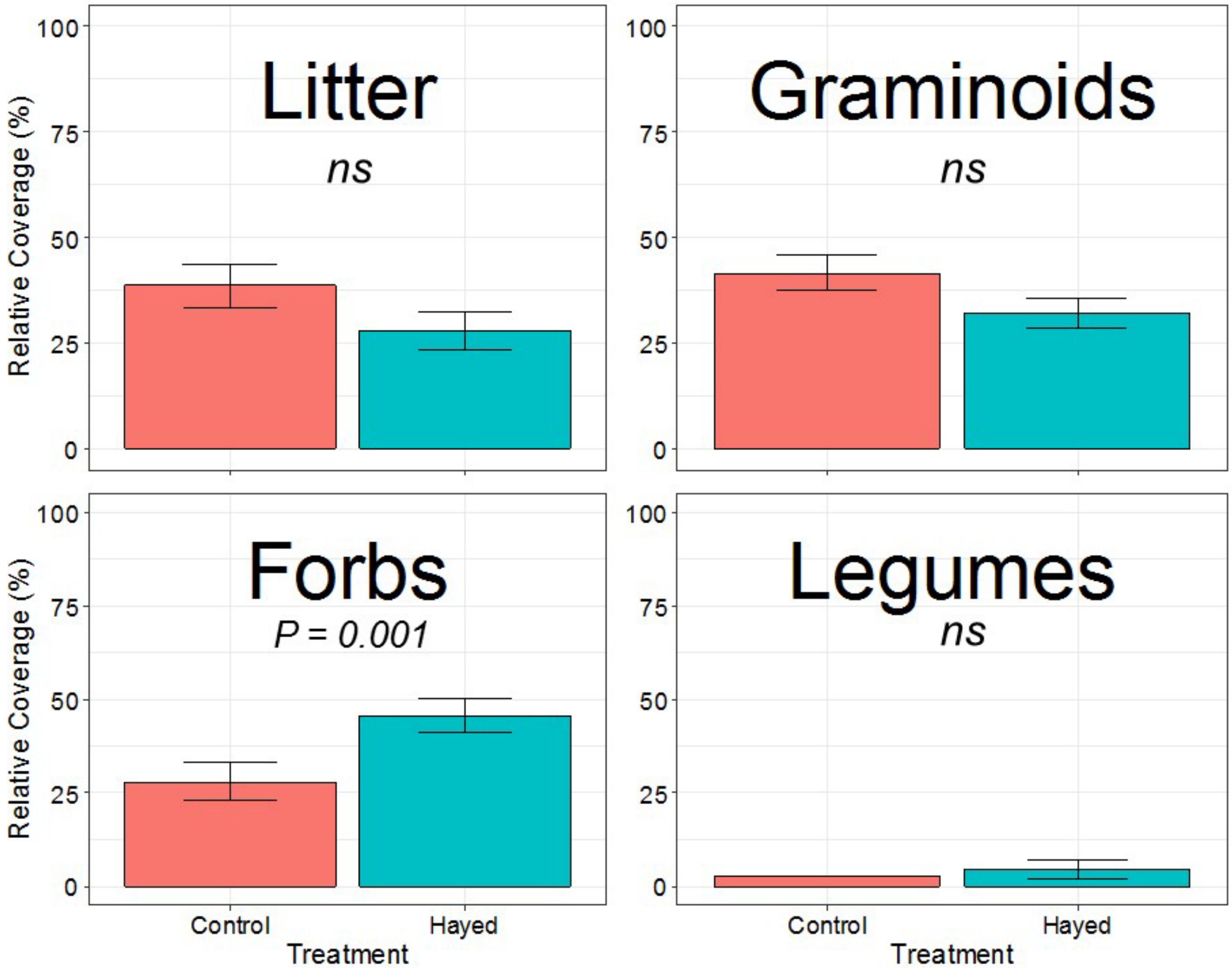

Figure 5 Mean canopy coverage of litter, graminoids, forbs, and legumes. Error bars denote standard error. 'ns' signifies no significant difference between treatments at the 0.05 significance level under the Wald's Chi-Square test. Where significant, the P-value is shown.

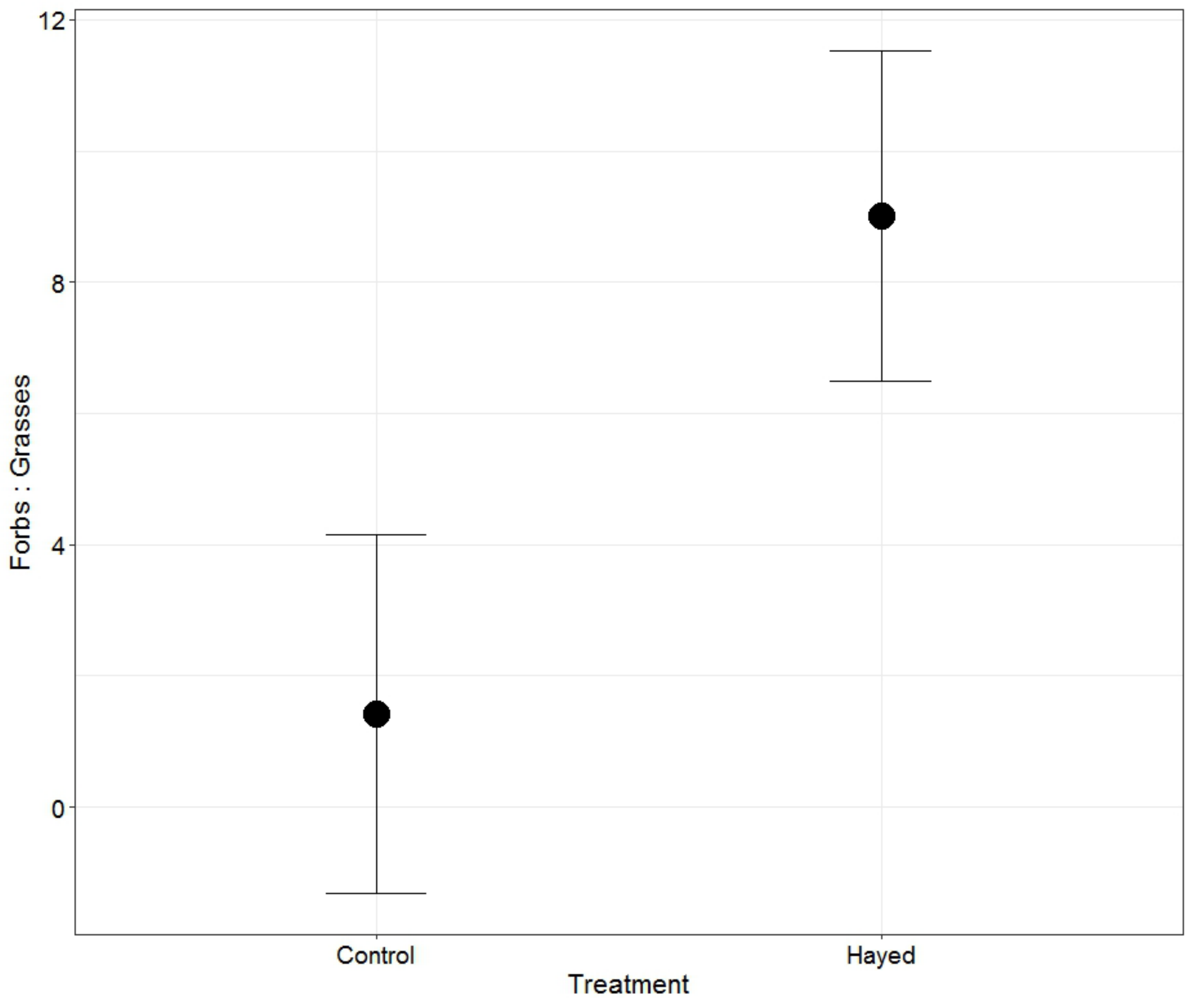

Figure 6 Mean ratio of forb to grass coverage in control and hayed units. Error bars show standard error. Treatment was significantly different at P = 0.0401.

Soil Nitrogen

Haying treatments had no significant effect on total nitrogen at the 0.05 significance level (P = 0.0511); however, month significantly affected total nitrogen (P = 0.0183) when control and hayed treatments were considered together (Figure 5). In this case, the only months that differed significantly in soil N levels were July and September 2017 (P = 0.0451), wherein July was greater than September by 0.014%. It is possible additional years of haying are needed before changes in soil nitrogen can be observed.

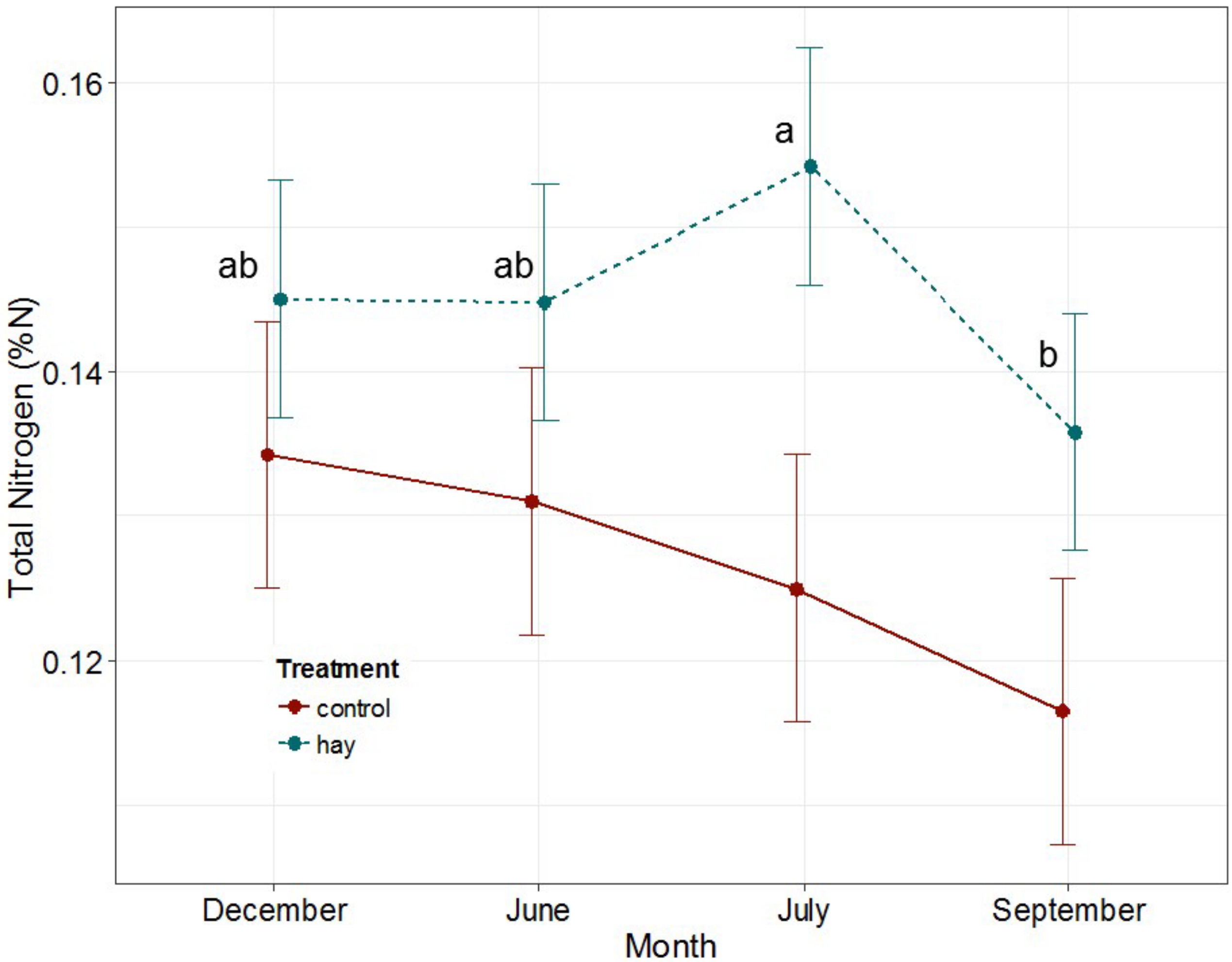

Figure 7 Mean soil total nitrogen by treatment and month. Error bars denote standard error. Letters denote Tukey's test significant differences among month when control and hayed treatments are considered together. Months that share letters are not significantly different. Months with different letters are significantly different at the 0.05 level.

Conclusion and Management Implications:

The goal of this study was to document any changes in soil nitrogen and vegetation, especially as it relates to forb and bloom coverage, in response to haying. Few differences were noted in soil nitrogen and vegetation after three years of consistent haying. Notably, forb coverage was significantly different between control and hayed units, with hayed units on average having 17.5% greater coverage than control units. Additionally, the ratio of forbs to grasses significantly increased by 5.3-fold in hayed units compared to control units. However, this did not seem to drive an increase in overall bloom coverage, which did not significantly differ between control and hayed units. That there was no difference in bloom coverage between the treatments may be reflected by the results of a paired pollinator study, which did not find significant differences in pollinator diversity and abundance between treatments (Foltz Jordan & Herou 2018). The exception to this was for the month of May, which found higher bee diversity and abundance in hayed treatments. Our vegetation survey did not occur during May, which will be an important month for future haying studies, as early forbs and forb blooms are likely more visible then due to a reduction in thatch from the previous year's haying. Since hayed units showed a shift to higher forb:grass ratios, this could suggest a higher number of early-season blooms over control units.

Overall, given some of the observed desirable changes in vegetation, haying appears to be a viable method for periodic thatch removal, as is often required in prairies, and may be an appropriate alternative to prescribed burns. More research is needed regarding the timing of haying, as it relates to promoting pollinator habitat and nutrient removal, and comparing responses of vegetation and pollinator habitat to different disturbance regimes, such as haying and prescribed burns. Additionally, longer-term data are needed to determine the effects, if any, of haying on soil nutrient levels.

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