2015 Project Abstract
For the Period Ending June 30, 2018

PROJECT TITLE: Effects of Grazing Versus Fire for Prairie Management
PROJECT MANAGER: Susan Galatowitsch
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2015, Chp. 76, Sec. 2, Subd. 03o

APPROPRIATION AMOUNT: $414,000
AMOUNT SPENT: $400,652
AMOUNT REMAINING: $13,348

Overall Project Outcome and Results

Without disturbance, Minnesota's tallgrass prairies would transition to woodland and forest. Current management includes prescribed fire and conservation grazing to maintain prairie plant communities, with the assumption that pollinator communities will also benefit. While effects of fire on northern tallgrass prairie are well-documented, information has been lacking on effects of conservation grazing on vegetation and insects in Minnesota. To address this knowledge gap we evaluated vegetation, bees, and butterflies on burned or grazed remnant prairies in western Minnesota. Quantitative assessments of plant, bee and butterfly communities were based on randomly placed transects at each site; species lists were augmented by directed searches of the sites.

Of 328 plant species identified, 52 were found only on grazed sites and 57 only on burned sites. On a scale from 0 (weeds) to 10 (species found only in undisturbed remnant prairie), burned sites averaged 4.1 and grazed sites 3.7, which suggests that the grazed sites were a bit weedier than the burned sites.

Of 40 butterfly species observed, 30 were seen at both burned and grazed sites. Nine of the 40 species are reliant on native prairie. In general, species that were seen at more sites were also more abundant. Common species tended to be more abundant at burned sites and rarer species tended to be more abundant at grazed sites.

To date, 69 species have been identified from over 7,200 collected bees; a few taxonomically challenging specimens are as yet unidentified. Of conservation interest are the 11 species of bumble bees, three of which are listed as "vulnerable" by the IUCN (*Bombus fervidus*, *B. pensylvanicus*, and *B. terricola*).

Burning and grazing favored varying communities of plants, bees, and butterflies, suggesting that each management type has a role in maintaining Minnesota's prairie ecosystems. Results of our research are providing land managers with information necessary for them to be effective stewards of prairie plant communities and the pollinators that depend on them.

Project Results Use and Dissemination

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

Date of Report: August 27, 2018

Final Report

Date of Work Plan Approval: June 11, 2015

Project Completion Date: June 30, 2018

PROJECT TITLE: Effects of Grazing Versus Fire for Prairie Management

Project Manager: Susan Galatowitsch

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Location: Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$414,000**
	Amount Spent:	**$400,652**
	Balance:	**$13,348**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03o

Appropriation Language:
$414,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to compare the effects of conservation grazing and prescribed fire on tallgrass prairie plants and pollinators in Minnesota in order to inform and improve land management practices. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Effects of Grazing Versus Fire for Prairie Management

II. PROJECT STATEMENT:

Minnesota's tallgrass prairies depend on disturbance (e.g., fire, grazing, drought), without which they would rapidly transition to woodland and forest. Drought alone will not maintain prairies in Minnesota, so land managers use prescribed fire and "conservation grazing" (the use of grazing by domestic animals to achieve conservation goals) to preserve prairie plant communities and the many pollinators, birds, and mammals that depend on them. Although effects of fire on northern tallgrass prairies are well documented, there are *no* studies of the effects of conservation grazing on Minnesota prairies in the published literature, and gradients in temperature and precipitation make extrapolation from studies to the west and south of Minnesota risky. Yet, because prescribed fires are expensive, require significant personnel numbers and time, can only be completed during specific windows of time, and may have negative effects on some pollinators, managers have turned to conservation grazing, *despite its unknown consequences*. The study proposed here aims to address this knowledge gap, taking advantage of existing prairies with known management histories.

Our primary goal is to conserve and enhance Minnesota's tallgrass prairies by providing the tools necessary for federal, state, local, and private land managers to be effective stewards of prairie plant communities and the pollinators and other animals that depend on them. We will accomplish this goal via biological monitoring (of both plants and pollinators), analysis of effects of fire and grazing on plants and pollinators, and by wide dissemination of our findings.

First, we will identify Minnesota prairies that meet our criteria of having known management histories, and including both burning and grazing management strategies. Fortunately, Minnesota is home to thousands of acres of prairies with a wide variety of known management histories. We will work with the land management community to identify prairie tracts that have been managed predominantly with fire or predominantly with grazing throughout the tallgrass prairies of Minnesota.

We will then assess the effects of grazing intensity and prescribed fire on native plant species richness and diversity and the prevalence of invasive grasses in at least 75 prairies. Because of their potential effects on vegetation, we will also measure rates of nitrogen cycling, soil characteristics, and surrounding land use. All prairies will be assessed for vegetation cover in year one, and a subset resampled in year two. We will also assess the direct and indirect effects of grazing and fire on pollinator species richness (native bees and butterflies), because pollinating insects are sensitive to both management (direct effects) and plant species composition (indirect effects). We will use field surveys and observation transects designed to provide detailed information on the diversity and abundance of solitary bees, bumble bees, and butterflies. These surveys will be conducted during both summers at a random sample of the 75 prairies, using sampling intervals that will account for differences in insect flight times. The attached figure illustrates potential pathways of direct and indirect effects of management on key prairie characteristics; our research will allow us to evaluate the relative importance of these pathways.

Finally, we will compile our findings and disseminate them to land managers using a variety formats, with the goal of providing unbiased information on the implications of fire and grazing for Minnesota's tallgrass prairies. The ultimate outcome of this work will be a well-informed management community that will understand the relative and varying effects of fire and conservation grazing on Minnesota's prairie resources.

III. OVERALL PROJECT STATUS UPDATES:

Note that these sections were written as the project unfolded, so verb tense may not reflect the fact that, at this point, the steps are completed.

Project Status as of *January 2016***:** Since the inception of the LCCMR funding we have been identifying remnant prairie locations on state, federal and private land with adequate burning and grazing histories using ArcMap, a GIS software package. To date, 769 remnant prairie map polygons have been identified as being primarily burned, 126 primarily grazed and 207 with a combination of burning and grazing. Because conservation grazing is a relatively new federal and state management method (<5 years), it is possible that we will be working with private/easement land owners to obtain our required number of grazed sites. In addition, while many land managers have been practicing burning or grazing for many years, their site boundaries and management records have not yet been digitized; we will work with land managers as needed to assist in digitizing data for sites of interest.

We are also working to refine methods for vegetation and insect sampling. In late January, we are hosting a symposium to discuss projects with similar goals, and to get feedback on our proposed methods. We are working with bee and butterfly experts to refine our sampling and identification methods.
Two students working on this project started their graduate programs in fall 2015 (Patrick Pennarola, PhD student, and Julia Leone, MS student). Portions of the research funded by LCCMR will provide Patrick and Julia with content for their thesis research. Because we obtained other funds for Patrick and Julia in fall 2015, we are able to fund more time for Jen Larson, who is overseeing site selection and project planning.

Project Status as of *July 2016***:** To date we have selected 57 remnant prairies (34 grazed, 23 burned) under federal, state and private ownership, ranging in size from 1-130 hectares. We are adding additional sites as management information becomes available, and permission from agencies and land owners is granted, with the goal of attaining 75 remnant sites. Since our last report, protocols for bee, butterfly and vegetation sampling have been finalized, and sampling is underway, having started in early June. The bee and butterfly surveys are being led by graduate students Patrick Pennarola (bees) and Julia Leone (butterflies). Grant Piepkorn (undergraduate) was hired using separate UMN funds, to assist Patrick and Julia. Karin Jokela (MS, lead botanist) and Kathryn Schmidt (undergraduate, assistant botanist) were hired in spring 2016 to conduct our vegetation surveys. Patrick, Julia, Karin, Kathryn, and Jen participated in the MN DNR Native Plant Community and plant identification training at Chippewa Prairie (TNC) to enhance their plant identification skills and ensure accurate reporting of vegetation at our field sites.

Project Status as of *January 2017***:** To date we have selected 75 remnant prairies (27 grazed, 48 burned); the number of grazed sites declined due to some sites with same-year grazing rotations being merged to single sites. Since our last report, we have completed our field season. Karin Jokela (MS, lead botanist) and Kathryn Schmidt (undergraduate, assistant botanist) completed vegetation surveys on 43 of the total sites; our 2017 botanists will re-visit a subset of 20 of the remnants, on which insect surveys also are taking place, in addition to the remaining sites not yet visited in 2016. Karin Jokela and Jennifer Larson contributed to vegetation data entry and quality assurance of the survey data. Julia Leone and Patrick Pennarola (both PhD students) performed butterfly and insect surveys on a subset of the 20 remnants mentioned previously, visiting each site 3 times during the 2016 field season. Julia has completed data entry of her field observations as well as some preliminary analyses. Patrick has pinned, labeled and identified around 300 netted specimens, and will process bowl trap specimens this winter. Jennifer Larson presented 2016 findings at the LCCMR pollinator projects meeting, organized and hosted at the University of Minnesota in December, 2016, as well as at the first annual (The) Nature Conservancy "Science Slam." Jennifer also has prepared soil samples for texture analysis, and pending results, will conduct nutrient availability tests on soil collected from the 43 remnants visited in 2016.

Project Status as of *July 2017***:** Not required per notice from LCCMR staff.

Project Status as of *August 15, 2017*: Since our last report, we have nearly completed our second and final field season. Larissa Mottl (MS, lead botanist) and Madison Rancour (undergraduate, assistant botanist) have finished repeat vegetation surveys on the 20 remnant sites chosen for insect surveys, and are currently completing the single-year vegetation surveys and soil sampling on the 32 remnants not visited in 2016. Madison and Larissa have started data entry and quality assurance of 2017 data. Julia Leone and Patrick Pennarola (UMN graduate students) are currently finishing their third and final round of butterfly and bee surveys, respectively, for the 2017 field season.

Amendment Request (08/15/2017): We are submitting a request for a rebudget that will not affect the overall scope of work, but will correct errors made in the original budget. We have not made any changes to the rest of the work plan document. The total amount allocated for Activity 2 is slightly less than originally budgeted because nitrogen analysis costs were only part of Activity 2, and all other travel costs were split evenly between Activities 2 and 3.

1. When we calculated the field crew travel expenses of $17,940, we neglected to multiply the total amount by 2 seasons, thus the total budgeted for travel expenses should have been $17,940 x 2 for field expenses (instead of $17,940), $2580 for Larson and Oberhauser travel, and $12,000 for 2 field vehicles (total = $50,460 vs. $32,520 in the original budget). To address this error, we request moving $11,940 from the salary line in the same Activity columns into the travel line. Travel funds are split evenly between Activities 2 and 3, and the total amounts for these activities will not change.
2. The additional funds for travel are available because both of our graduate students received fellowships in their first year, decreasing the amount needed for their stipends.
3. The nitrogen analyses are not as expensive as we anticipated. We request moving $6000 from the "other research expenses" budget line into the travel line to make up for the rest of the travel deficit.

Additionally, we request a change in the Project Manager. Karen Oberhauser is leaving the University of Minnesota at the end of September for a position at the University of Wisconsin. Karen shares project management responsibilities with Dr. Diane Larson (USGS), and Jen Larson serves as project coordinator. Both Diane and Jen will continue with the project. Dr. Susan Galatowitsch, University of Minnesota, has agreed to assume official Project Manager responsibilities, with the understanding that project continuity will be provided by Diane and Jen. Sue's expertise in prairie biology and long-term monitoring, as well as her experience with previous LCCMR projects and final reports, mesh well with this project.

Amendment Approved by LCCMR (8/21/2017)

Project Status as of *January 2018***:** We successfully completed our second and final field season. Vegetation surveys on 51 remnant prairies were performed by botanists Larissa Mottl and Madison Roncour, assisted and supervised by Jen Larson. Jen Larson's position was altered from a temporary-casual position to a Researcher 3 at the University of Minnesota, to reflect her time spent in project coordination; please note the mention of her increased time in the January, 2016 update. Data entry and error-checking of all vegetation data collected from 2017 is complete, and has been combined with 2016 data to complete our vegetation survey database. Preliminary findings for vegetation on the subset of sites used for insect surveys show that plant indicator species at burned sites were all native species in both 2016 (3 species) and 2017 (7 species). Grazed sites showed mixed results, with even numbers of native and introduced indicator species in 2016 (14 species total) and 60% introduced indicator species in 2017 (10 species). Indicator species for the grazed sites were generally weedier and less conservative than those for burned sites. Mesic plant communities differed more than wet plant communities between grazed and burned sites where insects were surveyed.

Julia Leone has completed butterfly surveys on a subset of 20 remnant prairie sites, and all observational data has been entered and error-checked. Preliminary results show that butterfly species observed during 2016 and 2017 varied greatly in their frequency of occurrence; several species were only seen at one site, while a few were seen at most sites. Overall, species that occupied more sites were also more abundant. Five of the six most abundant butterfly species were more commonly encountered at burned sites. Only one of these, the Common Wood Nymph (*Cercyonis pegala*) is prairie associated. The Regal Fritillary (*Speyeria idalia*), a highly prairie dependent species listed as a Federal Species of Concern by the U. S. Fish and Wildlife Service, was also encountered more frequently at burned sites. Several less abundant prairie dependent species were more commonly encountered at grazed sites, including several species in the subfamily Hesperiinae, which feed on graminoids in their larval stage.

Patrick Pennarola completed bee surveys on the same 20 prairie remnant sites, and we have hired a University of Minnesota temporary-casual employee, Grace Haynes, to assist with processing insects collected via bowl traps. Preliminary results for bees indicate that while most genera were seen relatively equivalently at grazed and burned sites, there were some differences. Fifteen genera were observed at burned sites, and 21 were observed at grazed sites. Two genera were seen at burned sites exclusively: *Hylaeus,* a solitary, stem-nesting bee, and *Nomada*, a solitary bee that lays its eggs in the nests of other species. Six genera of solitary, ground-nesting bees were observed only at grazed sites: *Calliopsis, Dieunomia, Nomia, Perdita, Sphecodes,* and *Svastra*. Patrick presented preliminary results at a Department of Entomology seminar at the University of Minnesota in December. Patrick and Julia also presented their preliminary results in the Little Lunch on the Prairie Webinar Series, hosted by the MN DNR, and provided a summary handout for all participants.

Amendment Request (2/26/2018): Per our recent update, we are planning two workshops (plant-focused and insect-focused) that begin on the tail end (and in conjunction with) of the MN DNR Native Plant Community training at TNC's Seven Sisters Prairie, June 26-28. In addition to presentations, demos, and hands-on instruction from our group, we invited members of the pollinator research community to participate and present, with the hope that we will reach the needs of a larger audience, and encourage land managers attending the DNR training to stay an extra day for our workshop. We have gotten confirmation from graduate student Ian Lane and post-doc Dr. Erin Trieber from Dr. Dan Cariveau's lab at the University of Minnesota, and National Monitoring Coordinator Laura Lukens from Monarch Joint Venture to contribute. We have around $5300 remaining in travel funds, and would like to extend some of those funds to Ian, Erin, and Laura. This would amount to dorm space for 7 people (including Julia Leone, Patrick Pennarola and myself from our group) for 1 night, meal costs, and either vehicle rental via UMN fleet or mileage on a personal vehicle (with encouragement to carpool). We were able to secure dorm space at UM-Morris at $30/person, substantially less than hotel charges.

In the current budget line item, the travel justification descriptions are associated with field site visits and not workshop travel. This is a request to use our remaining travel funds for workshop travel.

Amendment Approved by LCCMR 3/15/2018

Amendment Request (8/14/2018): In reviewing our final budget, we have $13,348 remaining. However, there is an unanticipated negative balance for Activity 3, and subsequent total personnel balance of -$121. We are requesting to move $121 from our Activity 3 Equipment/Tools/Supplies, current balance $1,474, to Activity 3 personnel to make up for this difference.

Amendment Approved by LCCMR 8/21/2018

Overall Project Outcomes and Results:

August 17, 2018. Without disturbance, Minnesota's tallgrass prairies would transition to woodland and forest. Current management includes prescribed fire and conservation grazing to maintain prairie plant communities, with the assumption that pollinator communities will also benefit. While effects of fire on northern tallgrass prairie are well-documented, information is lacking on effects of conservation grazing on vegetation and insects in Minnesota. To address this knowledge gap we evaluated vegetation, bees, and butterflies on burned or grazed remnant prairies in western Minnesota. Quantitative assessments of plant, bee and butterfly communities were based on randomly placed transects at each site; species lists were augmented by directed searches of the sites.

Of 328 plant species identified, fifty-two were found only on grazed sites and 57 only on burned sites. Mean Coefficient of Conservatism, with values that range from 0 (non-native species) to 10 (species found only on high quality prairie) was 4.1 on burned sites and 3.7 on grazed sites.

Of 40 butterfly species observed, 30 were seen at both burned and grazed sites. Nine of the 40 species are reliant on native prairie. In general, species that were seen at more sites were also more abundant. Common species tended to be more abundant at burned sites and rarer species tended to be more abundant at grazed sites.

To date, 69 species have been identified from over 7,200 collected bees; a few taxonomically challenging specimens are as yet unidentified. Of conservation interest are the 11 species of bumble bees, three of which are listed as "vulnerable" by the IUCN (*Bombus fervidus*, *B. pensylvanicus*, and *B. terricola*).

Burning and grazing favored varying communities of plants, bees, and butterflies, suggesting that each management type has a role in maintaining Minnesota's prairie ecosystems. Results of our research are providing land managers with information necessary for them to be effective stewards of prairie plant communities and the pollinators that depend on them.

IV. PROJECT ACTIVITIES AND OUTCOMES: Overview. Site and graduate student selection will begin in July 2015, or when funds are secured. Research will be conducted over two field seasons. Field teams will be hired in March 2016, and field work will occur during the 2016 and 2017 growing seasons (May – September), with insect identification and statistical analysis during the subsequent fall, winter, and spring seasons. All dissemination vehicles (reports, website and workshops) will be completed by June 2018.

ACTIVITY 1: Identify prairie tracts, collect management histories, assemble GIS layers in preparation for field work.

Description: Because the effects of land management on perennial vegetation can take years to become evident and are in part dependent on variation in abiotic factors, we are using a retrospective approach to assess the relative effects of management by grazing versus fire on tallgrass prairies, prairie dependent pollinators and butterflies, and invasive grasses. The Minnesota DNR, The Nature Conservancy, and the US Fish and Wildlife Service all include conservation grazing and fire in their prairie management strategies and all have expressed a willingness to allow us to study these prairies. During the first 6 months of the project, we will compile a list of prairies from these sources and determine which have complete management histories for at least the past 10 years, with the goal of identifying 75 prairies (see spatial range of our potential study sites in figure 2), approximately half of which have been predominantly managed via grazing and half via fire. Both fire and grazing may be applied in various ways, and these must be taken into account in evaluating their effects. We will gather the following management information about these sites: the years and seasons in which the management was applied, the fire conditions (wind and humidity) on the day of a fire, and the number of animals and length of time they grazed in a given area (animal-unit month, or aum, defined as one 1000-lb cow grazing for 1 month). Additionally, precipitation prior to, during, and following the management action will help us evaluate the fuel load available for a fire or forage available for grazers and the potential for vegetation to recover following a management action.

For each prairie, we will compile landscape information including size; distance and connectivity to nearest remnant; soil types within the prairie boundaries; proportion of prairie, cropland, pasture, Conservation Reserve Program, wetland, riparian, or other land uses in a 10-km wide buffer around the prairie; and mean temperature and total precipitation during each growing season over the past 10 years.

Summary Budget Information for Activity 1:	**ENRTF Budget:**	**$ 91,809**
	Amount Spent:	**$ 91,809**
	Balance:	**$ 0**

Outcome	**Completion Date**
1. GIS map layers for each prairie tract	May 2016
2. Spreadsheet of management actions and dates for each prairie tract	May 2016

Activity Status as of *January 2016***:** As of January 2016, we have obtained GIS shapefiles and management histories from prairie remnant tracts in the Morris and Litchfield Wetland Management Districts (federal) and a list of prairie remnants recommended by the MN DNR with associated management histories. We will randomly select a subset of these remnant tracts to study within 3 geographic areas in the Prairie Parkland Province, to maximize time spent at each site, and minimize travel time between sites. Based on work up to now, our limitation will be obtaining enough sites with grazing histories that span 10 years, because conservation grazing is a relatively new management method for many state and federal land managers, often less than 5 years. Morris has the greatest number of conservation grazing sites thus far, but we will continue to contact private land managers based on sites recommended by the MN DNR.

Activity Status as of *July 2016***:** Since January 2016, we discovered that the majority of our graze-only sites reside within the Morris Wetland Management District boundaries, with only a handful of privately-owned sites residing outside these boundaries. Due to this limitation, and in rethinking our plan for data analyses, we decided to pair sites of similar size and soil drainage class (as a proxy for wet, mesic or dry prairie type) within individual wetland management districts, instead of randomly selecting sites in 3 geographic areas as stated above. As we receive management data from privately-owned graze-only sites (fence lines, rotation information), we will select the remainder of our burn only sites for comparison, based on area and prairie type.

Activity Status as of *January 2017***:** Since July 2016 we paired 27 graze-only sites with 27 burn-only sites of similar area and prairie type. Because there were remnant areas for which the native plant community had not yet been determined, we used Natural Resources Conservation Service soil drainage class data as a proxy for prairie type. To obtain our 75 site goal, we randomly selected burn-only sites from the remaining pool of available remnant tracts. The area, prairie type, and year of management action have been documented in an Excel spreadsheet for paired sites, and for additional sites visited in 2016. This information for remaining sites to be visited will be cataloged prior to the 2017 field season.

Activity Status as of *July 2017***:** Not required per notice from LCCMR staff.

Activity Status as of *August 15, 2017***:** Since January 2017, we have obtained area, prairie type, and management action boundaries for the sites visited in 2017. This information has been added to the existing Excel database, and we will check all entries for accuracy following the completion of the 2017 field season.

Activity Status as of *January 2018***:** Since the August 15 update, we worked with land managers to obtain stocking rates for our grazed sites, and climate data surrounding burn dates for the last 10 years (https://www.ncdc.noaa.gov/cdo-web/datatools). We added this data to our Excel database, and uploaded it for analysis onto a server hosted by the Bee Lab at the University of Minnesota. The remnant prairies chosen for our study range in size from 1.13 hectares to 144.7 hectares, with a median area of 10.6 hectares. Of the 27 grazed sites, 17 are managed by Morris WMD and the remainder are privately owned and managed. Privately owned sites were grazed every year over the 10 year period from 2005-2010, whereas sites managed by Morris WMD were grazed on average in 3.3 years over the same 10 year time period. Privately grazed sites also had greater stocking rates compared to Morris WMD grazed sites, 1.4 AUM/acre and 0.95 AUM/acre, respectively, averaged over all sites and years grazed. In comparison, all burned sites were owned and managed by the MN DNR, TNC or Morris WMD. These remnants were burned in 1.5 years over the 10 year period, averaged across all sites and years.

Final Report Summary: Starting in 2015, we selected 73 remnant prairie sites that had been exclusively burned or grazed for management between 2005 and 2015. During the summers of 2016 and 2017, we performed vegetation surveys at these sites, with pollinator surveys occurring on a subset of 20 sites (see Activity 3). Twenty-seven of the sites were graze-only, 46 sites were burn-only. We worked with private landowners (10 sites) and multiple agencies including The Nature Conservancy (TNC, 6 sites), US Fish and Wildlife Service (51 sites), and the MN Department of Natural Resources (8 sites) to obtain management histories for each of our chosen field sites; two sites were co-managed by TNC and MN DNR. Because records at Morris WMD indicated that some remnants had not yet been mapped by MN DNR, we used soil drainage class from Natural Resources Conservation Service (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) as a proxy for wet, mesic, and dry prairie. The vegetation of a selected management area within a given site was sampled in proportion to the area of the three prairie types, on transects that were randomly placed along elevation gradients prior to field sampling to prevent bias.

Landscape surrounding a given site may have a positive or negative impact on remnant prairie vegetation and insects, depending on its composition and the ability of remnant prairie inhabitants to utilize it. We created a 1.5 km buffer (note: we determined that our originally stated 10 km buffer was too large to reflect biological processes at the sites) surrounding each of our field sites using ArcMap 10.5.1 and determined percent land use within each buffer using USDA CropScape data layers from 2017, MN DNR native and RIM (Reinvest In Minnesota) data, and South Dakota State University potentially undisturbed land (PUDL) layers (Figure 2). We then summarized the land cover data into the following categories as a percent of the total land area: non-flowering crop, flowering crop, developed, forest, native prairie, prairie, RIM prairie, PUDL prairie, open space, water, and wetland (Table 1.1). All land cover information has been added to our site database table. Across all sites, percent cropland (flowering and non-flowering combined) occupied the greatest total land cover (46.75%), while prairie (native prairie, prairie, RIM prairie, and PUDL prairie combined) occupied 20.68%. Grazed site buffers contained a greater percent of native prairie, compared to burned sites (11.64% and 8.09%, respectively).

Table 1.1 Definitions of land cover types.

Category	Definition
non-flowering crop	crop lacking showy flowers (e.g., wheat, corn), as defined by USDA
flowering crop	crop with showy flowers (e.g., soybeans, sunflowers), as defined by USDA
developed	areas with a mixture of some constructed materials; impervious surface cover ranges from 20%-100%, as defined by USDA
forest	area with trees cover constituting great than 20% of the vegetation cover, as defined by USDA
native prairie	remnant prairie, as mapped and defined by either MN DNR or USFWS
prairie	grass/pasture, as defined by USDA
RIM prairie	Reinvest in Minnesota, prairie easements, as defined by MN DNR
PUDL prairie	Potentially Undisturbed Land, as defined by SDSU
open space	can include barren space, idle cropland, shrubland, as defined by USDA
water	open water, as defined by USDA
wetland	herbaceous and woody wetlands, as defined by USDA

Lastly, we calculated departure from the 30 year normal for growing season (May-September) precipitation (mm) and maximum daily temperature (°C) for each of the years 2005-2015 in which management occurred, and for the years in which we sampled (2016-2017; Figures 3a and 3b). We accessed the National Oceanic and Atmospheric Administration climate data at: https://www.ncdc.noaa.gov/cdo-web/datatools/.

We expect to publish at least two peer-reviewed articles that will incorporate landscape and climate data with our vegetation, bee, and butterfly survey data. All data will be made available to the public via ScienceBase (www.sciencebase.gov) upon publication of the manuscripts.

ACTIVITY 2: Compare effects of grazing and fire on native plant species richness and composition and abundance of invasive grasses [Kentucky bluegrass (*Poa pratensis*), reed canarygrass (*Phalaris arundinacea),* smooth brome (*Bromus inermis*)].
Description: Using the prairies identified in Activity 1, we will conduct surveys to assess native plant species richness (both forbs and grasses), and exotic grass cover. The prairies we sample will vary in size, perhaps substantially. Because we want to compare species richness, which increases with area sampled, yet we do not want to miss rarer species, we will use a two-tiered approach. First, we will conduct prairie surveys during June -

September to estimate vegetative cover by species and total species richness of vegetation. We will stratify our sampling so that all potential vegetation types (wet, mesic, and dry) are sampled. In addition to the random transects, a time-constrained botanist-directed walk will be done at each polygon to search for plant species not found in the transect plots. This will yield a more complete species list than the random design for assessing presence of uncommon or rare species. Within each polygon we will collect and combine three soil samples collected at random points to assess soil nitrogen dynamics. We will conduct vegetation surveys at least once at all of the prairies over the two field seasons, with surveys repeated on a random subset of 25% in both years to assess variation due to sample year; dramatic changes in species composition are not expected, but there may be differences in detection of some rarer species. These data will allow us to relate native plant species richness and abundance of invasive grasses to management history and grazing intensity, while taking into account nitrogen dynamics, and soil and landscape characteristics. We hypothesize that there will be a strong relationship between management strategies and the plant composition of the prairie tracts.

Summary Budget Information for Activity 2:

ENRTF Budget:	**$ 164,096**
Amount Spent:	**$ 156,316**
Balance:	**$ 7,780**

Outcome	**Completion Date**
1. Preliminary analysis of first field season completed; status report sent to cooperators.	May 2017
2. Data analysis from both field seasons completed	December 2017
3. Information dissemination via web site, workshops, and fact sheet	June 2018

Activity Status as of *January 2016***:** This activity has not yet occurred. Our first field season will be May-September, 2016.

Activity Status as of *July 2016***:** We are currently mid-season in vegetation sampling; our field season began in early-June, and will continue through August 2016. Because estimation of cover can vary substantially among individuals, we decided to use nested plot frames, in which the vegetation only need be identified, and the section of the plot frame in which a species is found recorded. Our botanists are also doing a time-constrained walk to search for plant species not found in nested plots along the transect. The order in which the sites are being sampled is randomized, and we hope to sample at least 2/3 of the total sites in 2016.

Activity Status as of *January 2017***:** We completed vegetation surveys on 43 of the 75 total prairie remnant sites using nested plot frames and botanist-directed walks. The number of plots per site was scaled according to area, with no more than 30 plots in a given site. Data from the 2016 field season has been entered, with quality assurance/quality control ongoing. Botanists for the 2017 field season will re-visit the 20 remnant sites in which native bees and butterflies have been surveyed, along with the remaining 32 sites not yet visited.

Activity Status as of *July 2017***:** Not required per notice from LCCMR staff.

Activity Status as of *August 15, 2017***:** To date we have completed vegetation surveys at the 20 remnant sites chosen for bee and butterfly surveys, and surveys at the remaining remnant sites will be complete by the end of the 2017 field season. Data entry from 2017 has started, and our botanists (Madison Rancour and Larissa Mottl) have been meticulously reviewing data sheets to ensure accuracy.

Activity Status as of *January 2018***:** Our vegetation surveys for 2018 are complete and all data have been entered and error-checked for accuracy. Data analysis for vegetation surveys will be completed this winter, following assessment of our 2017 field season soils collected for texture and nitrogen. Soil texture is currently being analyzed at the University of Minnesota Research Analytical Laboratory.
Preliminary qualitative results show that at burned sites, plant species indicators included only native species, including common milkweed, Maximillian sunflower, and blue lettuce in 2016, and giant sunflower, prairie

dropseed, and balsam groundsel in 2017, among others. Grazed sites showed a mixed result of both native and non-native plant indicator species. Native species in both 2016 and 2017 included swamp verbena and field pussytoes. Introduced indicator species found in both years at grazed sites included spiny plumeless thistle, common plantain, and white clover. Indicator species for the grazed sites were generally weedier and less conservative than those for burned sites. This was also reflected in multivariate projections of the vegetation. We will disseminate results of our vegetation surveys in a webinar hosted by the Prairie Reconstruction Initiative on March 13, 2018, as well as a workshop and field day associated with the MN DNR Native Plant Community Training June 27-28, 2018.

Final Report Summary: Vegetation lies near the base of the prairie food web and we evaluated the direct effects of fire and grazing management on it. Direct effects on vegetation have implications for managers' goals, such as reduction of noxious or undesirable species. Any changes in vegetation as a result of management also have the potential to influence higher trophic levels, including the pollinators investigated in Activity 3. Sample site selection and transect location methods are described in Activity 1. To sample vegetation, we assessed frequency of each species on 0.5 x 2m plots located on the transects (SOP 1). Frequency of each species encountered is expressed as the proportion of plots occupied out of the total number of plots at a site, which varied with the size of the site. For vegetation sampling, we separated sites into prairie type (dry, mesic, or wet) because we expect moisture to be a strong predictor of vegetative community composition. Number of site-by-prairie type polygons (hereafter "polygons") sampled can be found in Table 2.1.

Both smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) were widely distributed across our study polygons and occupied a large proportion of the plots on each polygon where they occurred (Table 2.2). Reed canarygrass (*Phalaris arundinacea*) did not occur on dry polygons, but occupied more than half of all wet polygons under both burned and grazed management (Table 2.2). Phragmites (*Phragmites australis*) occurred uncommonly, and only on wet polygons. Both leafy spurge (*Euphorbia esula*) and plumeless thistle *(Carduus acanthoides*) were rarely encountered. Canada thistle (*Cirsium arvense*) was commonly encountered on both burned and grazed polygons, with the exception of grazed dry, where it was not found (Table 2.2).

Plant species richness (standardized to the total number of unique species observed on four plots/polygon as determined by species accumulation curves) averaged 24.6 (range 23.0 species on dry polygons to 24.9 species on wet polygons, with mesic intermediate) on burned sites and 24.4 (range 24.2 on wet polygons to 25.0 on dry polygons, with mesic intermediate) on grazed sites. Coefficient of conservatism (C) is a measure of how characteristic species are of high quality prairie, ranging from 0 (non-native species) to 10 (species only observed on high quality prairie). Mean C averaged 4.1 on burned sites (range 3.8 on wet polygons to 4.3 on mesic polygons, with dry intermediate) and 3.7 on grazed sites (range 3.7 on wet polygons to 4.0 on dry polygons, with mesic intermediate).

Nitrogen mineralization and net nitrification describe how quickly nitrogen is cycling through the system, with slower rates typical of higher quality remnant prairie. Nitrogen mineralization rates at burned sites averaged 2.05 µg N/g soil/day (range 1.53 on dry polygons to 2.48 on wet polygons) and at grazed sites averaged 2.13 µg N/g soil/day (range 1.27 on dry polygons to 2.59 on wet polygons). Net nitrification rates at burned sites averaged 2.23 µg N/g soil/day (range 1.71 on dry polygons to 2.70 on wet polygons) and at grazed sites averaged 2.31 µg N/g soil/day (range 1.39 on dry polygons to 2.79 on wet polygons). Soil bulk density (the weight of soil/volume) increases with compaction, which might occur when livestock repeatedly trample an area. Average bulk density at burned sites was 0.84 g/cm^3 (range 0.77 at wet polygons to 0.91 at mesic polygons) and at grazed sites the average was 0.97 g/cm^3 (range 0.80 at wet polygons to 1.15 at dry polygons).

We shared our results via a Prairie Reconstruction Initiative-sponsored webinar on March 13, 2018, a demonstration of monitoring methods as part of a DNR plant identification field workshop at Seven Sisters Prairie on June 27, 2018, and as part of the field day workshop we organized at one of our study sites, Overby WPA, on June 28, 2018. We expect to publish at least two peer-reviewed articles that will synthesize vegetation, bee, and butterfly data, and the data will be made available to the public via ScienceBase (www.sciencebase.gov), a repository for data and metadata.

In summary, grazing and fire produced similar native species richness and composition. Of the three invasive species of concern, *Poa pratensis* was slightly more common on grazed sites, where its average frequency was 0.86, versus burned sites, where its frequency was 0.75. With regard to publications, the vegetation data will mainly be used to support the bee and butterfly papers. However, there is the possibility of a stand-alone paper after a more detailed look at vegetation differences.

Table 2.1 Number of sampled polygons by management type and prairie type

Prairie type	Burned	Grazed
Dry	3	5
Mesic	36	23
Wet	33	19

Table 2.2 Proportion of site x prairie type map polygons and proportion of plots within map polygons occupied by problematic and noxious plant species. *Phalaris arundinacea* was not encountered in dry polygons and *Phragmites australis* was only encountered on wet polygons.

		Proportion of polygons occupied[1]		**Proportion of total plots occupied/polygon**[2]	
Species	**PrairieType**	**Burned**	**Grazed**	**Burned**	**Grazed**
Bromus inermis	Dry	1.00	0.80	0.68	0.71
	Mesic	0.94	0.83	0.77	0.81
	Wet	0.79	0.84	0.48	0.53
Carduus acanthoides	Dry	0	0.20	0	0.50
	Mesic	0.06	0.26	0.10	0.11
	Wet	0	0.05	0	0.50
Cirsium arvense	Dry	1.00	0	0.33	0
	Mesic	0.81	0.52	0.37	0.30
	Wet	0.79	0.79	0.51	0.37
Euphorbia esula	Dry	0.33	0.20	0.09	0.50
	Mesic	0.03	0.09	0.07	0.38
	Wet	0.06	0	0.06	0
Phalaris arundinacea	Mesic	0.33	0.26	0.13	0.23
	Wet	0.79	0.53	0.35	0.29
Phragmites australis	Wet	0.03	0.05	0.20	0.04
Poa pratensis	Dry	1.00	1.00	1.00	0.97
	Mesic	1.00	1.00	0.88	0.93
	Wet	0.91	1.00	0.65	0.80

[1] Proportion refers to the presence of the species on at least one plot within a map polygon of the Prairie Type.
[2] Proportion refers to the average of plots occupied per Prairie Type polygon. For example, *Bromus inermis* occurred in all burned, dry polygons and occupied on average 0.68 of the plots per burned, dry polygon.

ACTIVITY 3: Compare effects of grazing and fire on pollinator species richness.

Description: We will conduct bee and butterfly surveys on a subset of 20 randomly-selected prairies (10 with primarily fire and 10 with primarily grazing management histories) which will be sampled in both years, due to known year-to-year variation in insect abundance and species composition.

Bees will be surveyed in two ways, passively via bowl and glycol traps, and actively, via netting. We will conduct these surveys three times per summer (June 1-August 31) at each of the 20 sites. We will use standard 3.25 oz plastic bowls in three colors (white, yellow, and blue) placed at 5-m intervals along the same transects as used for the vegetation surveys (above). The bowls will be filled with soapy water, placed on the ground, and left in place for 24 hours. All insects captured on a transect will be placed in a single whirlpack bag and kept in a cooler until they can be dried and pinned. Glycol traps, which can be left out for a week or more at a time, will be deployed in concert with the butterfly "citizen science" surveys described below and will allow us to expand our number of sampled sites. Pollinators also will be netted during time-constrained walks (timing proportional to the size of the site) through each site to better reflect all the species present on the site. These insects will be placed individually into glassine envelopes and the flower species upon which they were captured, the site, and the date will be recorded on the envelope. Envelopes will be placed in kill jars charged with ethyl acetate, except for bumblebees, which can be identified in the field and released. Insects will be pinned and the information on the envelope will be transcribed and linked to the specimen by an ID number.

Butterflies can usually be identified non-destructively, so we will assess their presence and abundance in specific survey locations, using the transects identified for the vegetation surveys and conducting the surveys during the same visits that we survey the bees (confining our surveys whenever possible to days that are at least 70 °F and with low wind). We will use protocols adapted from those proposed by Pollard (1977), and used by several North American Butterfly Monitoring Networks (see www.nab-net.org). Briefly, observers walk the transect and record all butterflies seen within 6 meters of the census route. When necessary, butterflies will be netted for identification, and released. When feasible, we will work with existing or new citizen science programs (e.g., those organized by the North American Butterfly Association, Bumble Bee Watch, and the Minnesota Bee Atlas currently being considered by the LCCMR for 2015 funding) to engage the public in our butterfly and bee surveys, after training them in survey protocols and identification. This engagement will both increase our capacity to conduct these time-consuming surveys (and perhaps allow us to add more survey sites in the second year), and will result in more dissemination. Our analyses will allow us to assess both the indirect effects of management on pollinator communities (through effects on the plant communities) and direct effects (e.g., killing some insects during burns, disturbance by grazing). We hypothesize the indirect effects will be greatest, but that high fire frequency or grazing intensity could have direct effects on pollinator diversity and abundance.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 158,095
Amount Spent: $ 152,298
Balance: $ 5,567

Outcome	Completion Date
1. Preliminary analysis of first field season completed; status report sent to cooperators.	May 2017
2. Data analysis from both field seasons completed; list of pollinator species sent to cooperators	December 2017
3. Information dissemination via web site, workshops, and project summary sheet	June 2018

Activity Status as of *January 2016*: This activity has not yet occurred. Our first field season will be May – September, 2016.

Activity Status as of *July 2016*: Bee and butterfly surveys are currently underway on a subset of 20 remnant prairie sites (10 burned, 10 grazed). Bees are being sampled by bowl traps along the same transects being used to assess vegetation, and also by netting throughout the remnant polygon during time constrained walks, as listed above. We have made every effort to ensure that we are not duplicating bee sampling efforts; Crystal

Boyd (MN DNR) is using bowl traps at Glynn Prairie SNA, and is allowing us to use her data. Butterflies are being non-destructively sampled, when possible, along 400 meters of the same transects being used for bee and vegetation sampling using Pollard walks, as listed above. No insect collection is taking place where Dakota skippers have been previously sighted, so our northern most sites in the Felton Prairie complex will only have vegetation sampling.

Activity Status as of *January 2017***:** Native bee and butterfly surveys took place on a subset of 19 of the remnant sites. One site was not visited due to lack of access, but is still scheduled for surveys in 2017. Each site was visited 3 times during the field season, along randomly located transects. Bees were sampled by bowl traps along the random transects as well as directed netting. Butterflies were sampled using Pollard walks along the same transects, and via an opportunistic walk to increase species list for each site. Julia Leone has entered all of the data from her butterfly surveys and performed preliminary analyses. Patrick Pennarola has pinned the approximately 300 netted specimens, and identified the bumble bees. Identification of the remaining netted specimens, along with processing and identification of the bowl trap specimens will be ongoing through the winter.

Activity Status as of *July 2017***:** Not required per notice from LCCMR staff.

Activity Status as of *August 15, 2017***:** Native bee and butterfly surveys are currently underway for the 2017 field season. Julia Leone and Patrick Pennarola chose another grazing remnant site (from the pool of available sites) to replace the site for which we lacked access in 2016. They are on schedule to complete three site visits at each site during the 2017 field season, along the same randomly located transects as those used in 2016. Identification of netted bee specimens, along with processing and identification of the bowl trap specimens will be ongoing through the winter. Data entry for both bees and butterflies will continue at the end of the 2017 field season.

Activity Status as of *January 2018***:** Julia Leone and Patrick Pennarola successfully completed native butterfly and bee surveys at the subset of 20 sites chosen to survey insects. Each site was visited 3 times between May-August 2017. Julia has completed data entry, and preliminary analyses. A total of 38 species were observed during 2016 and 2017 surveys. Thirty of these species were observed at both management types. Four species were seen only at sites managed with fire and four species were seen only at sites managed with grazing. Of the species seen only at grazed sites, two of these are prairie dependent - *Coenonympha tullia* and *Polites themistocles*. One of the species seen only at burned sites, *Atrytone arogos*, is also highly dependent on prairie. Six of the eight species seen only at one management type had fewer than 5 observations each, indicating that these species have very low abundances or are difficult to detect.

Patrick has pinned and identified all hand-netted bees to genus, and is working with Grace Haynes to process the thousands of specimens collected via bowl traps. They have completed processing 2016 specimens and are working through 2017 specimens. The genus *Bombus* (bumble bees) was the most widely distributed genus, seen at all but one of our 20 sites. *Apis* (honey bees) and *Melissodes* (a genus of long-horned bees) were both seen at 18 sites. Two genera of sweat bees, *Augochlorella* and *Lasioglossum*, were also widely distributed, being present at 16 and 15 sites, respectively. While abundance data is not yet available, it is clear from the samples that have been processed that these two genera will be among the most abundant.

Updates for both bee and butterfly surveys were sent to our cooperators, as required by each agency. Patrick and Julia also presented in the "Little Lunch on the Prairie" webinar series in November, hosted by the MN DNR, and provided a summary sheet to all participants. They are on track to present in a Prairie Reconstruction Initiative webinar on March 13, as well as at a workshop and field day in conjunction with the MN DNR Native Plant Community training June 27-28.

Final Report Summary:

Note: Due to the departure of Karen Oberhauser, we did not pursue Citizen Science methods for the butterfly and bee sampling. None of us had the necessary expertise to implement a Citizen Science protocol and we were able to achieve our objectives without employing Citizen Scientists.

Butterfly sampling methods:
Methods for site selection and transect delineation are described in Activity 1. Butterfly surveys took place 3 times at each site during the summers of 2016 and 2017. Adult butterflies were surveyed using a standardized Pollard Walk for relative abundance, during which we walked a 400m transect on each site visit at a steady pace of 10m/minute and recorded all individuals seen within a 5m square in front. An observation walk was used to supplement the species list at each site (not used for abundance analyses). Butterflies were primarily sight identified or captured, identified, and released. Voucher specimens were collected and have been deposited in the University of Minnesota Insect Collection.

Butterfly analysis methods:
Butterfly abundance and richness are being assessed using Poisson distributed generalized linear mixed effects models in R version 3.4.1. Abundance and richness are the response variables, and management type the primary predictor of interest. Because each of our 20 insect survey sites were visited three times each summer, site will be included as a random effect. Vegetation variables such as plant species richness, forb frequency, and graminoid frequency will be included to assess the direct vs. indirect effects of management on butterflies. An indirect effect of management on butterflies can be rephrased as a direct effect of management on the vegetation community, and is described further in Activity 2. A direct effect of management is likely when management type explains additional significant variation in butterfly species richness and abundance even after any vegetation variables in the model have been accounted for. Additional variables of interest are being considered in model selection (e.g. site area, percent native prairie in a 1.5 km buffer around the site, year).

Butterfly Species Richness: Forty butterfly species were observed over both years, 30 of which were seen at both burned and grazed sites. Nine of the 40 observed species were prairie dependent or prairie associated. These are species that rely on the native prairie as their primary habitat. Some, like the Arogos skipper (*Atrytone arogos*), are considered highly dependent on remnant prairie. Others, like the Common Wood Nymph (*Cercyonis pegala*), are often considered to be dependent on grasslands in general. They are treated as prairie associated species in our study because many experts agree that they could not persist in the Minnesota landscape matrix without remnant prairie. Ten species were observed at sites managed with only one management type. Of these butterfly species that were management-specific, five were seen only at grazed sites and five were seen only at burned sites. Of the prairie associated species, 8 were seen at grazed sites and 7 at burned sites. Many of these were seen in very low abundances.

Butterfly abundance: More butterfly individuals were seen at burned sites than at grazed sites, although this differed by species. Two species of interest, the Regal Fritillary (*Speyeria idalia,* a Minnesota Species of Concern) and the Monarch (*Dannaus plexxipus*) were seen more frequently at burned sites. The prairie associated Long-Dash skipper (*Polites mystic*) and Tawney-edged skipper (*Polites themistocles)*, both of which feed on grasses during their larval stages, were encountered more often at grazed sites. Overall butterfly abundance was similar in 2016 and 2017. In general, species that were seen at more sites were also more abundant. Common species tended to be more abundant at burned sites and rarer species tended to be more abundant at grazed sites.

In summary, butterfly species richness was similar, but composition differed between grazed and burned sites; butterfly abundance was higher at burned sites than at grazed sites (Figures 4a and 4b).

Products: Results for Activity 3 have been shared during a Prairie Reconstruction Initiative-sponsored webinar on March 13, 2018, as part of the field day workshop we organized at one of our study sites, Overby WPA, on June 28, 2018, and at several professional meetings including the North Central Branch Entomological Society of America (NCB-ESA) on March 19, 2018, the joint meeting of the Lepidopterists' Society and Societas Europaea

Lepidopterologica on July 13, 2018, and the North American Congress for Conservation Biology on July 23, 2018. An additional paper will further describe the influence of species traits and environmental characteristics on prairie butterfly occupancy using the model-based fourth-corner solution proposed by Brown et al. in their 2014 paper in Methods in Ecology and Evolution. Manuscripts for the butterfly work are currently in preparation; Julia is submitting an abstract this month for the monarch issue of Frontiers in Ecology and Evolution.

Bee sampling methods:
We conducted bee surveys 3 times at each site during the summers of 2016 and 2017 using two methods - passive trapping and active netting. Bowl traps are a highly replicable means of collecting bees over a period of time, with little-to-no observer bias. Bowls were placed along the same transects as outlined in Activity 1, starting at a randomly selected end point. Bowls were divided among transects in wet, mesic, and dry prairies proportionally to the amount of the area of each type present at the site. However, not all bees are attracted to standard bowl traps. Therefore, we accompanied traps with directed netting to round-out species lists and provide a more accurate view of species richness when combined with bowl data. Bees were only collected while visiting flowers, to account for detection biases. Specimens will be deposited at the University of Minnesota Insect Collection.

Although glycol traps had been considered as a sampling device, we ultimately abandoned that plan due to concerns about their attractiveness to cattle and logistics of their deployment.

Bee abundance:
Approximately 12,300 bees were collected in bowl traps in 2016 and 2017. We are analyzing these data using Poisson distributed generalized linear mixed effects models in R 3.2.4. Bee abundance is the response variable. Management type, forb frequency, and the proportion of sand in soils were chosen as predictors of bee abundance due to research questions. To account for experimental design and effort, site area, calendar day, year, the number of bowl traps retrieved, and the total time for which bowls were deployed, these are also included as predictor variables. Site is treated as a random variable within the model.

Bees were collected in similar quantities between management types, with approximately 5,900 individuals at burned prairies and 6,400 individuals at grazed prairies. Year-to-year variation was much larger, with 3,500 bees collected in 2016 as compared to 8,700 bees collected in 2017. While species identification is not yet complete, we have sufficient abundance data to conclude that management type itself does not significantly affect total abundance.

Bee species richness:
Patrick worked with Sam Droege to determine species-level identifications for the bees collected in this study. We are currently less than 200 bees away from identifying all ~13,000 specimens. As of this writing, sixty-nine species have been identified from over 7,200 bees, which accounts for ~60% of individuals collected. This includes 11 species of bumble bees, three of which are listed as “vulnerable” by the IUCN (*Bombus fervidus*, *B. pensylvanicus*, and *B. terricola*). The northern amber bumble bee (*B. borealis*) was found predominantly at burned sites, whereas the black-and-gold bumble bee (*B. auricomus*) was found predominantly at grazed sites. The recently listed rusty patched bumble bee (*B. affinis*) was not detected during the course of this survey.

Most of the remaining ~40% are from a single difficult genus (*Lasioglossum*) and most are likely to represent species already identified. However, there are also several dozen bees that are likely highly diverse, and represent species not yet identified in this study. We are seeking expert taxonomic guidance on these specimens. Therefore, the number of species collected may increase.

We will use a similar model as that described above for butterflies to analyze the response of bee species richness to management type. We will also include terms controlling for the effort of the directed netting, as the timing of meandering walks varied due to site size and occasionally weather conditions.

Products: Results for Activity 3 have been shared during a University of Minnesota Entomology Department seminar on December 5, 2017, a Prairie Reconstruction Initiative-sponsored webinar on March 13, 2018, and as part of the field day workshop we organized at one of our study sites, Overby Waterfowl Production Area, on June 28, 2018. As mentioned in Activity 1, we expect to publish at least two peer-reviewed articles that will synthesize vegetation, bee, and butterfly data, and the data will be made available to the public via ScienceBase (www.sciencebase.gov). Patrick will be spending fall of 2018 finishing his graduate thesis. This will directly contribute to future manuscripts, as two chapters will be written with publication in mind. The analyses and interpretations of bee data may be published separately or in concert with butterfly data.

V. DISSEMINATION:

Description: Our deliverables will include 1) written materials, 2) a website, and 3) workshops. Written materials will be targeted to both managers and the general public in the form of manuscripts in the published literature and a management-oriented handout that will be disseminated at workshops, through partners, and via a project website. The website will be hosted on the University of Minnesota Extension website, and linked to the Northern Prairie Wildlife Research Center (if permitted), as well as to relevant butterfly and bee citizen science projects. We will highlight the engagement of citizen scientists when relevant.

Many organizations in Minnesota work on prairie conservation, and we will use our connections with these organizations (including Minnesota chapters of The Wildlife Society and The Prairie Enthusiasts, The Nature Conservancy, the Minnesota DNR, and the US Fish and Wildlife Service) to plan and conduct at least 3 workshops for interested land managers throughout the state in late 2017 and early 2018). At these workshops, we will provide managers with a framework for designing a disturbance regime that will achieve their management goals for prairie plant and pollinator diversity. While our research will focus on remnant prairies, our findings will also be relevant to management of restored prairies, and we will thus not limit dissemination to managers of remnant prairies. By soliciting managers' input during site selection, we can capitalize on their continued interest and involvement in the study to ensure that the results are put to use. The continued involvement of USGS and University of Minnesota personnel with Minnesota land managers, along with audience-appropriate dissemination vehicles, will ensure access to these results in the long-term. All dissemination products and activities (reports, manuscripts, website and workshops) will be completed by June 2018.

Status as of *January 2016***:** This activity has not yet occurred.

Status as of *July 2016***:** This activity has not yet occurred.

Status as of *January 2017***:** This activity has not yet occurred.

Status as of *July 2017***:** Not required per notice from LCCMR staff.

Status as of *August 15, 2017***:** This activity has not yet occurred.

Status as of *January 2018***:** To increase our project visibility with the management community, we have focused on seeking opportunities with maximum potential participation. The webinar presented by Julia Leone and Patrick Pennarola in November 2017 was well attended by personnel from MN DNR, US FWS, Minnesota Board of Water Resources, USGS, Minnesota Zoo, Audubon MN, and MN Soil and Water Conservation Districts, among others, and followed by a question-answer period. We will be presenting in an additional webinar hosted by the Prairie Reconstruction Initiative on March 13, 2018. Our workshop and field day are scheduled for June 27-28, in conjunction with the MN DNR Native Plant Community Training. By incorporating our workshop and field day with this training, we are increasing the likelihood of contact with land managers that will already be near many of our field sites. Plans are in place to create a website, hosted by USGS Northern Prairie Wildlife Research Center (www.npwrc.usgs.gov), and link it to the Monarch Joint Venture (https://monarchjointventure.org/) and cooperator sites. Manuscripts and a U.S.G.S. Fact Sheet will be forthcoming, pending required data and metadata review and archiving and manuscript review by U.S. Geological Survey, following their Fundamental Science Practices.

Final Report Summary:

1. January 27, 2015, Pollinators and Habitat World Café Workshop: we coordinated a world café style workshop for researchers from UMN, MN DNR, Carleton College, MN Zoo, and TNC to discuss vegetation and insect sampling procedures, research objectives, data and specimen management, and personnel. This workshop provided across-agency networking to share ideas on how to collectively improve research methods with regard to insect and vegetation sampling.
2. November 3, 2015, LCCMR Pollinator Projects Update Meeting: Effects of Grazing Versus Fire for Prairie Management. Presenters: Diane Larson, U.S. Geological Survey, Karen Oberhauser, University of Minnesota, Jen Larson, University of Minnesota. Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Julia Leone, University of Minnesota, Conservation Biology Graduate Program
3. December 7, 2016, LCCMR Pollinator Projects Update Meeting: Effects of Grazing Versus Fire for Prairie Management. Presenters: Jen Larson, University of Minnesota, Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Diane Larson, U.S. Geological Survey, Karen Oberhauser, University of Minnesota.
4. January 31, 2017, Society for Range Management: Pollinator Symposium: Effects of Grazing vs. Fire on Community Composition of Butterflies in Minnesota Remnant Prairies. Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Diane Larson, U.S. Geological Survey, Karen Oberhauser, University of Minnesota, Jen Larson, University of Minnesota
5. April 18, 2017, University of Minnesota Entomology Department Thesis Proposal seminar, What mechanisms are driving butterfly community composition in Minnesota tallgrass prairie? Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program
6. July 31, 2017, Meeting of the Lepidopterists' Society: Effects of Grazing vs. Fire on Community Composition of Butterflies in Minnesota Remnant Prairies. Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program, Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Diane Larson, U.S. Geological Survey, Karen Oberhauser, University of Minnesota, Jen Larson, University of Minnesota
7. October 8, 2017, Washington Island Art and Nature Center talk: Notes from the Field: butterfly surveying tales and techniques. Julia Leone, University of Minnesota, Conservation Biology Graduate Program
8. November 28, 2017, Conservation Sciences Brown Bag Lunch Seminar: Effects of fire. vs. grazing on tallgrass prairie butterflies: Plans and Progress. Julia Leone, University of Minnesota, Conservation Biology Graduate Program
9. November 30, 2017, Little Lunch on the Prairie webinar: To Burn or to Graze: Effects on Minnesota Remnant Prairie Plants and Pollinators. Presenters: Julia Leone, University of Minnesota, Conservation Biology Graduate Program, Patrick Pennarola, University of Minnesota, Entomology Graduate Program. Co-authors: Diane Larson, U.S. Geological Survey, Jen Larson, University of Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
10. December 5, 2017, UMN Entomology Department seminar: Burning v. grazing: How does the form of disturbance drive patterns in prairie bee diversity? Presenter: Patrick Pennarola, University of Minnesota, Entomology Graduate Program
11. March 9, 2018, LCCMR Pollinator Projects Update Meeting: Effects of fire vs. grazing management on remnant tallgrass prairie plants and pollinators. Presenters: Julia Leone, University of Minnesota, Conservation Biology Graduate Program, Patrick Pennarola, University of Minnesota, Entomology Graduate Program. Co-authors: Diane Larson, U.S. Geological Survey, Jen Larson, University of

Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
12. March 13, 2018, Prairie Reconstruction Initiative (PRI) webinar: To Burn or to Graze: Effects on Minnesota Remnant Prairie Plants and Pollinators. Presenters: Diane Larson, U.S. Geological Survey, Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Jen Larson, University of Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
13. March 19, 2018, North Central Branch Entomological Society of America (NCB-ESA) Meeting, Madison, WI: To graze or to burn? Effects of management on Minnesota tallgrass prairie butterflies. Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Diane Larson, U.S. Geological Survey, Jen Larson, University of Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
14. June 27-28, Prairie Vegetation and Insect Monitoring Workshop: Effects of grazing versus fire for prairie management, Swelstad Bison Ranch and Overby WPA. Diane Larson (USGS) and Jen Larson (UMN) gave a vegetation monitoring methods demonstration, following the MN DNR native prairie plant community workshop on June 27, 2018. Julia Leone (UMN) and Laura Lukens (Monarch Joint Venture) demonstrated methods on native prairie butterfly and monarch surveys. Patrick Pennarola (UMN) gave a demonstration on native bee monitoring methods. Ian Lane (UMN-Bee lab) gave a presentation on bumble bees and Ian Trieber (UMN-Bee lab) provided information on stem-nesting bees.
15. July 11-15, 2018, Meeting of The Lepidopterists' Society: To graze or to burn: how management affects butterflies in Minnesota remnant prairies. Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Diane Larson, U.S. Geological Survey, Jen Larson, University of Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
16. July 21-26, 2018, North American Congress for Conservation Biology 2018: To graze or to burn: how management affects butterflies in Minnesota remnant prairies. Presenter: Julia Leone, University of Minnesota, Conservation Biology Graduate Program. Co-authors: Patrick Pennarola, University of Minnesota, Entomology Graduate Program, Diane Larson, U.S. Geological Survey, Jen Larson, University of Minnesota, Karen Oberhauser, University of Wisconsin, Madison, Susan Galatowitsch, University of Minnesota
17. Monarch Joint Venture has agreed to serve as a website host for our materials (https://monarchjointventure.org/our-work/projects/effects-of-grazing-versus-fire-for-prairie-management). The website is currently up and available for public usage.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel	$40,076 $144,372 $35,218	• Karen Oberhauser (Co-PI); 8.3% FTE for 3 years. Supervision of and participation in all project activities, direct supervision of graduate student focusing on pollinators. • U of M Master's Student (1 @50% FTE + fringe [tuition and insurance], year-round for 2 years), U of M PhD Student (1 @50%FTE for 15 months, 25% FTE for 3 months + fringe [tuition and benefits]. Help with site selection, aggregating data on sites, and research assistance hiring. Help set up research protocols; collect data on plants, pollinators, and soil; sort and identify insects; analyze project findings. • Student and staff research assistants, 3 @ 100% FTE for 3 months, 1 @ 100% FTE for 1 month, 1 @ 50% FTE for 5 months. Help with field

	$129,438	data collection, sort and identify insects, enter data, and (ideally) conduct related independent projects. • Jennifer Larson (civil service at U of M), Quality Assurance and Project coordination, 50% FTE for 2 years, 37.5% FTE for 7 months; 75% salary, 25% benefits; oversee biological monitoring; Larissa Mottl (civil service at U of M), lead botanist, 100% FTE for 3 months.
Equipment/Tools/Supplies	$1,082 $590	• Field Supplies: bowl traps, sweep nets, soil sample vials, binoculars, field notebooks, measuring tape, insect vials • Lab Supplies: insect pinning materials, chemicals
Other Research Expenses	$3,788	• U of M soil lab costs for nitrogen determinations ($12,000)
Printing:	$228	Fact sheets, plant ID guides, landowner participation requests
Travel Expenses in MN:	$45,860	Field crew travel: sampling plants, soil and insects at study sites, $83 motel + $46/person/day meals, 3 people x 60 days/season x 2 seasons; 2 people/room Larson and Oberhauser travel for training and supervision of field crew , $129/day, 2 people x 5 days/season x 2 seasons Field vehicle (UM-owned) mileage, gas and maintenance
Other:	$0	Workshop costs (room costs, miscellaneous supplies)
TOTAL ENRTF BUDGET:	**$400,652**	

Explanation of Use of Classified Staff: N/A

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

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: Grad students = 1.7 (1 @ 0.5 FTE for 2 years, 1 @ 0.5 FTE for 1 year, 0.25 FTE for 0.25 year, 0.5 FTE for .25 year), Oberhauser = 0.25, Undergrads = 1 (3 @ 1 FTE for 0.25 year, 1 @ 1 FTE for .083 year, 1 @ 0.5 FTE for .42 year), Larson and Mottl = 1.5 (Larson: .375 FTE for .583 years, .5 FTE for 2 years; Mottl: 1 FTE for .25 years): **total = 4.45**

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

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
In-kind services			
Salary for Sam Droege, U.S.G.S., 3.8% FTE for 3 years	$8,976.00	$1,000	
Salary for Diane Larson, U.S.G.S., 20% FTE for 3 years	$86,923.20	$86,923.20	
State			
In-kind services			
Salary for Karen Oberhauser, University of Minnesota; 1% FTE for 3 years	$4921	$0	

Salary for Susan Galatowitsch, University of Minnesota; 1% FTE for 10 months		$1,828.53	
TOTAL OTHER FUNDS:	**$**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners: Karen Oberhauser, Professor in Fisheries, Wildlife and Conservation Biology at the University of Minnesota (focus is conservation of Lepidoptera), will oversee funds within the University, provide butterfly identification expertise, and co-advise graduate students. **Diane Larson**, Research Scientist, U.S. Geological Survey (research foci are invasive species and pollination mutualisms), will oversee vegetation research and co-advise graduate students. **Sam Droege**, U.S. Geological Survey (foci are survey methods and taxonomy of hymenoptera) will oversee insect identification. The University of Minnesota will receive all of the funds. Both the USGS and the University of Minnesota will contribute space and time to the project. The time contributions of Larson (20% FTE for 3 years) and Droege (3.8% FTE for 3 years) are in-kind support from the USGS. 1% of Oberhauser's time will be in-kind support from the University of Minnesota.

B. Project Impact and Long-term Strategy: This research will begin to help us understand the impacts of conservation grazing, a commonly-used management technique in prairies, on plant communities and the bees and butterflies that depend on them. By comparing this practice to fire, a more thoroughly-studied practice in northern tallgrass prairies, we will be able to inform federal, state, local, and private land management practices. Thus, the ultimate goal of this project is better-informed management practices on Minnesota prairie remnants, including those owned by federal, state, and local government, as well as private landowners. The continued involvement of USGS and University of Minnesota personnel with Minnesota land managers, along with audience-appropriate dissemination vehicles, will ensure access to these results in the long-term. Because we are able to take advantage of existing variation in site management strategies, we anticipate that two field seasons will suffice, and do not foresee the need for ongoing funding

C. Funding History: N/A

Funding Source and Use of Funds	Funding Timeframe	$ Amount
None.		$

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

A. Parcel List: N/A

B. Acquisition/Restoration Information: N/A

IX. VISUAL COMPONENT or MAP(S): See attached graphic.

X. RESEARCH ADDENDUM: See attached Research Addendum.

XI. REPORTING REQUIREMENTS:

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

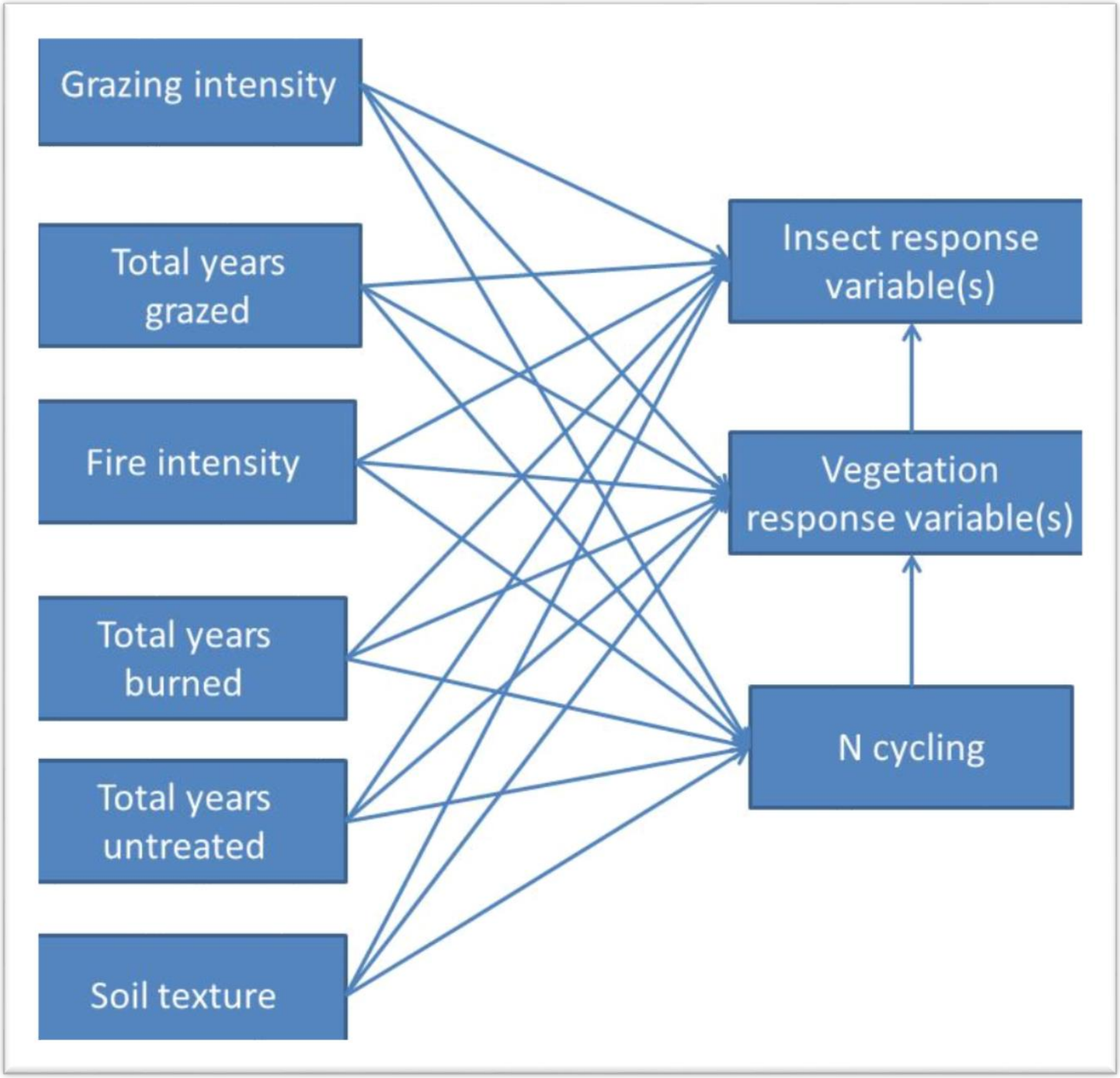
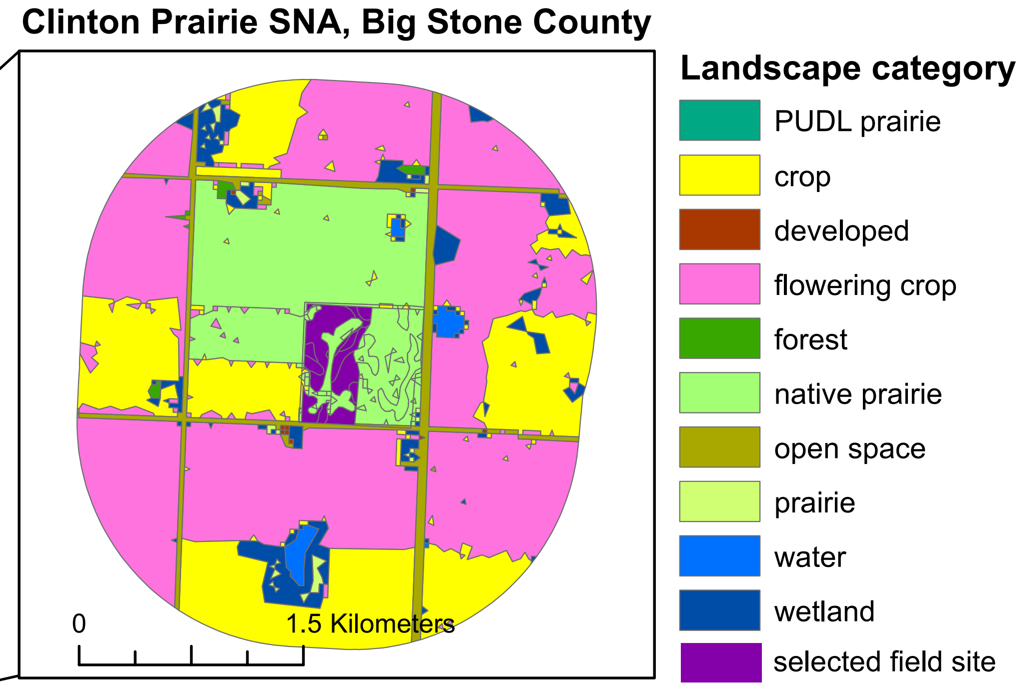


Figure 1. Hypothesized model for effects of conservation grazing and fire on prairie vegetation and prairie-dependent insects.

Landscape Analysis using CropScape Data Layers (USDA)



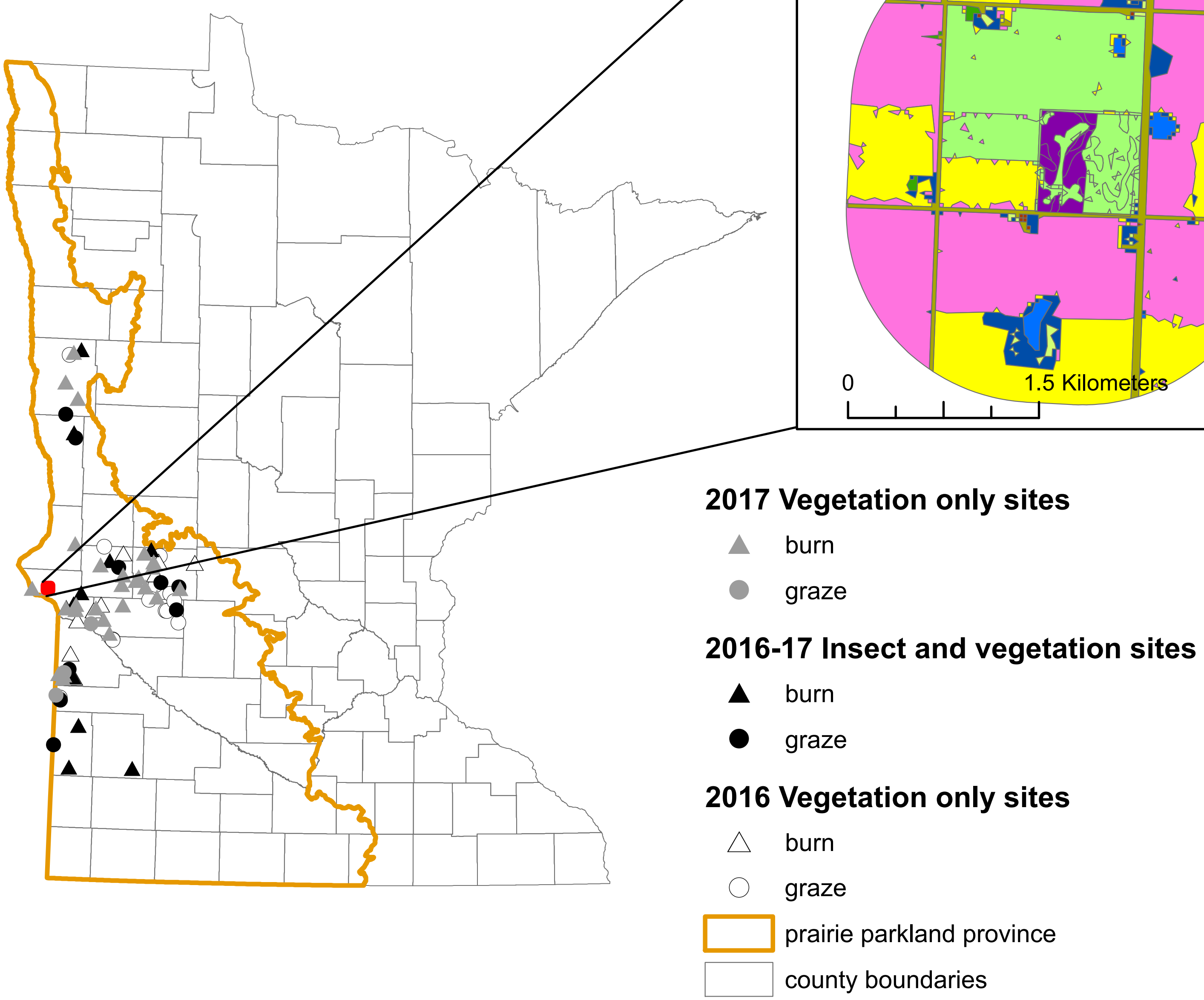


Figure 2. Locations of our vegetation-only and insect and vegetation field sites in the prairie parkland province in western MN, and an example of landscape analysis of one field site. We created 1.5 km buffers surrounding each field site, and calculated percent land cover within the buffer using USDA CropScape, USFWS, MN DNR, and South Dakota State University coverages. Map created with ESRI ArcGIS 10.5.1 by Jen Larson.

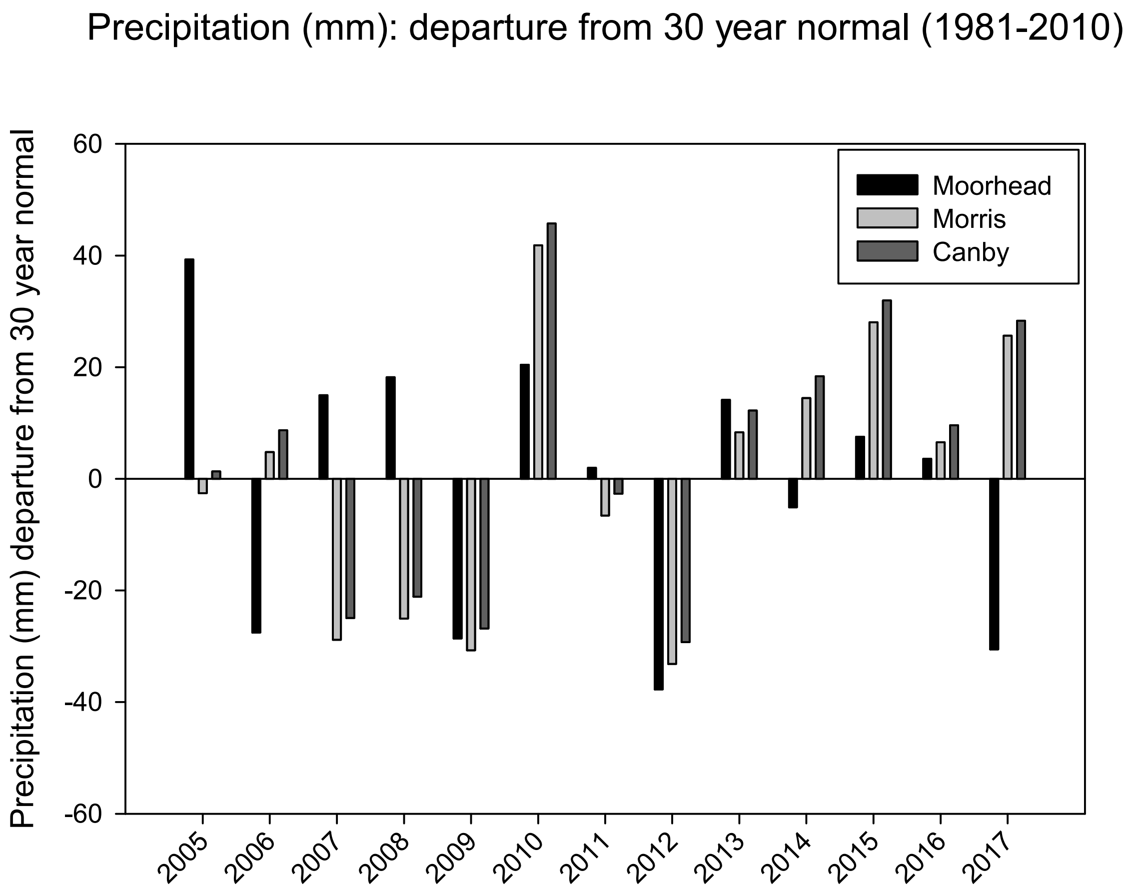


Figure 3a. Total average daily growing season (May-Sept) precipitation was calculated from data obtained from the National Oceanic and Atmospheric Administration (https://www.ncdc.noaa.gov/cdo-web/datatools) and then graphed as the difference from the 30 year normal. We used 3 stations in locations that span the north-south geographical range for our study sites.

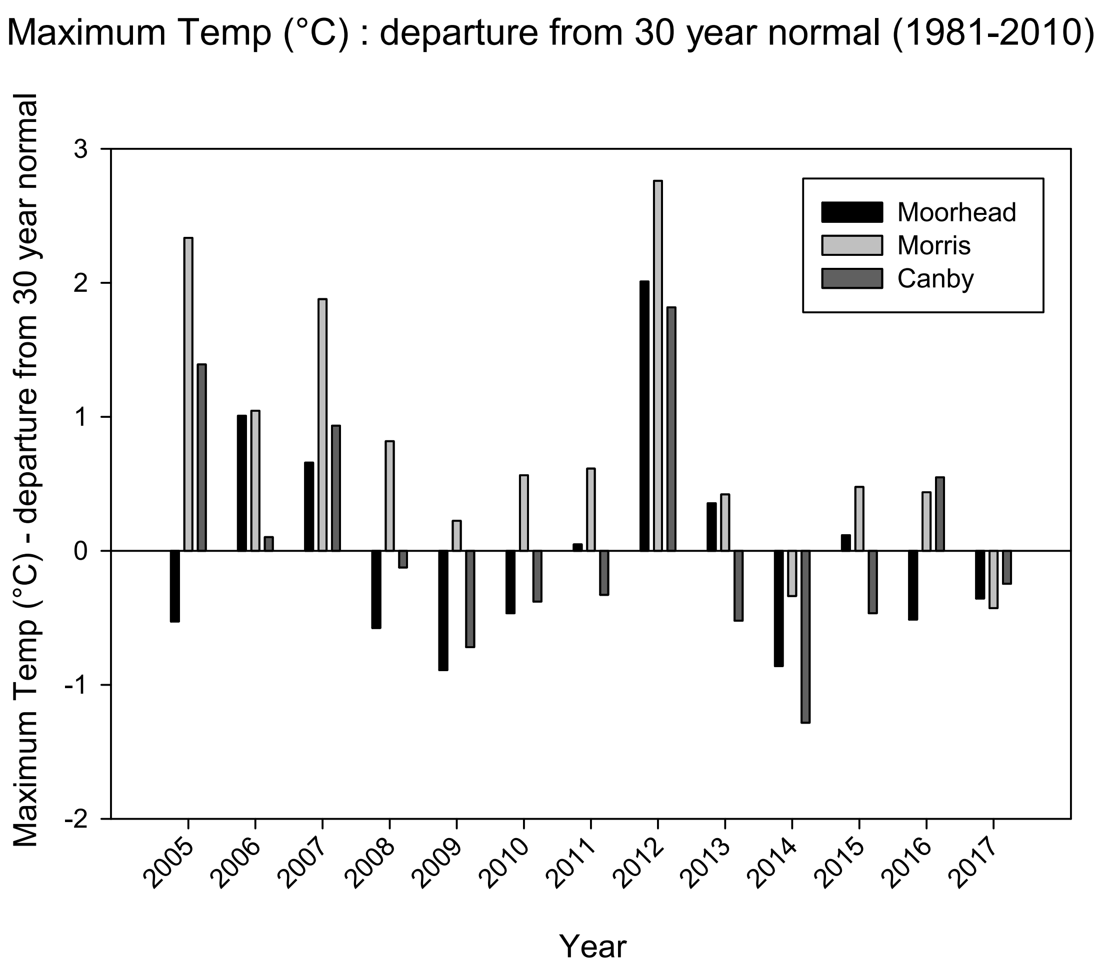


Figure 3b. Maximum average daily temperature during the growing season was calculated from data obtained from the National Oceanic and Atmospheric Administration (https://www.ncdc.noaa.gov/cdo-web/datatools) and then graphed as °C difference from the 30 year normal. We used 3 stations in locations that span the north-south geographical range for our study sites.

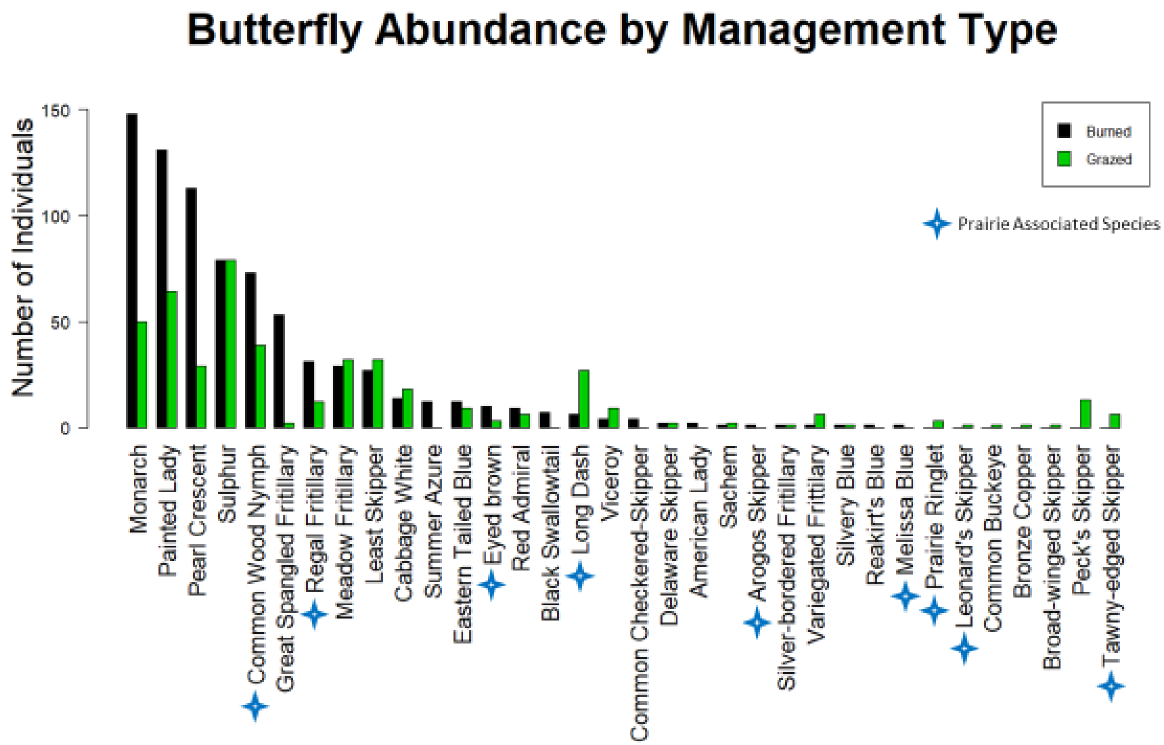


Figure 4a. Butterfly species abundance at burned versus grazed sites.

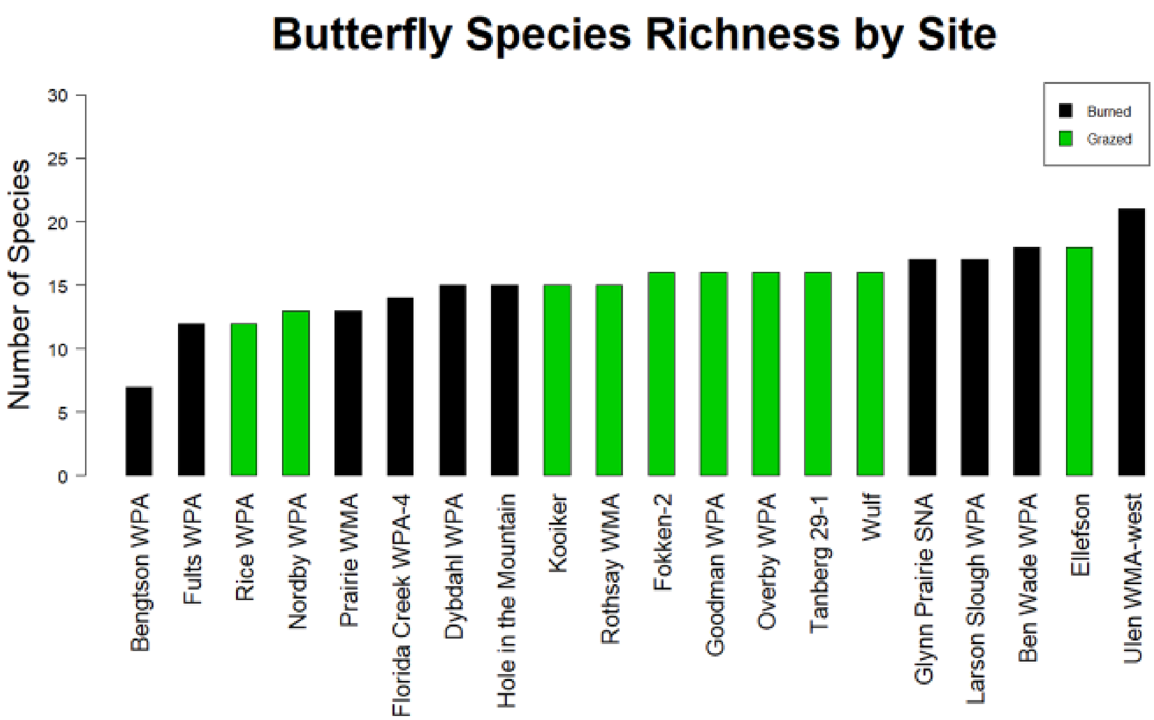


Figure 4b. Butterfly species richness at 20 remnant prairie sites.

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

Project Title: Effects of Grazing Versus Fire for Prairie Management
Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 03o
Project Manager: Susan Galatowitsch
Organization: University of Minnesota
M.L. 2015 ENRTF Appropriation: **$** 414,000
Project Length and Completion Date: 3 Years, June 30, 2018
Date of Report: August 27, 2018

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Revised Activity 2 Budget 08/20/2017	Amount Spent	Activity 2 Balance	Revised Activity 3 Budget 08/14/2018	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	Field work preparation: Identify prairie tracts, collect management histories, assemble GIS layers										
Personnel (Wages and Benefits)	$91,809	$91,809	$0	$128,588	$128,588	$0	$128,708	$128,708	$0	$349,105	$0
Karen Oberhauser (Co-PI); $40,845, 75% salary, 25% benefits, 8.3% FTE for 3 years		$9,772			$15,152			$15,152			
University of Minnesota Master's Students, $234,582, 56% salary, 44% benefits (including tuition), 50% FTE for 2 students each year for 3		$20,000			$62,186			$62,186			
Jennifer Larson (civil service at U of M, Quality Assurance and Project coordination), $12,656, 75% salary, 25% benefits, 10% FTE each year for 2 years		$62,037			$33,641			$33,761			
Student research assistants, $72,842, 2 at 50% FTE/year for 2 years					$17,609			$17,609			
Equipment/Tools/Supplies				$2,310	$836	$1,474	$2,189	$836	$1,353	$4,499	$2,827
Field Supplies (plot frames, markers, data sheets, nets, pan trap supplies, field guides, measuring tape, glassine envelopes, kill jars, soil sampling equipment): $2,800					$541			$541			
Lab Supplies (insect pinning/preserving equipment, materials for N extraction and soil texture): $1,820					$295			$295			
Other research expenses											
U of M soil lab costs for nitrogen determinations				$6,000	$3,788	$2,212			$0	$6,000	$2,212
Printing				$500	$114	$386	$500	$114	$386	$1,000	$772
Fact sheets for dissemination											
Travel expenses in Minnesota				$25,230	$22,930	$2,300	$25,230	$22,930	$2,300	$50,460	$4,600
Field crew travel (to ~37 sites once per summer, 20 sites plus 2 additional times for insect sampling and follow-up vegetation sampling, lodging and food costs for 2 grad students and 2 undergrad assistants [$83 motel + $46/person/day M&IE, 4 people x 60 days/season x 2 seasons; 2 people/room]); travel to workshops: $17,940					$13,644			$13,644			
Larson and Oberhauser travel for training and supervision of field crew: $129/day, 2 people x 5 days/season x 2 seasons: $2,580					$127			$127			
field vehicle (2, U of M owned, 2 field seasons) : $12,000					$9,159			$9,159			
Other											
Workshop costs: Room costs, miscelaneous supplies				$1,468	$0	$1,468	$1,468	$0	$1,468	$2,936	$2,936
COLUMN TOTAL	**$91,809**	**$91,809**	**$0**	**$164,096**	**$156,256**	**$7,840**	**$158,095**	**$152,588**	**$5,507**	**$414,000**	**$13,348**

Nested frequency plot SOP

Materials
Plot frame
Map of site showing boundaries and sampling point locations
Compass
GPS pre-loaded with sample points
Clipboard
Pencils
Data sheets
Identification guides and/or keys
Plant press
Hand lens
List of species planted and/or list of species previously found (optional)
Camera to photograph unknown plants

Introduction

Frequency has been long recognized as a reliable and repeatable measure of plant abundance for purposes of monitoring (Curtis and McIntosh 1950, DeBacker et al. 2011). It avoids observer bias associated with cover estimates. By nesting plots of different sizes, it can be used to assess trends in species that vary substantially in relative abundance. Frequency is sensitive to the overall distribution of each species, but simulation (Heywood and DeBacker 2007) and field (DeBacker et al. 2011) studies have demonstrated that a plot size that results in frequencies of 20 – 50% (35% is a good target) provides the greatest statistical power for assessing change over time. This frequency refers to the proportion of plots in which a species is detected within a reconstruction. For example, big bluestem may be dominant at a reconstruction, resulting in detection in every 0.5 x 2 m plot, making it impossible to assess any increase. However, it may be detected less often in a smaller plot size, perhaps 0.25 x 0.125 m. To assess changes in frequency over time of big bluestem in this example, the smaller plot frame size should be used to calculate frequency. When summarizing the data, use the plot frame size that yields approximately 35%.

In addition to monitoring, frequency has also been used to compare plant species occurring in different treatments, such as disturbance types, and within vegetation types (Larson et al. 2001, Larson 2003). Indices, such as species diversity and evenness, also can be calculated from frequency data. The drawback to any protocol that uses plots on transects is that inevitably, some species will be missed. For the most complete list of species occurring at a site, use of both the Nested Plot and the Meandering Walk Protocol is preferable.

Training

Field personnel. Sight-identification of species likely to be encountered (e.g., species planted, regional native and nonnative annuals and “weedy” species), as well as all regional invasive species, is necessary as a starting point. Those using this technique should also have familiarity with plant keys and methods to collect and press specimens for vouchers and identification. The ability to navigate to specific locations using a GPS is required.

Mapping
Prior to the field season, collect the GIS layers for the boundary of the site. If the planting did not take soil type into account, it may also be helpful to use a soil survey layer to separate wet, mesic, and dry prairie types. Soils data is available from the Natural Resources Conservation Service Web Soil Survey (NRCS WSS; https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). We used soil drainage class as a proxy for wet, mesic, and dry prairie types.

Create a map that includes the site boundaries. Create the systematic grid for the appropriate number of sample points (see Appendix for ArcMap tool) and download the points to a GPS unit. It is helpful to include soil polygons or topography on a satellite imagery base map for use in the field. The map and/or shapefile should be stored with the copy of the datasheets and data.

We chose to sample on a systematic grid to ensure sampling locations were distributed throughout the site to capture variability within the unit. At the same time, a systematic layout allows the observer to walk a straight line from one plot to the next rather than having to wander around to random points.

The number of plots in each seed mix area depends on the size of that particular reconstruction. Between 10 and 40 rectangular plots (0.5 x 2.0 m) are placed in a systematic grid throughout the site. Aim for 3 plots/ha with a minimum of 10 plots and a maximum of 40 plots. In other words, if a site is 3 ha (7.4 acres) or less, use 10 plots. For sites from 4–13 ha, use 3 plots/ha, and if a site is more than 13 ha (32 acres), use 40 plots. The number of plots is based on simulations using test data. The Appendix contains an annotated script in R for creating the systematic grid within ArcMap.

If GIS technology and a GPS unit are not available, the systematic grid will need to be laid out by hand on an appropriate satellite image of the site. An alternative method of navigating to each point will need to be developed (e.g., using compass direction and distance from an obvious starting point) and documented.

Plot frame and data sheet
The plot frame (Figure 1) is made from 0.5 inch PVC pipe, which can be obtained at most hardware stores. The size of the subunits within the plot frame doubles with each larger size. They can be modified, depending on the vegetation characteristics of the site to be monitored, as long as sizes are in multiples of 2 (e.g., the smallest subunit in Figure 1 is 50 cm x 12.5 cm, so the next smaller that could be added is 25 cm x 12.5 cm). The rectangular shape also needs to be retained because species captured varies with plot shape. Keeping in mind the 35% target, a site that is heavily dominated by a single species will need a smaller subunit size than a site that

has greater alpha diversity. In tall vegetation, it is useful to be able to remove one side of the frame so that it can be slipped into the base of the vegetation.

A sample data sheet is attached to this protocol. The key thing to note is that the species is entered only once at each sample plot location and the smallest subunit within which it is found is entered under the appropriate plot number.

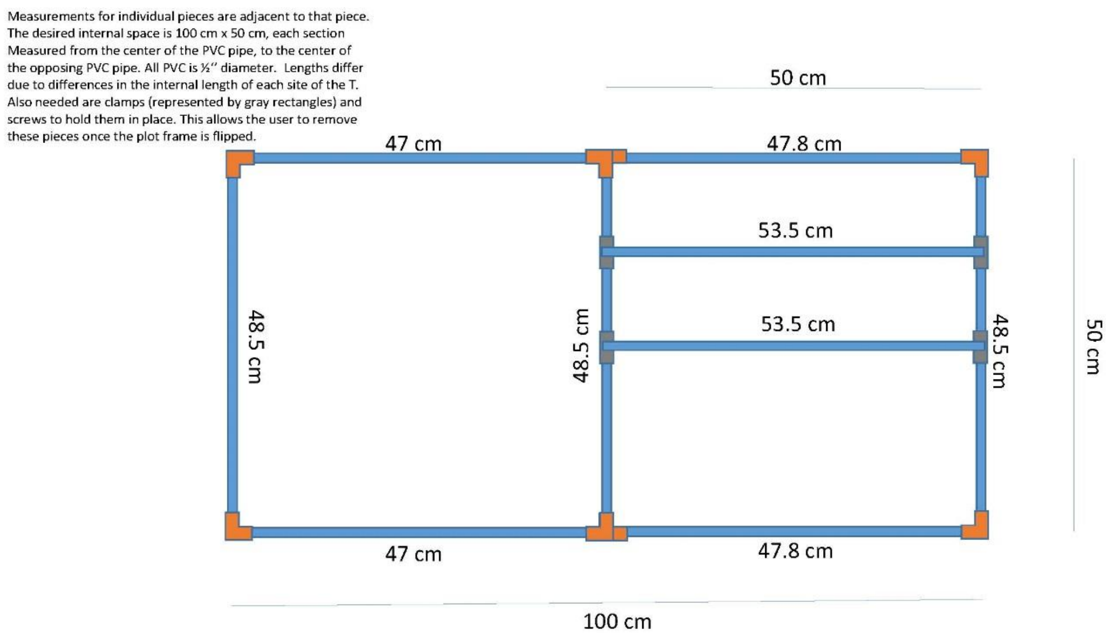


Figure 1. Nested plot frame. Subunit dimensions have been used in tallgrass prairie reconstructions, but in some cases the smallest subunit may need to be halved if any species are found to occur in > 50% of the 12.5 x 50 cm subunit.

Field methods

Methods

Using a hand-held GPS, navigate to the first plot location to be sampled. Select a compass direction at random and orient the plot in the same way with respect to that direction at each sample location. Alternatively, select a compass direction before going to the field and use it for all sampling. The goal is to avoid biasing plot placement.

Carefully adjust the vegetation so that only plants rooted within each subunit division are recorded. Record all native and nonnative species in the smallest subunit and place a 1 in the corresponding box of the data sheet. Continue inspecting subunits in order from smallest to largest, and record new species along with the subunit in which they first occurred on the data sheet. Each species that occurs in a given 1.0 m^2 plot will only be recorded once by writing the smallest subplot in which it occurred on the data sheet. The final subunit is always the 50 cm x 100 cm area of the plot frame after it is flipped on its short axis from left to right.

If you cannot identify a plant to species, give the highest level of detail possible or collect a sample for later identification. Ignore very small seedlings that cannot be identified with confidence.

Analysis

If changes in frequency of individual species over time is an objective, initial analyses should focus on determining optimal subunit size (35% frequency is a good target (DeBacker et al. 2011)) for each species of interest. The nested feature of the plots should be retained throughout monitoring so that optimal subunit size can be reassessed each sample period. Optimal subunit size indicates the abundance of species, with a smaller optimal subunit size indicating greater abundance (Curtis and McIntosh 1950). If the initial frequency of a species of interest is between 20 and 50%, it should be possible to track its change in frequency over time, whether it increases or declines.

To determine species richness or other quantitative metrics for the site, use a single subunit size – typically the entire plot so no species are omitted – to calculate frequencies by species.

References

Curtis, J. T., and R. P. McIntosh. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology **31**:434-455.

DeBacker, M. D., J. S. Heywood, and L. W. Morrison. 2011. Optimized Frequency Measures for Monitoring Trends in Tallgrass Prairie. Rangeland Ecology & Management **64**:301-308.

Heywood, J. S., and M. D. DeBacker. 2007. Optimal sampling designs for monitoring plant frequency. Rangeland Ecology & Management **60**:426-434.

Larson, D. L. 2003. Native weeds and exotic plants: relationships to disturbance in mixed-grass prairie. Plant Ecology **169**:317-333.

Larson, D. L., P. J. Anderson, and W. Newton. 2001. Alien plant invasion in mixed-grass prairie: effects of vegetation type and anthropogenic disturbance. Ecological Applications **11**:128-141.

Data sheet
Record the sizes of the subunits used. Don't forget to flip the plot for the final subunit.
Record the smallest subunit within which each species occurred in each plot.

Date:_____________ Site ID:___________________________ Page _____ of _____

Observer:_____________ Subunit sizes: (1) _____________ (2)_____________ (3)______________ (4)__________

(5)______________ (6) _______________ (7)________________

Species	1	2	3	4	5	6	7	8	9	10	Comment

Comments: ____

____

A somewhat different datasheet is on the next page:

Datasheet for Nested Plots Protocol

Record the sizes of the subplots used; use only as many as in the plot. Don't forget to flip the plot frame for the final subplot. Record the smallest subplot within which each species occurred in each plot.

Date:_____________ Observer:________________ Overall Site:_____________ Planting Site: ____________________

Seed Mix Area Name: ________________________ Prairie Type: ________________ Page ___ of ___

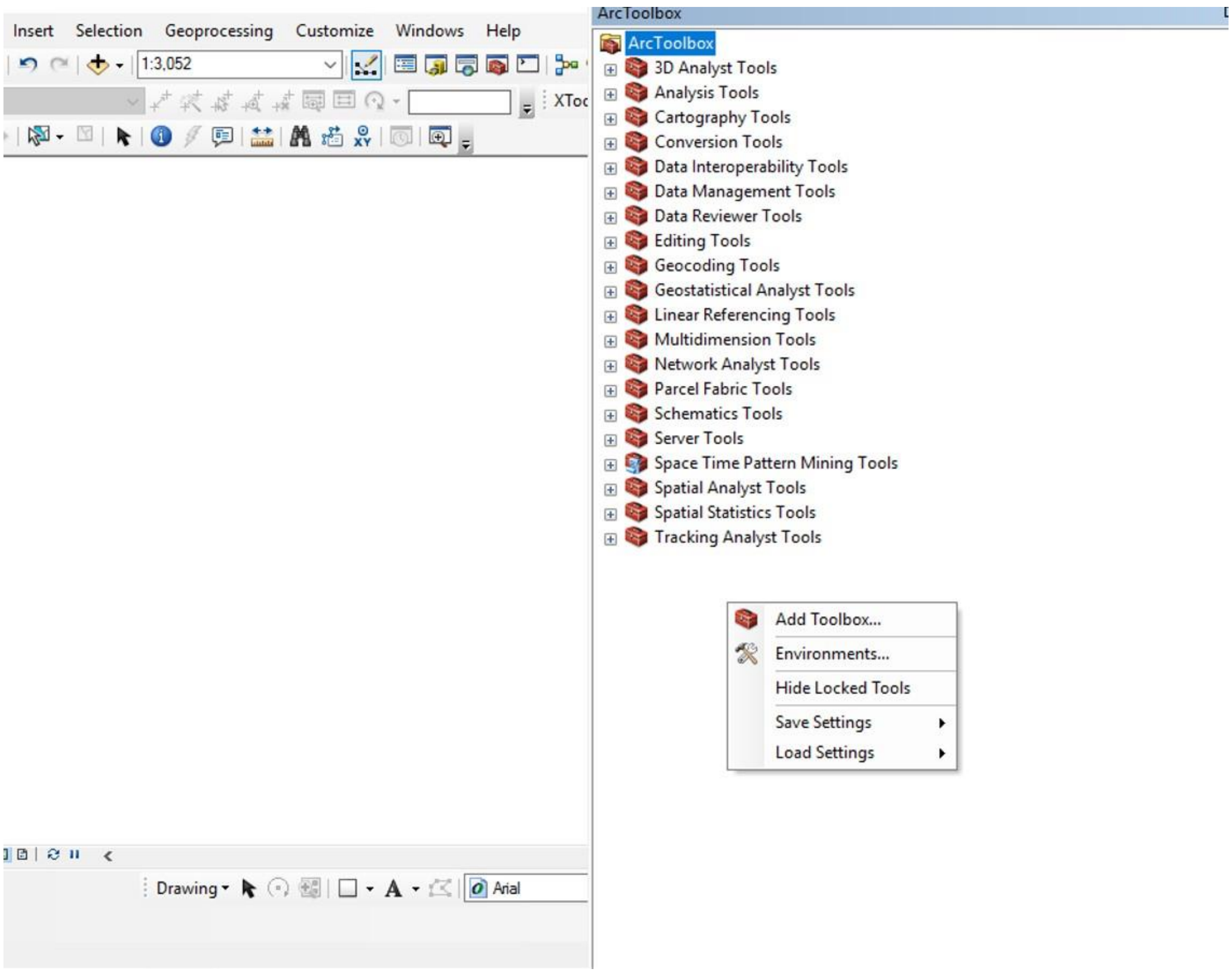
Subplot sizes (cm) - *Write in dimensions if you did not use these*: (1) 12.5 x 50 (2) 25 x 50 (3) 50 x 50 (4) 50 x 100 (5) 50 x 200

	Plot Number (minimum 10, maximum 40)										
Species											**Comment**

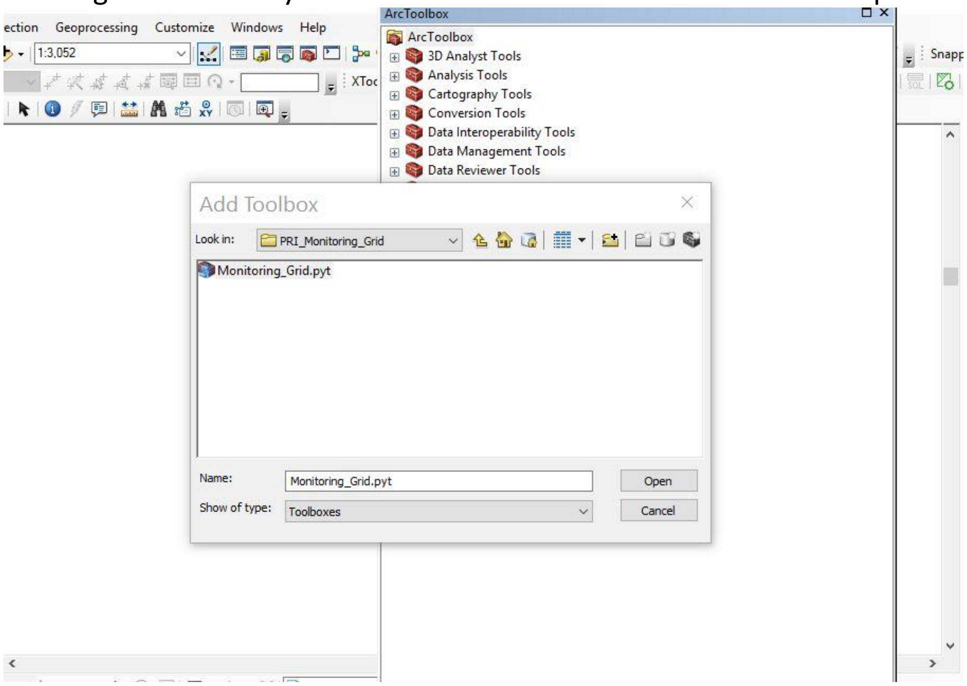
Appendix – Creating the Systematic Grid for Nested Frequency Plots

How to utilize the Monitoring Grid toolbox in ArcMap once you have downloaded and extracted the PRI_Monitoring_Grid.zip file from the PRI site.

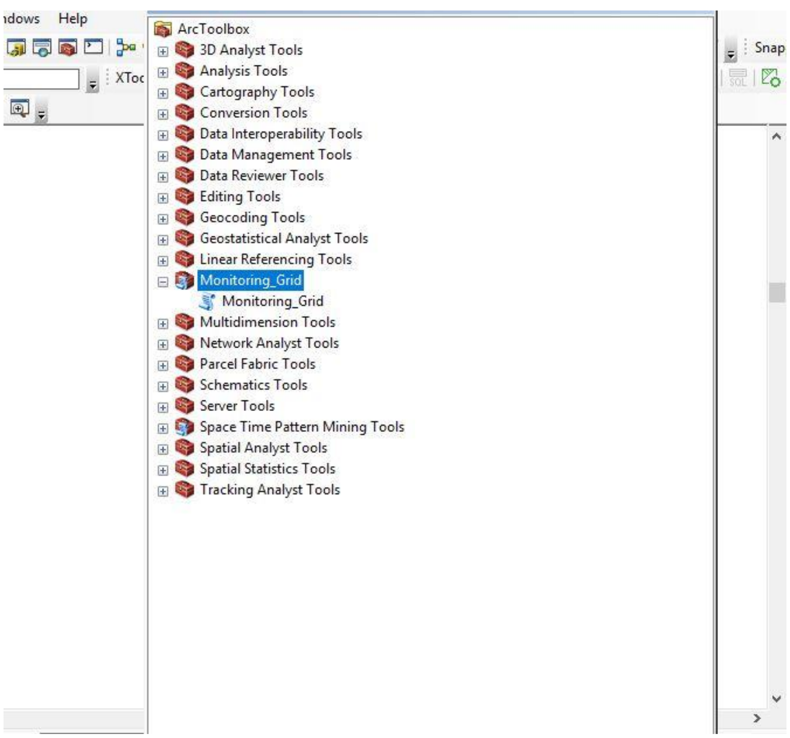
1. Open ArcToolbox
2. Right click in ArcToolbox and select "Add Toolbox"



3. Navigate to where you saved the extracted files and select and open the Monitoring_Grid.pyt file.

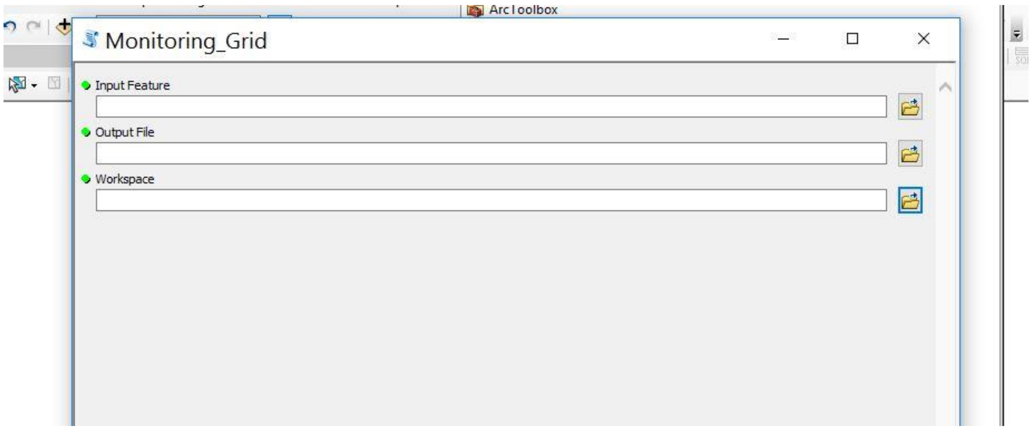


4. Once the Monitoring_Grid folder is added to your toolbox, expand and select the script contained within.



5. The **Input Feature** is the shapefile of the polygon of the area that you want to monitor. This tool is most efficient if the survey area polygon is the only polygon contained within the shapefile. Please contact Ben Walker (benjamin_walker@fws.gov) if you have many survey areas that you want to process in a single event. The **Output File** is the systematic grid that the tool will create, navigate and provide a name to the file.

Workspace is the folder location where the script will temporarily work to create the necessary files and subsequently delete them. On large survey areas, the tool may create more than 40 survey locations; please be aware and delete unnecessary points.



The process that the script runs to create the monitoring grid is outlined below:

```
            #Copy the shapefile so we aren't editing it#
      arcpy.CopyFeatures_management(inputfile1, "point_cr.shp")
            #Add a Square Meter Field and calculate the value#
      arcpy.AddField_management("point_cr.shp","area_sqm","Double")            expression1 =
"{0}".format("!SHAPE.area@SQUAREMETERS!")            arcpy.CalculateField_management("point_cr.shp",
"area_sqm", "!SHAPE.area@SQUAREMETERS!", "PYTHON", )
            #Define layers for next step#        outraster = "ratemp.tif"            field = "area_sqm"
            #Pull area value from polygon#            value = arcpy.da.SearchCursor("point_cr.shp",
("area_sqm",)).next()[0]
            #Set the sideboards for the number of sampling points#
size1 = sqrt(value/40)        size2 = sqrt(value/(math.ceil(value/10000)*3))            size3 = sqrt(value/10)


#Convert our layer to a raster based on the sideboards#            if int(value) >= 130000:
arcpy.PolygonToRaster_conversion("point_cr.shp", field, outraster, "", "", size1)
            elif int(value) in range(30000, 130000):
arcpy.PolygonToRaster_conversion("point_cr.shp", field, outraster, "", "", size2)
            else: arcpy.PolygonToRaster_conversion("point_cr.shp", field, outraster, "", "", size3)
            #Convert back to a point shapefile based on each cell's centroid#
      arcpy.RasterToPoint_conversion(outraster, outfile2, "Value")
            #Cleanup intermediate files#        arcpy.Delete_management("point_cr.shp","")
      arcpy.Delete_management("ratemp.tif","")
            arcpy.AddMessage ("POINTS SUCCESSFULLY CREATED")
```

Bee Sampling Protocol –June 2018

Effects of grazing versus fire for prairie management.

<u>Materials:</u>
GPS unit
Batteries
Stop watch
3.25oz plastic bowls; yellow, white, and blue
Binder clips
Wooden dowels or lengths of bamboo, cut to approximately 0.5m
Dawn dish soap
Gallon jug of water
Aerial insect nets
Ethyl acetate
Eyedroppers
Ethyl acetate kill jars
50mL polypropylene centrifuge tubes
cotton balls
Glassine envelopes
Field notebook
Pencil
Heavy paper
Whirl-Pak® bags
Brine shrimp net
70% ethanol
Cooler
Laser printer and acid-free cardstock for locality labels
Mason jar and metal ring of lid
Fine mesh
Scissors to cut mesh to size
Timer
Hair dryer
Petri dish (and a dry place to store them)
Pins
Foam block

<u>Bee protocols:</u>

We surveyed bees using two methods - passive trapping and active netting. Bowl traps are a highly replicable means of collecting bees over a period of time, with little-to-no observer bias. However, not all bees are attracted to standard bowl traps. Therefore, directed netting at a site by an observer can serve to round-out species lists and provide a more accurate view of species richness when combined with bowl data.

Deploying bowl traps:

Obtain 30 standard 3.25 oz plastic bowls in three colors (white, yellow, and blue). At a randomly selected end of a predetermined transect, deploy bowls in a ladder-like pattern. Place a wooden dowel or length of bamboo approximately 0.5m long into the ground. Use a binder clip to hold the lip of the bowl to the elevated end of the stake. Fill the bowl with a mixture of water and Dawn dish soap. Using this same method, place a second and third bowl set five meters away from the transect in opposite directions, in effect creating a 10m long perpendicular transect. Use one bowl of each color in this set. Pace out twenty meters along the original transect, towards the other end. Place another set of three bowls, using all three colors. Repeat this until 30 bowls are in place. (Note: This modification of a standard bee-bowl transect, in which bowls are placed every five meters, served to create 20-meter gaps through which cattle could pass without encountering bowls.)

Netting bees:

Next, collect bees using an aerial net during a meandering walk of the site. The duration of this walk can vary depending on site size, but should always be recorded so that the collection effort can be calculated later. Wander through the site, looking for flowers. Net bees that are observed on flowers. (Note: We only collected bees when they were on flowers, in an attempt to minimize detectability biases.) Once captured in a net, bees tend to fly upwards. Hold the end of the net up so that bees corral themselves into the end of the net. Insert a 15mL polypropylene centrifuge tube containing an ethyl-acetate soaked wad of cotton into the net and maneuver it underneath a single bee. With some manipulation of the net and the tube, the bee will fall into the tube. Cap the tube while it is still in the net to prevent escape. Using a pencil, record the species of flower the bee was found on, the site name, date and time on a glassine envelope. Place the now quiet bee into this labeled envelope and put the envelope into a charged ethyl-acetate kill jar. Repeat until all bees are removed from the net. Continue the meandering walk, repeating the above procedures when bees are encountered on flowers.

Collecting bowl traps:

Approximately 24 hours later, collect bowls. Unclip bowls from their stakes, and dump the contents of each bowl through a brine shrimp net. (Note: We removed moths and butterflies from our samples, with butterflies set aside and moths discarded.) Collect stakes, bowls, and clips. Once all bowls are removed, or periodically if necessary, transfer the contents of the shrimp net to a single Whirl-Pak®. Label the bag with a permanent marker, noting the site, date, number of bowls collected, the time at which the last bowl was deployed and at which the last bowl was collected. Replicate this information in pencil on a sturdy piece of paper and insert into the bag. Fill bags with sufficient 70% ethanol to fully cover all insects. Seal the Whirl-Pak® by squeezing out as much air as possible, rolling the top of the bag down to the level of the ethanol, bending the wires together and twisting them together. Place samples in the freezer until they can be washed, dried, and pinned.

Processing bowl samples:

Once in a laboratory, bowl traps can be processed. Remove a single sample from the freezer and empty into a Petri dish. Split the sample into multiple dishes if it is too large. Add liquid so that insects can be moved around and slightly disentangled. Using a stereo-microscope and forceps, separate bees from non-bees, placing non-bees into a separate Petri dish. Pour the bees into a mason jar. Add warm water and a small amount of Dawn dish soap. Place a piece of fine mesh over the mouth of the jar and attach the metal ring component of the jar lid. Cover the mesh with a gloved hand and shake the jar vigorously for one minute. Rinse the soap out through the mesh. This will take multiple rinse cycles. Once insects are no longer soapy, blow a hairdryer through the mesh, rotating the jar until no insects stick to the sides of the jar. Adding small pieces of balled-up paper towel can help fluff bees and remove some excess moisture. Remove metal ring and mesh. Pour all insects from jar into a covered petri dish. Copy collection information from Whirl-Pak® bag onto a slip of paper and include it in the Petri dish. The sample may then be refrozen to be pinned at a later date, or pinned immediately.

Butterfly Sampling Methods

Effects of grazing verses fire for prairie management

June 5, 2016

Julia Leone

Introduction:

Native tallgrass prairie once stretched across much of the Midwestern United States. Now, less than 2.4% of original extent of tallgrass prairie remains (Samson et al. 2004). In Minnesota, we have lost over 98% of the tallgrass prairie and what remains is highly fragmented. Historically, the prairie was maintained through wildfire and bison grazing (Middleton 2013). In its current state, land managers seek to manage the prairie in a way that mimics these historic strategies, using managed burns and, more recently, conservation grazing. The tallgrass prairie of Minnesota is home to many butterfly species which are sensitive to disturbance. Although much has been documented about the effects of fire on northern tallgrass prairie, much less is known about the effects of conservation grazing, particularly for prairie dependent butterflies in Minnesota. The butterfly sampling methods below seek to address the questions of how these different management regimes affect abundance, community composition, species richness, and diversity of butterfly species found in Minnesota's tallgrass prairie.

We will survey butterflies using a modification of the "Pollard Walk" (Pollard 1977; Pollard and Yates 1993). These methods have been widely used to answer questions of butterfly abundance, community composition, species richness, dominance and diversity (Murphy and Weiss 1988; Swengel 1996; Thomas 2005; Swengel and Swengel 2013).

Butterfly surveys will occur during the 2016 and 2017 growing seasons (May-September). Butterfly surveys will be conducted on a subset of 20 randomly-selected remnant prairie polygons out of a total of 75, all with a 10-year known management history. Ten polygons will have been predominantly grazed, 10 predominantly burned.

Butterfly presence and abundance will be assessed in specific survey locations within each polygon, using the same transects used for vegetation surveys and bee bowls. Each of the 20 sites will be surveyed three times per summer, moving from furthest south to furthest north to follow phenology. Start and end time, temperature, wind speed, and % cloud cover will be recorded and surveys will be confined, when possible, between 0930 h and 1830 h when temperatures are above 18^{o} C, sustained winds are less than 17 km/h, and cloud cover is <50%. The observer will walk the transect at a steady pace of approx. 10m/min, identifying and recording each butterfly seen within a 5-meter box to the front (2.5m on either side) (Shepherd and Debinski 2005; Davis et al. 2007; Vogel et al. 2007; Davis et al. 2008; Kadlec et al. 2012). We will take care not to sample any rare or endangered butterflies, such as *Hisperia dacotae* or *Oarisma Poweshiek*.

Transects will be delineated on maps prior to the field season and will run parallel to any elevation gradient; if none exists, a random numbers table will be used to select a compass bearing.

Field Materials:

GPS, spare batteries

Insect nets

Stopwatch (to time walk)

Watch or cell phone (for start and end time)

Wind gauge

Thermometer

Binoculars

CO_2 dispenser

Extra CO_2 cartridges

Clear centrifuge "sleep" tubes (ca. 4cm diameter)

Digital camera/phone for photographing difficult to ID individuals

Kill jars

Ethyl acetate for kill jars

Glassine envelopes

Data sheets

Butterfly identification guides/sheets

Flowering plant identification guides/sheets

Clip boards

Sharpies

Pencils

Duct tape

Flags

Flagging tape

Scissors

First aid kit

Specimen preparation materials:

Pins (size 1, 2, 3)

Pin holder

Label height setter

Glassine paper

Foam block

Butterfly spreading block

Cotton

Scissors

Forceps

Inkjet printer and acid-free cardstock for locality labels

Humidifier

Sampling Procedure:

1) Prior to visiting each field site, a random point generator will be used to create random points within each polygon using ArcMap. Transects will run through a random point, parallel to any elevation gradient, and will equal a total fixed length of 400m. We will start our transects 10 m from the edge of the polygon to minimize edge effects. The number of transects will vary depending on polygon shape and size.

2) Download GPS points for transects within each polygon onto GPS unit from computer or laptop prior to going into the field.

3) Locate the first transect within the polygon. Ends of transects will be marked with flags and numbered. Each numbered transect corresponds with a GPS location.

4) Charge kill jars with ethyl acetate to prepare to collect any difficult to identify/voucher specimens.

5) Record start time, wind speed, temperature, and percent cloud cover. Record end time when finished surveying transect.

6) Each 400m transect will be surveyed once per site visit. The observer will walk the transect at a steady pace of 10m/min. All butterflies seen 5m ahead and 2.5m on either side of the observer will be identified and recorded. The clock should be stopped to process and record individuals. Butterflies can be netted if difficult to identify on the wing and, in rare circumstances, collected to identify in the lab (see below). Butterflies netted for identification will be released after identification.

7) If a butterfly cannot be identified by netting and examining in the field, it can be collected, placed in a sleep tube, given a light pulse of CO_2 to knock it out, and then identified or photographed for later identification. Butterflies should be removed from sleep tube as soon as they have ceased moving to prevent any harm and identified or photographed in hand. Recovery takes 30 seconds to a few minutes, after which butterfly will be released.

8) If a butterfly cannot be identified by netting and examining in the field or by the CO_2 method described above, we will collect the specimen for identification in our lab at a later date. Each butterfly will be placed in its own glassine envelope with unique number (initials + polygon ID + transect number), time of capture and % open sky, and the envelope placed in a kill jar charged with ethyl acetate. We will collect at least one voucher specimen of each butterfly species encountered across all sites to assemble a voucher reference collection.

9) Vouchered butterflies will be spread, pinned, identified, and databased at the University of Minnesota Insect Collection.

10) After transect walk is complete, a time-constrained opportunistic walk will be conducted to look for other butterflies not seen along transect. Record starting and ending time. Time will vary based on polygon size, shape, habitat quality, etc.

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Effects of Grazing Verses Fire for Prairie Management Study - **2017 Butterfly Transect Datasheet**

Date:_____________

Avg Wind speed:_______**km/h**

Location: ________________________ **Transect ID:** _______________ **Temperature:**________ **C**

Cloud Cover: ________ **%**

Transect length: _________________ **Management:** ______________ **Start time:**___________ **h**

Prairie type: _____________________ **Observer:** __________________ **End time:**____________ **h**

No.	Time	Butterfly Species	#	Activ.	Dist (m)	Status	PT	Comments
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								

Management: G=Grazed, B=Burned **Prairie type:** D=Dry, M=Mesic, W=Wet **Dist**: Est. distance from observer **PT** = Prairie type

Activity: N = nectaring, R = resting, I = interacting, F = flying, FL = flushing, M = mating, OV = ovipositing, O = other

Status: CR=captured and released, P=photographed, C=CO2 method, V=vouchered, GS=good sight, S=sight, PS=Poor sight

Effects of Grazing Verses Fire for Prairie Management Study - **2017 Butterfly Opportunistic Walk Datasheet**

Avg Wind speed:_______km/h

Temperature:________ C

Cloud Cover: ________ %

Start time:___________ h

End time:____________ h

Date:____________ Observer: _________________

Location: _______________________ Management: ______________

No.	Time	Butterfly Species	#	Activ.	Dist (m)	Status	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
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16							
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19							
20							
21							
22							
23							

Management: G=Grazed, B=Burned

Activity: N = nectaring, R = resting, I = interacting, F = flying, FL = flushing, M = mating, OV = ovipositing, O = other

Status: CR=captured and released, P=photographed, C=CO2 method, V=vouchered, GS=good sight, S=sight, PS=Poor sight

June 28, 2018

Prairie Vegetation and Insect Monitoring Workshop

Effects of grazing versus fire for prairie management

Project summary:

Minnesota's tallgrass prairies depend on disturbance (e.g., fire, grazing, drought), without which they would rapidly transition to woodland and forest. Land managers often use prescribed fire and "conservation grazing" (the use of grazing by domestic animals to achieve conservation goals) to preserve prairie plant communities and the many pollinators, birds, and mammals that depend on them. Although effects of fire on northern tallgrass prairies are well documented, there are no studies of the effects of conservation grazing on Minnesota prairies in the published literature. Yet, because prescribed fires are expensive, require significant personnel numbers and time, can only be completed during specific windows of time, and may have negative effects on some pollinators, managers have turned to conservation grazing, despite the lack of research. Our study addresses this knowledge gap.

Methods:

Plant communities were assessed at 75 remnant burned or grazed prairies in 2016 and 2017. Sites were chosen based on having been either only-grazed or only-burned between 2005-2015. Twenty of these sites were also surveyed three times each summer for bees and butterflies. See the provided vegetation monitoring and bee and butterfly sampling protocols for additional details, instructions, and required supplies. In addition to our field surveys, we also performed a landscape-level analysis to determine percent land cover type within a 1.5 km buffer surrounding our field sites using USDA CropScape, USFWS, MN DNR, and South Dakota State University coverages. This information will be used to assess potential influence of surrounding landscape-level differences on plant, bee and butterfly presence at each field site.

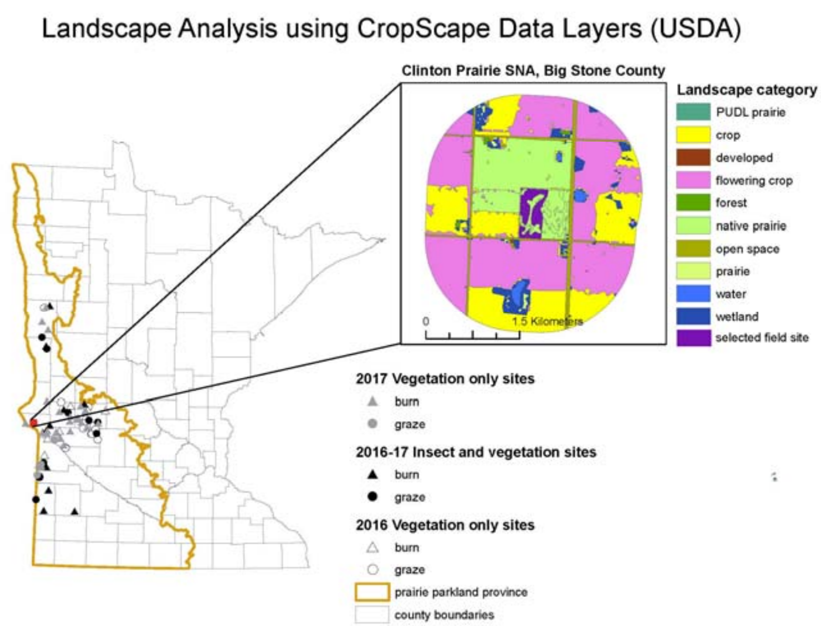

Figure 1. Locations of our field sites in the Prairie Parkland Provence in western MN, and examples of landscape analyses of one field site. Map created with ESRI ArcGIS 10.5.1 with data from MNDNR, USDA, and SDSU by Jen Larson.

Conclusions: Vegetation on burned sites was generally less weedy than that on grazed sites. Nonetheless, burning and grazing favored different communities of bees, and butterflies, suggesting that each management type has a role in maintaining Minnesota's prairies.

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