2019

The effects of native and domestic grazers on the health of bumble bee (Bombus spp.) populations in a historical tallgrass prairie ecosystem

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THE EFFECTS OF NATIVE AND DOMESTIC GRAZERS ON THE HEALTH OF BUMBLE BEE (BOMBUS SPP.) POPULATIONS IN A HISTORICAL TALLGRASS PRAIRIE ECOSYSTEM

By

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Honors Scholarship Project

Submitted to the Faculty of

Olivet Nazarene University

for partial fulfillment of the requirements for

GRADUATION WITH UNIVERSITY HONORS

February, 2019

BACHELOR OF SCIENCE

in

Zoology

Scholarship Project Advisor (printed)	Signature	Date
Honors Council Chair (printed)	Signature	Date
Honors Council Member (printed)	Signature	Date

ACKNOWLEDGMENTS

This research was performed under the supervision of Dr. Derek Rosenberger of Olivet Nazarene University. Dr. Rosenberger provided great assistance and support throughout the entire process: from the formation of this study and the writing of proposals and permit requests to compiling and analyzing data, writing reports, and opening doors to present at multiple scientific conferences. Dr. Rosenberger, as well as co-student researcher Anne Hughes-Wagner, spent hours in the field assisting in data collection by performing transect surveys in multiple locations. Funding for the research was provided by the Hippenhammer research grant. Midewin National Tallgrass Prairie made this research possible by providing permits to perform surveys on their property, as well as by generously providing escorts in the bison pasture so we could safely perform surveys there. Finally, I cannot thank Olivet's honors program enough for providing this opportunity and for support throughout the process both by faculty and other students.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Bumble bees (*Bombus spp.)* play an important role in the pollination of ecologically and economically significant plants worldwide. In recent years, bumble bee populations have suffered decline throughout North America, particularly in the Midwest. Many factors likely contribute to this decline, including the use of pesticides, disease, and habitat loss. Although cattle grazing space is a common use for Midwestern grassland, a comparison had not been made between the capacity of cattle pasture to support bumble bee communities with the capacity of tallgrass prairie, a habitat thought to be optimal for requisite floral resources. Additionally, the reintroduction of bison is becoming increasingly prevalent in the Midwest, both as a restoration tool and as a farmed meat, but it is not known if there is an effect of bison grazing on bumble bee communities. In this study, we sought to determine what effects grassland management for restored prairie, cattle pasture, and bison pasture have on the community composition of bumble bees at Midewin National Tallgrass Prairie in northeastern Illinois. Abundance, species richness, and diversity were recorded across transects in each habitat type using standard sweep net protocol. We found that restored prairie supports significantly higher abundance and species richness of bumble bees than either cattle or bison pasture. This study can be used to inform grassland managers of conservation implications when making land use decisions in the face of habitat loss and decline of bumble bees across the Midwest.

Keywords: bumble bee, conservation, prairie, grassland, pollinator, bison, cattle, grazing

INTRODUCTION

Bumble bees (*Bombus* spp.) are a vital piece of many ecosystems worldwide. Ninety percent of wild plants in North America depend on pollinators like bumble bees to survive and reproduce (Chavarria, 2000). Consequently, pollinators are especially crucial to a multitude of ecosystems by playing an important role in the survival of organisms low on the food chain. Humans are not exempt from pollinator dependence, as bumble bee pollination is vital not only to natural systems, but some managed agricultural systems as well (Corbet et al., 1991; Goulson et al., 2008). Bumble bees play a significant role in food production, as 15 billion dollars per year are spent on foods pollinated by bees (Chavarria, 2000). Bumble bee colonies are widely reared for crop pollination because they can lower production costs, increase yields, and even improve fruit quality (Kevan et al., 1991; Velthuis, 2006).

Despite the clear value of bumble bees, this environmentally and economically vital population is in trouble. The species richness and abundance of bumble bees, both wild and managed, as well as many other pollinators, have been declining over the last 50 years, especially in the Midwest (Cameron, 2011; Grixti, 2009). Concern is rising for this issue because of the serious environmental and socioeconomic effects of bumble bee decline. Already, one North American species of bumble bee, the rusty patched bumble bee (*Bombus affinis*), once found throughout eastern North America, has recently been listed as endangered (Szymanski, 2016). Other species have also suffered, as only 11 of the 16 species on record in 1950 were collected in extensive sampling performed in 1999 across Illinois (Grixti, 2009). Furthermore, half of the bumble bee

species found historically in Illinois have become locally extinct or have suffered significant declines in abundance or distribution (Grixti, 2009).

While more research needs to be done on the cause of the observed decline, known drivers include introduced parasites and pathogens, the increasing reliance on pesticides in agriculture, and habitat loss, often due to agricultural development (Grixti, 2009; DeWalt et al., 2005; Hladik, 2016). In the Midwest, tallgrass prairie, a habitat vital to the existence of bumble bee communities, is one of the most threatened habitats on Earth. Only about 0.01% of Illinois' original tallgrass prairie remains (White 1978; Taft et al. 2006) with 95% of the original prairie in the northern two-thirds of Illinois having been converted to agricultural land as of 2005 (DeWalt et al., 2005). Conversion of tallgrass prairie to agricultural land is particularly detrimental to bumble bee populations because it strips the habitat of the floral resources that bumble bees depend on (Kremen et al. 2002).

Various methods to counteract bumble bee declines have been proposed, such as improving management of amenity grasslands, eco-friendly pest management and other environmentally conscious agricultural practices, encouraging gardeners to plant bee-friendly flowers, and protecting and restoring natural and semi-natural habitats (Goulson et al., 2015). Active prairie restoration is a particularly effective method, as restoration of agricultural areas has been shown to increase native bee abundance and species richness to natural, undisturbed remnant prairie levels within 2-3 years of restoration (Griffin, 2017). However, much of the Midwest is still covered in agricultural

land, and prairie restoration is an expensive and time consuming method, so it is not always an immediate option.

At Midewin National Tallgrass Prairie in northeastern Illinois, conservationists are working to restore a variety of agricultural fields back to the wild tallgrass prairie ecosystem that once covered much of the Midwest. Many healthy restored prairies now exist at Midewin, though many land plots on the property have yet to undergo active restoration. Some of these unrestored plots are managed using cattle grazing to keep exotic plants under control as degradation of native grasslands makes them more susceptible to non-native weedy species. (Wilsey et al. 2009). While cattle serve as a source of periodic disturbance and are effective at keeping the invasive grasses that displace native floral resources from getting out of control (Fuhlendorf and Engle 2004), the degree to which this grassland management method supports native bumble bee communities remains unclear.

In addition to the use of cattle as a grassland management method, Midewin National Tallgrass Prairie, as well as other tallgrass prairie restoration sites across the Midwest, are experimenting with the reintroduction of bison as a possible restoration tool. Like cattle, bison are grazers and provide periodic disturbance that can help curb the domination of invasive grasses. However, as a historically native species, bison differ from cattle in that they have been a natural part of the tallgrass prairie ecosystem before being removed from the landscape (The National Forest Foundation, 2012). Bison and cattle differ in grazing behaviors, as bison spend half as much time per day grazing and move 50% - 150% faster when grazing than cattle do (Kohl, et al. 2005).

These differences in grazing habits may affect the plant communities of the landscapes being grazed. Although one study found that bison and cattle grazing sites were 85% similar in plant richness and diversity (Towne et al. 2005), the 15% difference, though seemingly minor, may still affect bumble bees due to the correlation between rich floral resources and bumble bee species richness and abundance. Because rich floral resources are beneficial to bumble bee communities, increasing the abundance and species richness of floral resources can be beneficial to bumble bee communities (Potts et al. 2003, Hines and Hendrix 2005, Roulston and Goodell 2011).

While one study has suggested that cattle grazing is beneficial to bumble bee communities in terms of species richness and abundance compared to unmanaged grassland in Northwest Europe (Carvell, 2001), few have assessed the effects of grazing on bumble bee community dynamics (Carvell, 2001; Hatfield & LeBuhn, 2007), and none have compared cattle pastures with restored tallgrass prairie (Xie et al., 2008). Additionally, no studies have assessed the effect of bison grazing on bumble bee communities or the differences between bison and cattle grazing on bumble bee communities (Harmon-Threatt and Chin, 2019).

Our primary objective in this study was to determine how land management for restored prairie, active cattle pasture, and active bison pasture at Midewin National Tallgrass Prairie impact bumble bee populations. Due to the importance of floral resources for bumble bee populations (Spiesman 2017, Potts et al. 2003, Hines and Hendrix 2005, Roulston and Goodell 2011), we hypothesized that restored prairies support greater bumble bee abundance, species richness, and diversity than cattle and

bison pastures due to the expectation of higher dominance of floral resources in an actively restored and seeded prairie (Harmon-Threatt and Hendrix, 2014; Delaney et al. 2015). We also hypothesized that bison pastures support greater bumble bee abundance, species richness, and diversity than cattle pastures because bison grazing allows for higher plant species richness than cattle grazing (Towne et al. 2005). Determining the capacity of cattle pasture and bison pasture to support bumble bee populations in relation to restored prairie could provide valuable data for effective grassland management and conservation efforts.

METHODS

Bumble bee communities at Midewin were assessed within multiple restored tallgrass prairie areas of the preserve and compared to multiple large tallgrass cattle pastures and tallgrass bison pastures (see Appendix 1). We used a timed transect survey method (Xie, Williams, Tang, 2008) to survey 100m transects located in each habitat type over two years. The majority of the transects were spread evenly across two separate restored prairie locations (South Patrol Road and Iron Bridge prairies), two separate cattle pastures (pastures E9 and W1), and three connected bison pastures (NW, NE, and SW pastures). South Patrol Road Prairie transects were placed along a path that runs through the area, rather than through the inner prairie, due to tall and dense vegetation in the prairie itself. This was done in order to keep survey sampling consistent with the lower and less densely vegetated cattle and bison pastures. Bumble bee populations along the path were likely representative of the communities within

the prairie as a whole, as determined by a comparative study of floral resources on and off of the South Patrol Road path that showed no significant differences between floral compositions (see Appendix 2). Because bee populations depend upon floral resources for nectar and pollen (Roulston and Goodell 2011), close similarity between floral resources likely indicates close similarity of bumble bee populations as well.

Each transect was surveyed one time between the beginning of July and the end of August over the course of two survey years, 2017 and 2018. Surveys were conducted approximately twice a week. Transects to be surveyed each day were randomly selected prior to the survey date. Surveys were only performed on days with partial to no cloud cover, no rain, and temperatures between 23 and 29°C, the preferred range for bumble bee activity. On normal survey days, two restored prairie and two cattle pasture transects were surveyed, starting at 11 AM, alternating the order of locations surveyed. Bison pasture surveys were completed periodically over the same duration and following the same environmental requirements.

During each 30 minute transect survey, an aerial sweep net was used to capture all bumble bees sighted along each transect. All bumble bees caught during the 30 minute duration were placed in vials and put on ice until the end of the survey period, at which time they were identified to species and released. Date, time, location, temperature, and species of flower on which the individual was captured, if applicable, were also recorded for each survey. Additional surveys were also completed in various restored prairie and cattle pasture locations across Midewin using the same methods to increase sample size and expand the spatial coverage of the surveys performed.

The statistical program R was used to analyze data from both years using ANOVA in a mixed effects framework, with year as a random effect. Residuals were visually assessed to ensure assumptions of homoscedasticity and normality of errors were met. Square root transformation was required for abundance to meet these assumptions. Means between habitats were compared using a Tukey HSD test. Diversity was calculated using Shannon's Diversity Index.

RESULTS

Nearly 500 bees were captured over two years in restored prairie, cattle pasture, and bison pasture transects (Table 1). We found a total of six bumble bee species between the three habitat types. *B. griseocollis* was the most common species found in each location, while *B. fervidus* was the least common species found in the restored prairie, *B. pensylvanicus* was the least common species found in the cattle pasture, and *B. bimaculatus* was the least common species found in the bison pasture.

Table 1. Relative abundance (%) of bumble bees for restored prairie, cattle, and bison pasture.

Bombus Sp.	Restored Prairie (n=276)	Cattle Pasture (n=73)	Bison Pasture (n=128)
B. griseocollis	31.2	45.2	53.1
B. impatiens	30.8	16.4	3.9
B. auricomus	18.5	15.1	39.1
B. bimaculatus	17.8	9.6	0.8
B. pensylvanicus	1.1	5.5	0.0
B. fervidus	0.7	8.2	3.1

Average abundance of bumble bees was affected by habitat (Fig. 1, $F_{1,94}$=12.89, p<0.0001). Restored prairie had over three times more bumble bees per transect than cattle pasture (Fig. 1, Z=4.68, p<0.0001), and 1.7 times as many bees than bison pasture (Fig. 1, Z=3.62, p=0.00083). Abundance was two times greater in bison pasture compared to that of cattle, however they were not significantly different (Fig. 1, Z=-0.36, p=0.93).

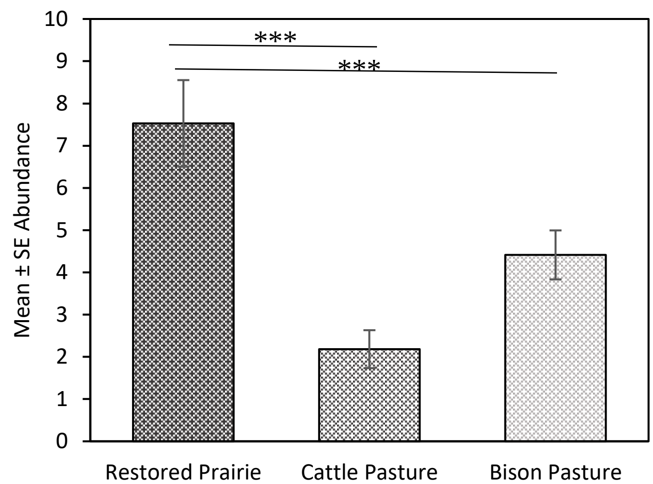

Figure 1. Mean total abundance of bumble bees per transect is greater in restored prairie (n = 33) than cattle pasture (n = 36) and bison pasture (n = 29) at Midewin National Tallgrass Prairie ($F_{1,94}$=12.89, p<0.0001). ***denotes p-value of less than 0.001.

The average species richness, or number of species between sites was also affected by habitat (Fig. 2, $F_{1,94}$=16.12, p<0.0001). Nearly twice as many species were found on average in restored prairie compared to cattle pasture (Fig. 2, Z=4.6, p<0.0001) and 1.5 times as many species were found in restored prairie compared to bison pasture (Fig. 2, Z=4.84, p<0.0001). Though cattle and bison pasture were not significantly different, richness was 1.5 times greater in bison pasture compared to cattle pasture (Fig. 2, Z=0.89, p=0.65).

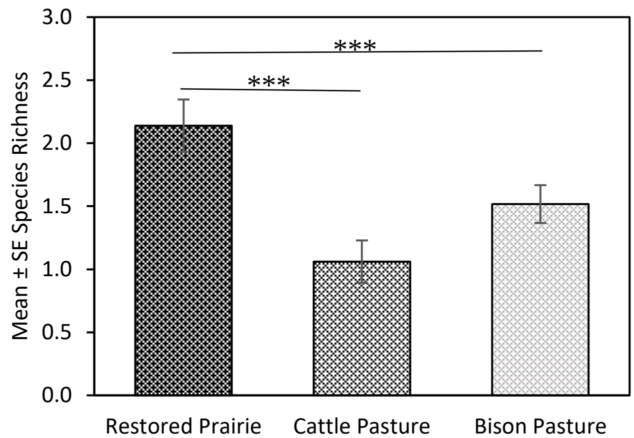

Figure 2. Mean bumble bee species richness per transect is greater in restored prairie (*n* = 33) than cattle pasture (*n* = 36) and bison pasture (n = 29) at Midewin National Tallgrass Prairie ($F_{1,94}$=16.12, p<0.0001). ***denotes p-value of less than 0.001.

Diversity was affected by habitat (Fig. 3, $F_{1,64}$=4.73, p=0.012) but was only significantly different between restored prairie and cattle pasture. Diversity was calculated by Shannon's Diversity Index, which is used to calculate species diversity in a community, taking both abundance and evenness of the species present into account. We used Shannon's D-value, which ranges from 0 to 1, with 1 being complete evenness. Diversity was 1.7 times higher in the cattle pasture than the restored prairie (Fig. 2, Z=-3.08, p=0.0062).

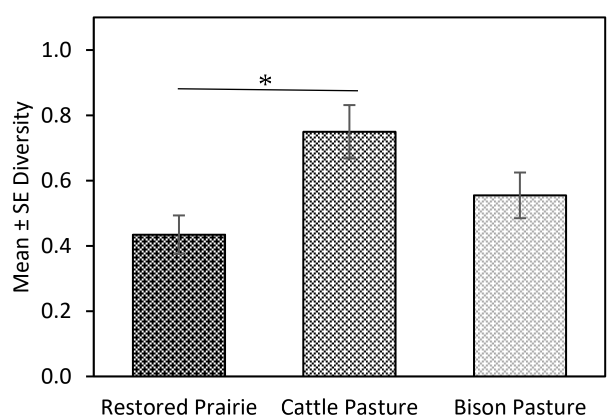

Figure 3. Mean diversity is greater in cattle pasture (n=36) than in restored prairie (n=33) at Midewin National Tallgrass Prairie ($F_{1,64}$=4.73, p=0.012). * denotes p-value of less than 0.05.

In the restored prairie, the most common flower visited by bumble bees was Wild Bergamot (*Monarda fistulosa*), making up 31% of the host flowers, while the most common flower host in both the cattle and bison pasture was Queen Anne's Lace (*Daucus carota*), making up 26% and 37% of the host flowers, respectively (Table 2). Twenty four floral species total served as hosts in the study, although the number of flowers visited in each location differed. Over twice as many floral host species were recorded in the restored prairie than in either the cattle or bison pasture (Fig. 4).

Table 2. Relative percentage of flowers landed on by bumble bees in restored prairie, cattle pasture, and bison pasture (July and August).

Flower Common Name	Flower Scientific Name	% Prairie	% Cattle	% Bison
Wild Bergamot	*Monarda fistulosa*	30.83	12.07	13.04
False Sunflower	*Heliopsis helianthoides*	20.95	0.00	0.00
Rattlesnake Master	*Eryngium yuccifolium*	6.72	0.00	0.00
Gray Headed Coneflower	*Ratibida pinnata*	5.93	1.72	0.87
Culver's Root	*Veronicastrum virginicum*	5.93	0.00	0.00
Tall Bellflower	*Campanula americana*	5.53	0.00	0.00
Queen Anne's Lace	*Daucus carota*	4.74	25.86	37.39
Swamp Milkweed	*Asclepias incarnata*	4.74	0.00	0.00
Prairie Sunflower	*Helianthus petiolaris*	3.16	0.00	0.00
Compass Plant	*Silphium laciniatum*	2.77	0.00	0.00
Wild Parsnip	*Pastinaca sativa*	2.77	0.00	0.00
Goldenrod	*Solidago sp.*	1.58	0.00	0.00
Red Clover	*Trifolium pratense*	1.19	22.41	26.09
Prairie Blazing Star	*Liatris pycnostachya*	0.79	0.00	0.00
Meadow Salsify	*Tragopogon pratensis*	0.79	0.00	0.00
Bull Thistle	*Cirsium vulgare*	0.40	20.69	5.22
Partridge Pea	*Chamaecrista fascicul*	0.40	0.00	0.00
White Sweet Clover	*Melilotus albus*	0.40	0.00	0.00
Showy Tick Trefoil	*Desmodium canadense*	0.40	0.00	0.00
Common Chicory	*Cichorium intybus*	0.00	5.17	14.78
Cutleaf Teasel	*Dipsacus laciniatus*	0.00	8.62	0.87
White Clover	*Trifolium repens*	0.00	3.45	0.00
Blue Vervain	*Verbena hastata*	0.00	0.00	0.87
Birds Foot Trefoil	*Lotus corniculatus*	0.00	0.00	0.87

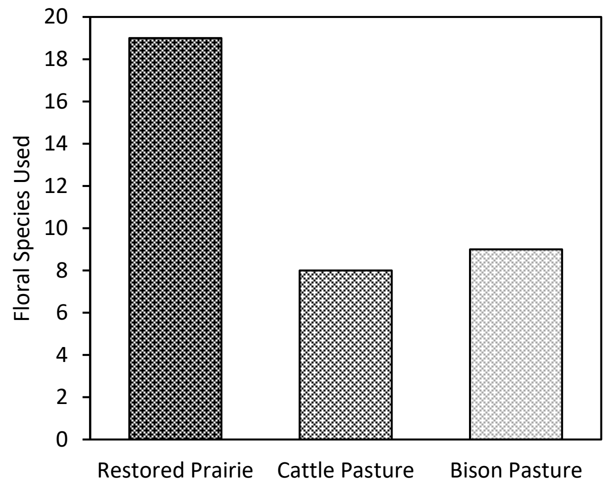

Figure 4. Number of floral host species used is higher in restored prairie than cattle and bison pastures.

DISCUSSION

The large drop in bumble bee abundance and species richness from restored prairie to both cattle and bison pasture suggests that bison and cattle pastures are not as effective as restored prairie at supporting bumble bee populations (Fig. 1). These findings support our hypothesis that restored prairie will support greater bumble bee abundance and species richness than cattle or bison pasture due to higher floral density in the actively restored prairie (Hegland 2006).

These findings further suggest that bumble bee abundance is positively affected by the species richness of floral resources (Potts et al. 2003, Hines and Hendrix 2005, Roulston and Goodell 2011), since the abundance (Fig. 1) and species richness (Fig. 2) of bumble bees found in each location mirrored the number of species used as floral hosts in each location (Fig. 4). In the restored prairie, where three times as many bees of twice

as many species were found, two times as many species of flowers were utilized as well (Fig. 1, 2, 4). This supports previous research that shows that areas with high floral density better support bumble bee populations (Hegland 2006), although more research is needed to further investigate species richness correlations in these habitats. Additionally, these findings suggest that cattle pasture has less capacity to support bumble bee communities than restored prairie, although cattle pasture has been previously shown to better support bumble bee populations than unmanaged grasslands (Carvell, 2001; Hatfield, 2007).

Unlike abundance and species richness, bumble bee diversity was actually higher in the cattle pasture than in the restored prairie (Fig. 3). While this may seem contradictory, the high diversity in cattle pasture may be attributed to a few causes. Because floral resources differed between locations, the number and dominance of bumble bee species may differ accordingly, due to morphological differences in bumble bee species that cause them to favor certain flower types as well as differences in foraging behavior of different species. Key differences in floral resources between locations may include requirements for short- or long- tongued nectar retrieval, seasonal availability, and dominance of flowers that attract either generalist or specialist bees.

Our finding that bumble bee species richness and abundance was greater in bison pasture compared to cattle pastures, although not statistically significant, is intriguing, and warrants future research. In this study, we were not able to compare cattle and bison grazing in a restored prairie plot, but instead compared restored prairie

with unrestored cattle and bison pastures. While this study does provide a baseline for the effectiveness of using cattle and bison grazing as grassland management methods, to more specifically study the effect of cattle and bison grazing as part of a prairie restoration process, a study should be done to compare an actively restored prairie with cattle or bison to an actively restored prairie without cattle or bison.

By assessing the impact of prairie restoration, cattle pastures, and bison pastures on bumble bee species richness and abundance, this study will help guide conservationists in taking further action to protect these ecologically important species. This study provides evidence that both cattle and bison pastures have less capacity than restored prairie to support bumble bee populations in historical tallgrass prairie regions of the Midwest. Our results suggest that bison pasture may support bumble bee populations better than cattle pasture, but more work is needed to validate this finding. Although grazed grassland may better support bumble bee populations than unmanaged grassland (Carvell, 2001), this study suggests that restored prairie is a better grassland management choice for supporting healthy bumble bee populations.

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APPENDIX 1

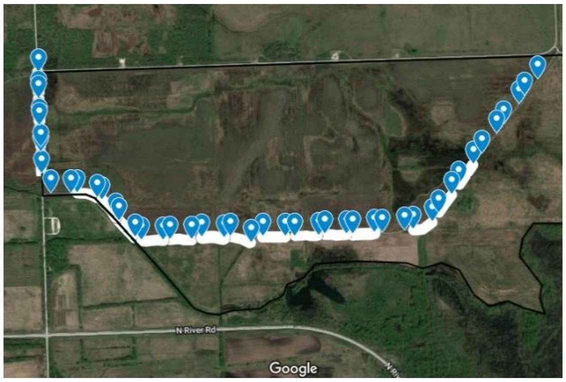

Figure A1: South Patrol Road transects.

Figure A2: Iron Bridge Prairie transects.

Figure A3: Cattle pasture E9 transects.

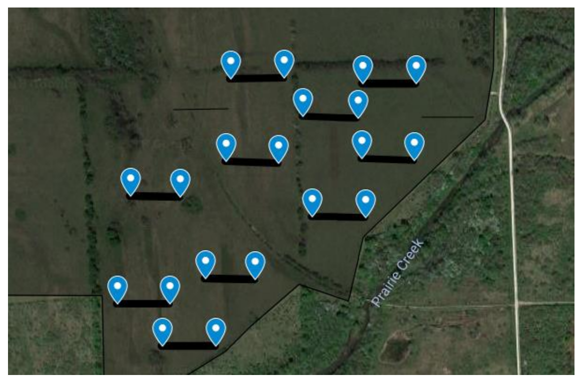

Figure A4: Cattle pasture W1 transects.

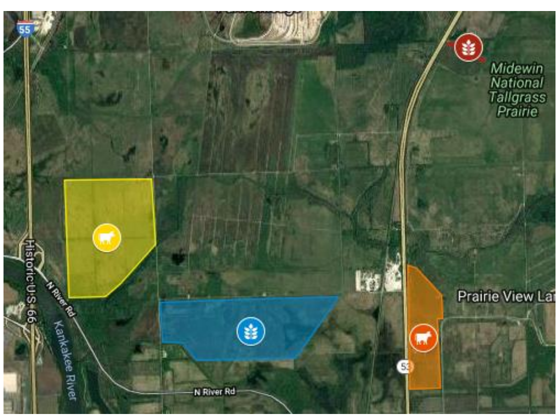

Figure A5: Sample sites.

APPENDIX 2

In order to compare data on the South Patrol Road path with data off path in the other locations, we had to make sure that the path was representative of the prairie as a whole. To determine this, we performed a comparative study of floral resources on and off of the South Patrol Road path. We chose to compare floral resources because bee populations depend on floral resources (Roulston and Goodell 2011), so close similarity between floral resources likely indicates close similarity of bumble bee populations as well. Five 10m transects were placed randomly along the path, and five more 10m transects were placed 10m off of the path, into the prairie. A string was placed along each transect, and the number of flower heads and species of those flowers were recorded along the length of the line. No significant difference was found in abundance or species richness on and off the path (Figures A6 and A7).

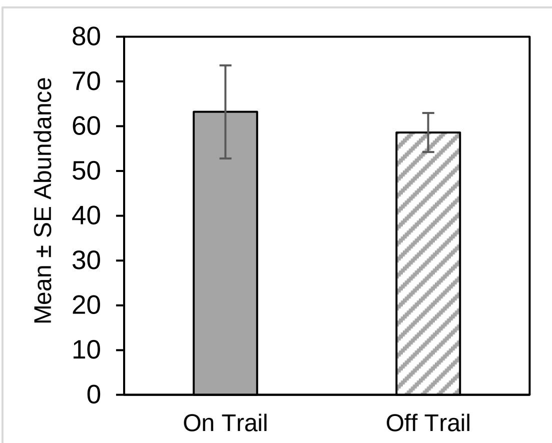

Figure A6: Floral abundance on and off SPR trail was similar.

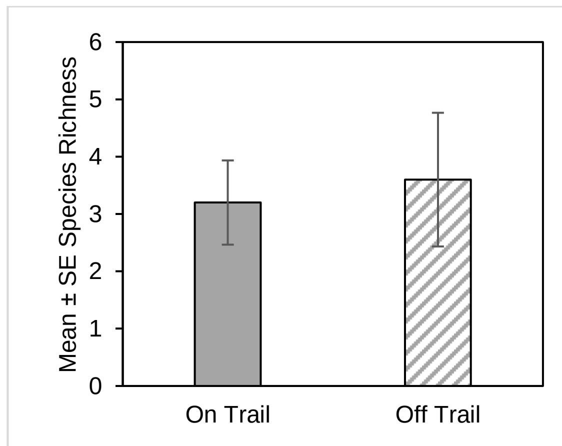

Figure A7: Floral species richness on and off SPR trail was similar.