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Pollinator Networks in Established Urban Prairies Compared to Rural Remnant Prairies

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POLLINATOR NETWORKS IN ESTABLISHED URBAN PRAIRIES COMPARED TO RURAL REMNANT PRAIRIES

A Master's Thesis

Presented to

The Graduate College of

Missouri State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Biology

By

Amanda Lynn Coleman

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ABSTRACT

Prairies support over 800 species of plants, insects, birds, fish, and mammals, even though only 1% of remnant prairies remain in the United States. Importantly, urban prairie “gardens/plots” are gaining popularity for their ecological services. However, it is not known to what extent these small urban prairies can sustain the plant-pollinator interactions that are vital to both the insects and the plants. The goal of my research was to examine plant/pollinator interactions in three urban prairies in southwest Missouri and compare them to rural prairies because rural prairies were predicted to have stronger plant/pollinator networks. Rural units were: Woods Prairie, Providence Prairie, and La Petite Gemme Prairie. Urban units were all in Springfield, MO: Valley Water Mill Park, Kickapoo Edge Prairie at Nathaniel Greene Park, and the Springfield Conservation Nature Center. From May through August 2018, I sampled the five most abundant forbs in bloom, the number of pollinator visits, and fidelity from dawn to dusk in all six units. I also examined the habitat matrices within an 8 km^2 radius around each prairie using ArcGIS Pro Online. I found that similarity between focal forb species in rural prairies and urban prairies was low. Insect visitation was significantly dependent on prairie type (rural/urban), month, insect group, and the interactions between them. Insect fidelity did not significantly differ between rural and urban prairies. The percentage of impervious surfaces in and around prairie types, as well as urban habitat matrices, did not negatively impact insect pollinator visits. These results suggest that current management of urban prairie units may be sufficient to sustain the same level of pollinator services as in rural prairies.

KEYWORDS: forbs, insect pollinators, insect fidelity, rural remnant prairies, urban prairies

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INTRODUCTION

Prairies are one of the most diverse habitats on Earth, home to over 800 plant species and numerous insects, fish, amphibians, birds, and mammals small and large (Anderson *et al.*, 1999). Unfortunately, prairies are also one of the most threatened (Rowe *et al.*, 2013). Global-wide conversion of prairies to agriculture and increasing urbanization has reduced prairie ecosystems to remnant fractions of their original range (Bates *et al.*, 2011; Hatten *et al.*, 2013). In North America, less than 1% of original prairies remain (Packard *et al.*, 2005; Rowe *et al.*, 2013). Tallgrass prairies once covered over one-third of the state of Missouri, but are now just 1% of their historical area (Anderson *et al.*, 1999).

At the same time, insects are on a global decline (Bates *et al.*, 2011; Ollerton, 2017), with one 27-year study finding 76% decline in flying insect biomass (Hallmann *et al.*, 2017). Widely accepted causes of insect decline include habitat loss and fragmentation, pesticides, pathogens, and climate change (Ahrné *et al.*, 2009; Potts *et al.*, 2010; Hatten *et al.*, 2013; Neame *et al.*, 2013; Blaauw and Isaacs, 2014; Baldock *et al.*, 2015; Ollerton, 2017; Plascencia and Philpott, 2017). Insects play vital roles as food for predators, as detritus feeders, and as pollinators (Hatten *et al.*, 2013; Hallmann *et al.*, 2017). Insect pollinators - bees, butterflies/moths, wasps, beetles, and flies – are important in pollinating an estimated 87.5% of wildflowers and 70% of crops worldwide (Bates *et al.*, 2011; Mader *et al.*, 2011). Insect pollinators are the driving force behind the success of prairie forbs (Mader *et al.*, 2011). Over 150 species of bees are found on prairies, ranging from generalists, which collect pollen and nectar from many types of forbs, to specialists, only seeking specific plants, co-evolved to ensure their mutual success (Anderson *et al.*, 1999). Bees are the most important group of pollinators (Potts *et al.*, 2016; Widhiono *et al.*,

2017) because they not only drink nectar from blooming flowers, and thus spread pollen to conspecific flowers through their visits, female bees also collect pollen to eat and provision their nests (Mader *et al.*, 2011). Other insect pollinators are not as widely studied, but their response diversity (varying responses of species to environmental pressures) and cross-scale resilience (resilience of species at varying scales) are beneficial for maintaining a diversity of flora (Senapathi *et al.*, 2017). Insect pollinators also exhibit fidelity, otherwise known as flower constancy, to visit one species of flower continuously, thereby increasing the probability that conspecific pollen will be transferred to the correct forb species (Jaworski *et al.*, 2015).

Prairie habitats cannot fully regenerate, especially if the land has been tilled or grazed (Packard *et al.*, 2005; Veldman *et al.*, 2015). The United States has not allowed prairies any legal protection and has yet to establish an economic value for them (Packard *et al.*, 2005). Prairie restoration is largely carried out by individuals or groups, rebuilding on any size land acquirable – from less than one hectare to several thousand hectares. Interest in the prairie ecosystem is not limited to the rural setting; urban residents and organizations also incorporate prairies wherever possible – in a front or back yard, a park, or an undeveloped parcel of land (Packard *et al.*, 2005). In fact, this study was initiated upon the request of the director of the Watershed Center of the Ozarks, Mike Kromrey, to understand if managed urban prairie gardens can be sustained through insect pollination services.

Management and restoration of prairies in rural areas has been studied at various scales (Prober and Thiele, 2005; Gieselman *et al.*, 2013; Swengel and Swengel, 2013; Smith and Cherry, 2014; Helden *et al.*, 2015; Bonari *et al.*, 2017). These studies ranged in scale from edaphic manipulations for grassland restorations (Prober and Thiele, 2005) to comparisons of management techniques over time in butterfly communities across multiples states (Swengel and

Swengel, 2013; Smith and Cherry, 2014). General findings include positive flora and fauna responses to management, such as fire or mowing. However, very little research has been carried out in small urban prairie plots/gardens. Therefore, it is not well-understood if smaller urban prairie gardens are sustainable through pollination services. Given that high insect abundance is indicative of a high-quality prairie (Anderson *et al.*, 1999) and old-growth prairies tend to have greater plant species diversity (Veldman *et al.*, 2015), I set out to answer five main questions related to urban prairies as compared to rural prairies: Are the dominating blooming forbs similar across rural and urban prairies? Are urban prairies as effective at attracting insect pollinators as are rural prairies? Do certain forbs attract more insect pollinators in rural or urban prairies? Do the visiting insect pollinators in urban compared to rural prairies have high fidelity to visit conspecific plants, thus increasing the potential of pollination? Is there a relationship between the habitat matrix in and around rural and urban prairies and plant/pollinator interactions?

Results of previous research on plant/pollinator networks along an urban to rural gradient have been variable, presenting the need for further research. For example, Geslin *et al.* (2013) experimented with open flowers and tubular flowers along an urbanization gradient in France. They found significantly lower insect pollinator visits to flowers in urban areas compared to suburban, agriculture, and semi-natural habitats. Syrphid flies and solitary bees significantly decreased with urbanization, but bumblebees were not impacted. The effects of urbanization upon insect pollinator interactions also were reported to limit outcrossing within open flowers (more generalist flowers). Ahrné *et al.* (2009) found a decrease in bumble bee diversity towards inner urban areas from more rural areas of Stockholm, Sweden. They also found that garden quality, based on management, affected bumble bee abundance and species composition. This indicates that poorly maintained urban gardens could weaken plant/pollinator networks. Bates *et al.* (2011) found pollinator diversity and abundance significantly decreased as urbanization increased along Birmingham, United Kingdom. Pollinator assemblages were also higher in suburban and rural sites and with higher floral quality. Plascencia and Philpott (2017) found a lower abundance of bees with more urbanization along the central California coast. However, Sirohi *et al.* (2015) found more diversity and abundance of bees in the urban "core" compared to meadows and nature reserves in Northampton, England. Baldock *et al.* (2015) found overall no significant difference in insect pollinator abundance and species richness between urban, farmland, and nature reserves in the United Kingdom.

I hypothesized that if I identified the five most common blooming forbs in rural remnant prairies and urban prairies in southwest Missouri, I would find that the rural remnant prairies have high similarity of focal forb species to urban prairies, as urban prairies are generally planted with seeds from local rural prairies. I also hypothesized that insect pollinator visits would be higher in rural prairies than urban prairies based on findings by Anderson *et al.* (1999) and Veldman *et al.* (2015) (see above). I hypothesized that insect group fidelity would not differ in rural and urban prairies founded on the evolution of pollinator syndromes and plant multi-sensory cues that motivate insect pollinator selection (Jaworski *et al.*, 2015). Lastly, I hypothesized that the habitat matrix around rural prairies would contribute to greater numbers of plant/pollinator interactions than the habitat matrix around urban prairies, as urban areas have a higher percentage of impervious surfaces which reduce nesting and available resources. I assessed plant/pollinator interactions in urban compared to rural prairies, and also assessed how current management practices and prairie histories (including edaphic factors and habitat matrix around the prairies) affect the most abundant plant species, pollinator group visits and fidelity at rural and urban prairies. Based on this information, recommendations (best practices) can be addressed for urban prairies.

METHODS

Rural and Urban Prairie Site Descriptions

The goal of the study was to examine the five most abundant forbs (focal forb species) blooming and pollinator visits by five insect groups in each month in urban prairies that were recently established. As a relative comparison, I examined rural prairies that shared a soil type with a given urban prairie. To address this goal, I carried out an observational study in three rural and three urban prairie units in southwest Missouri between May and August 2018 (Figure 1). The rural prairies are in counties with a population of less than 40,000, while the urban prairies are within the city of Springfield, MO (estimated population 168,122) in Greene County (estimated population 291,923) ("US Census, 2018") (Figure 1). The habitat matrices around rural prairies have more grassland/pasture and tilled croplands than the habitat matrices around urban prairies (Figure 2). The habitat matrices around rural prairies also have less parks and golf courses, single-family houses, barren land, and forest and shrubs than the habitat matrices around urban prairies (Figure 2).

La Petite Gemme Prairie (LP-R) is a rural prairie owned by the Missouri Prairie Foundation and managed by the Missouri Department of Conservation (MDC). It is a 15.0-hectare remnant prairie, located just south of Bolivar, MO (estimated population 11,038) in Polk County (estimated population 32,201) (Anderson *et al.*, 1999; "US Census, 2018"). This prairie is dry-mesic, with the western half containing an acidic hardpan, and includes a total of 321 plant species (Anderson *et al.*, 1999). It shares a soil type with urban Kickapoo Edge Prairie.

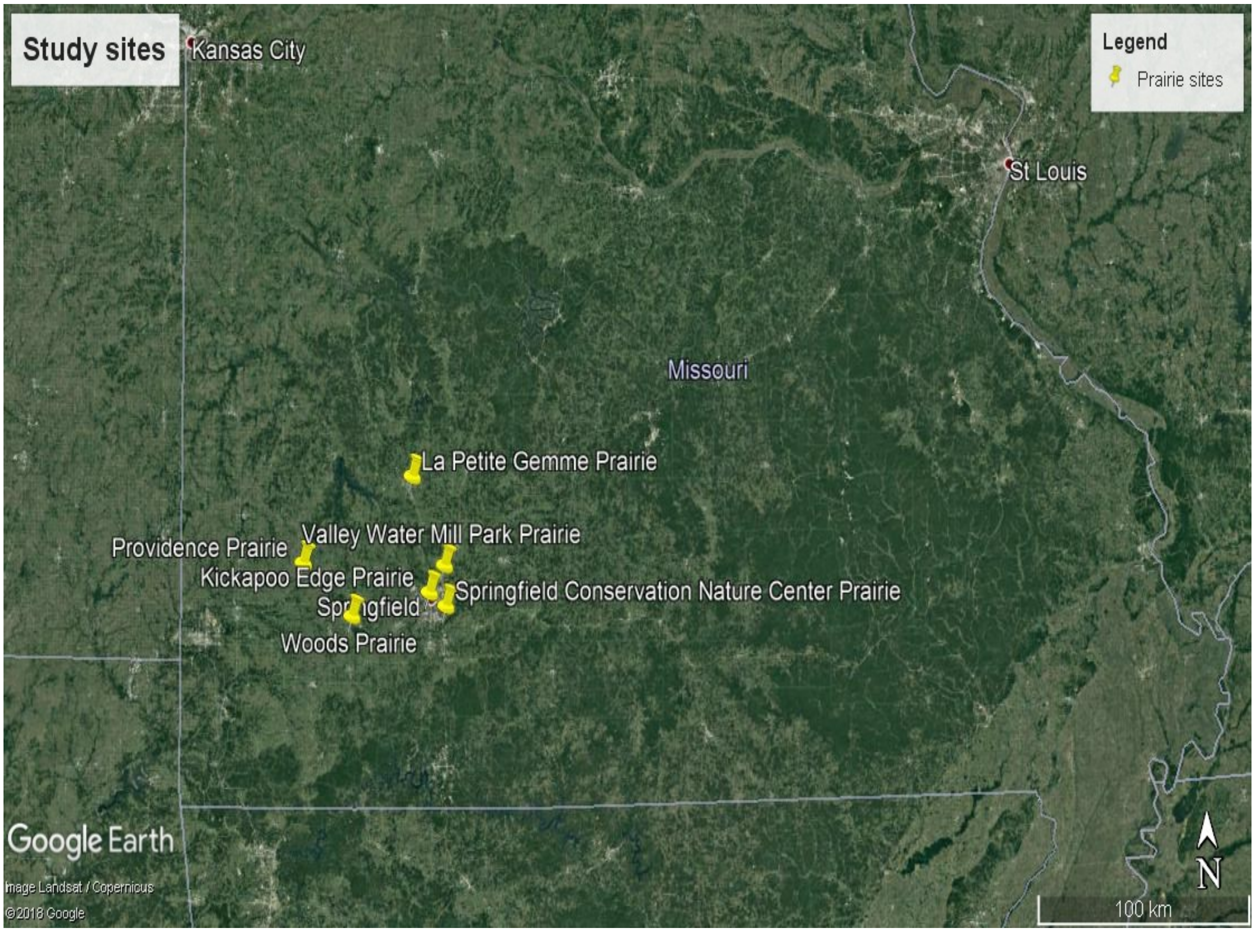


Figure 1. Map of rural and urban prairie study sites.

Woods Prairie (WP-R), located four miles east of Mt. Vernon, MO (population 4,017; Lawrence County - estimated population 38,359), is a rural prairie owned and managed by Ozark Regional Land Trust since 1999 ("Mt Vernon, MO"; "US Census, 2018"). It is an isolated 16.0-hectare remnant (Anderson *et al.*, 1999; Thomas *et al.*, 2004) of dry-mesic prairie on the southeastern-most edge of the natural prairies of southwest Missouri, home to a diverse flora of 228 plant species (Thomas *et al.*, 2004). It shares a soil type with urban Valley Water Mill Park Prairie.

Providence Prairie (PP-R) is a rural prairie in northern Lawrence County, MO (estimated population 38,359) ("US Census, 2018"). It was named this because it was by providence that

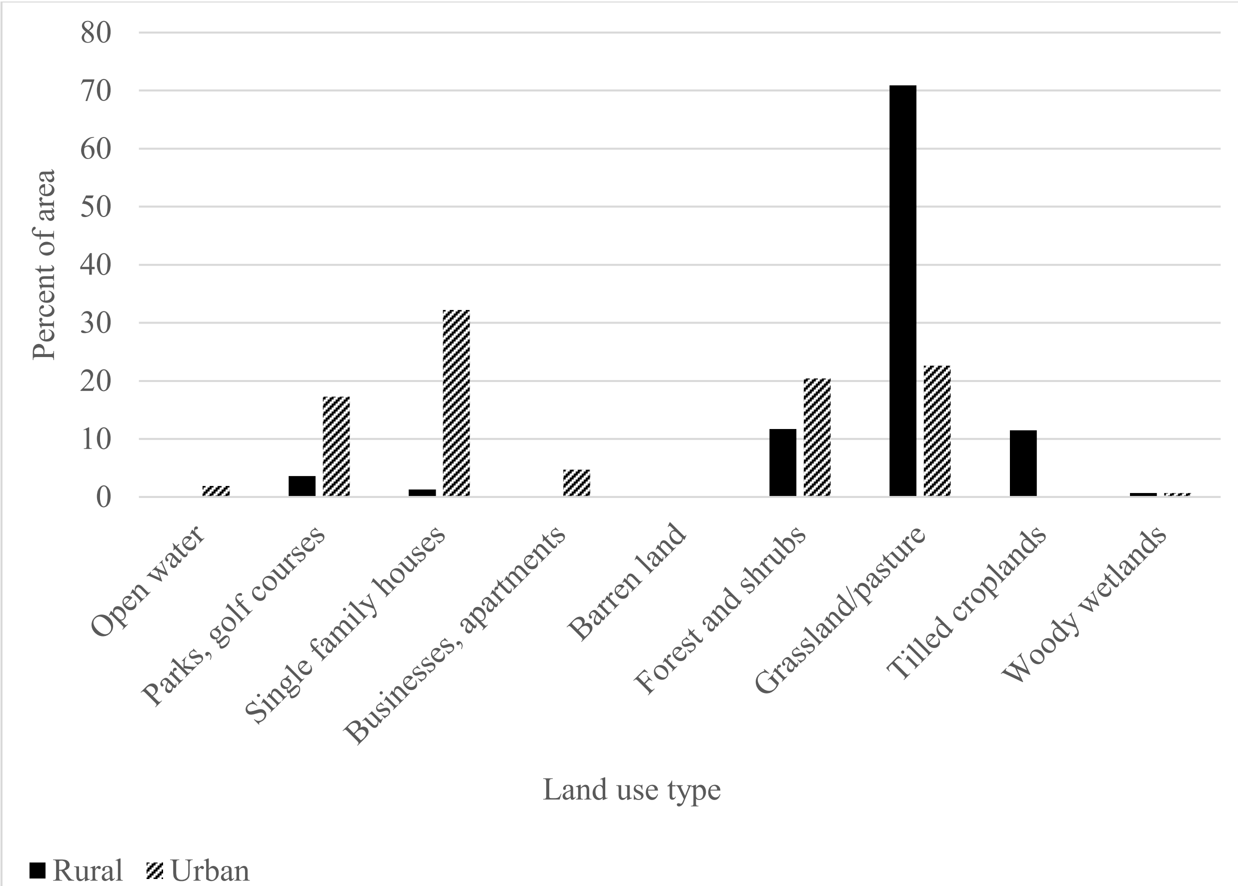


Figure 2. Comparison of land use types by mean percentage in and around rural and urban prairies within an 8 km^2 radius using Google Earth Pro imagery and the geographical information system software, ArcGIS Pro Online. Exact numbers are as follows: open water: rural 0.1%, urban 1.9%; Parks and golf courses: rural 3.6%, urban 17.3%; single-family houses: rural 1.3%, urban 32.2%; businesses and apartments: rural 0.1%, urban 4.7%; barren land: rural 0.0%, urban 0.1%; forests and shrubs: rural 11.7%, urban 20.4%; grasslands/pastures: rural 70.9%, urban 22.6%; tilled croplands: rural 11.5%, urban 0.0%; woody wetlands: rural 0.7%, urban 0.7%.

this prairie did not get plowed. The MDC purchased this land in 1994 and manages the 4.0 hectare of wetland prairie within the 79.0-hectare area. This prairie is known for showy wildflowers in the summer (Anderson *et al.*, 1999). It shares a soil type with urban Nature Center Prairie.

Kickapoo Edge Prairie (KE-U), an urban prairie owned and managed by the Springfield Botanical Gardens and the Missouri Prairie Foundation, is the remaining edge of the historical

Kickapoo Prairie where the first settler in Springfield established his homestead. This site is approximately 1.0-hectare of original prairie that was turned into farmland, then became forested after the agriculture. There is a nearby lake that was dredged at one point and the hardpan stream sludge was spread over the prairie. Work over the last 17 years has been successful at restoring it back to prairie (personal conversation with Ric Mayer of the Ozarks Greenway field crew on August 11, 2018). They continue to plant starts of native grasses and forbs from Missouri Wildflowers Nursery.

Valley Water Mill Park Prairie (VW-U), owned and managed by the Watershed Committee of the Ozarks, is a fairly new urban prairie, actively managed since 2013. This 0.21-hectare demonstration prairie, designed to educate visitors of the Watershed Center, is situated over a ground-source heat pump and construction-packed mixed soil. It was seeded in February 2015 with companion grass and a forb-heavy mix from Missouri Wildflowers Nursery. It is truly an island, surrounded by a pervious and impervious parking lot.

Springfield Conservation Nature Center (NC-U) is MDC owned and managed. Within this 32.0-hectare area is a 4.0-hectare floodplain situated next to Galloway Creek that employees and volunteers converted from agriculture land to prairie around 1993. Since then, it has been seeded and planted with native plants from Missouri Wildflowers Nursery and with seeds from Hamilton Native Outpost. The prairie gets flooded frequently due to excess runoff from nearby homes and businesses, creating a volatile matrix of introduced plant species that compete for space among the native grasses and forbs.

Focal Forb Species Observations

During the second half of each month from May to August 2018 I chose a site at random from my list of urban and rural prairies to visit to lessen temporal sampling bias (Bates *et al.*, 2011). Arriving at a prairie at dawn, I noted which forb species were in bloom and determined the five most abundant forb species as I walked the area of the prairie. I assigned an abundance code to each focal forb species based on a visual assessment of the forbs' overall cover in relation to all other vegetation in the prairie (prairie abundance codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover). I also observed distribution patterns of focal forb species and assigned distribution codes based on the overall groupings of the focal forb species (distribution codes: R=random, C=clumped, E=even).

I chose a patch of forbs from my focal floral species list and sat close enough to the patch so I could focus on individual flowers. A patch spanned across at least two individual plants and no farther than where I could focus and identify the flowers and visiting insect pollinator groups. I noted the time, then took global positioning system (GPS) coordinates of where I was sitting using a Garmin GPSmap 62st handheld navigator. Using a handheld Kestrel 4000 Pocket Weather Tracker, I took the temperature in degrees Celsius (°C), relative humidity as a percentage, and wind speed in meters per second. I did not collect data if the temperature was below 17°C, in the rain, or in high winds (Magrach *et al.*, 2017).

Focal Forb Species Lists

I compiled a list of focal forb species by family, as well as the prairie(s) and month(s) that each species was found. I identified any overlap of focal forb species found in both prairie types, and which focal forb species were native or introduced to Missouri tallgrass prairies using Steyermark's Flora of Missouri (Steyermark, volume 1, 1999, volume 2, 2006, volume 3, 2013). From the list I was able to determine if particular forb species occurred more in rural than urban prairies, and occurrence across both prairie types, soil types, and month. I listed distributions and abundances of focal forb species in each prairie. I then calculated the Jaccard similarity index (JSI) on the focal forb species within and between rural and urban prairies to quantify similarities between prairies.

Counts of Insect Pollinator Visits to Focal Forb Species

I observed patches of focal forbs for visiting insect pollinators from five groups (bees, Hymenoptera; butterflies/moths, Lepidoptera; wasps, Hymenoptera; beetles, Coleoptera; and flies, Diptera). Although bees and wasps are in the same order Hymenoptera, I grouped them separately because most wasps only visit flowers to drink nectar, unlike bees (see above) (Mader *et al.*, 2011). In addition, wasp's shorter tongues can only access nectar from shallow generalist flowers (Mader *et al.*, 2011). I documented pollinator visits to the five focal forbs for 20 minutes at a time. A visit was recorded when an insect pollinator landed on a flower of the focal forb species being observed. Another visit was recorded when the same insect pollinator landed on a focal forb species flower on a separate plant within my limited view. A visit was not recorded when the same insect pollinator landed on another flower from the same plant. The number of visits observed were not a count of separate individual insect pollinators, only of visits received to focal forb species. Observations of insect pollinator visits averaged 40-60 minutes per focal forb species per prairie per month. The total time spent observing patches of five focal forb species for insect pollinator visits across six prairies and four months was 6,080 minutes.

To test for significant differences in mean pollinator visits as a function of rural/urban prairie types, hardpan/mesic/wetland soil types, insect groups, months, and interactions between them, I performed an ANOVA using the statistical software package, Minitab, version 18. A significance level of $\alpha = 0.05$ was used.

I examined which focal forb species attracted the most insect pollinators, and calculated mean insect pollinator visits to rural and urban prairies. I calculated the mean insect pollinator visits to focal forb species that are native and introduced to tallgrass prairies.

I then performed a chi-square test of independence on insect pollinator visits in rural and urban prairies to identify if insect pollinator visits are independent of prairie type using the statistical software package, Minitab, version 18. A significance level of $\alpha = 0.05$ was used. I then performed a post-hoc Bonferroni test in Microsoft Excel, version Office 365, to avoid committing a Type I error in interpreting the chi-square output. The corrected critical value of 0.003 (0.05/15) was used.

Insect Fidelity

I tracked each insect pollinator group to identify fidelity of that group. Immediately after each session of watching focal forbs for insect pollinator visits, I determined which insect pollinator group had the greatest number of visits. I followed individual insects from that group for 20 minutes. I recorded the focal forb species each time the insect landed on a flower. If I lost sight of the individual insect, I would find a new individual from the same group to follow. I was not able to determine if the same insect came back or if it was a new individual. I repeated the procedures for consecutive counts of insect pollinator visits and counts of insect pollinator fidelity until dusk. The total time spent observing insect fidelity over six prairies and four months was 4,900 minutes.

I performed a two-sample t-test to examine if insect pollinator group fidelity, measured in percentages, differed as a function of prairie location using the statistical software package, Minitab, version 18. Significance level of $\alpha = 0.05$ was used.

Surrounding Habitat Matrix

I examined the proportions of impervious surface in an area of 8 km^2 within and around each prairie using Google Earth Pro imagery and the geographical information system software, ArcGIS Pro Online. I examined the data for possible associations between the number of insect pollinator visits and the surrounding habitat matrix.

RESULTS

Focal Forb Species Abundance in Rural and Urban Prairies

Total Abundance. I found that 66 species were focal forb species. That is, the species list for focal species includes 66 species (Table 1). Only 9 of these forbs overlapped in rural and urban prairies (Table 1). In rural prairies across four months, there was a total of 38 focal forb species, and in urban prairies there was a total of 37 focal forb species (Table 1).

Native and Introduced Focal Forb Species. I found that 58 out of 66 focal species were native. Of the 58 native focal forb species, 29 were found in only rural prairies (97.4% native across rural prairies) (Appendix A-1) and 21 were found only in urban prairies (78.4% native across urban prairies) (Appendix A-2). I found only 8 native focal forb species that overlapped in rural and urban prairies (Appendix A-3). Native forbs accounted for 87.9% of the focal forb species across all prairie types.

I found that 8 out of the 66 focal forb species were introduced. Of the 8 introduced focal forb species, 0 were found in rural prairies only, 7 were found in urban prairies only (Appendix B), and 1 was found in both rural and urban prairies (*Leucanthemum vulgare*).

Most Common Focal Forb Species. I also provide the identity of focal forb species by their commonness – that is, they appeared on the focal forb species lists more than the other focal forb species (Table 2). Three species found in urban prairies in May tied as the most common, four species tied in June, and three species tied in July (Table 2).

I also categorized the focal forb species for the most common forb species per month based on soil type (Table 3). The most common forb varied, and sometimes there were none shared (Table 3).

Table 1. Focal forb species by family, USDA symbol, prairies found in, and months observed. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Apiaceae			
Conium maculatum (poison hemlock)	COMA2	NC-U	May
Daucus carota (Queen Anne's lace)	DACA6	NC-U	June, July
Eryngium yuccifolium (rattlesnake master)	ERYU	LP-R, WP-R, PP-R	July
Torilis arvensis (field hedge parsley)	TOAR	KE-U	June
Asclepiadaceae			
Asclepias syriaca (common milkweed)	ASSY	NC-U	June
Asteraceae			
Achillea millefolium (common yarrow)	ACMI2	LP-R	May
Berlandiera texana (Texas green eyes)	BEBE4	WP-R	July, August
Cichorium intybus (common chickory)	CIIN	KE-U, VW-U	July, August
Cirsium discolor (field thistle)	CIDI	LP-R, PP-R	August
Coreopsis grandiflora (bigflower coreopsis)	COGR5	LP-R	May
Coreopsis lanceolata (tickseed coreopsis)	COLA5	PP-R, KE-U, VW-U	May
Coreopsis tinctoria (plains coreopsis)	COTI3	VW-U	June
Echinacea pallida (pale purple coneflower)	ECPA	WP-R	June
Erigeron annuus (annual fleabane)	ERAN	KE-U	May
Erigeron strigosus (daisy fleabane)	ERST3	PP-R, VW-U, NC-U	May, June, July
Eupatorium serotinum (late boneset)	EUSE2	PP-R	August

Table 1 continued. Focal forb species by family, USDA symbol, prairies found in, and months observed. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	**USDA code**	**Prairies present**	**Month found**
Helenium flexuosum (purple-headed sneezeweed)	HEFL	PP-R	June, July
Helianthus mollis (ashy sunflower)	HEMO2	LP-R, PP-R	August
Heliopsis helianthoides (oxeye sunflower)	HEHE5	KE-U	June, July, August
Leucanthemum vulgare (ox-eye daisy)	LEVU	WP-R, VW-U, NC-U	May
Liatris pycnostachya (gayfeather, blazing star)	LIPY	LP-R, WP-R, PP-R	June, July
Ratibida pinnata (gray-headed coneflower)	RAPI	LP-R, KE-U, VW-U	June, July
Rudbeckia hirta (black-eyed Susan)	RUHI2	LP-R, WP-R, PP-R, VW-U, NC-U	June, July
Rudbeckia triloba (brown-eyed Susan)	RUTR2	NC-U	July, August
Silphium integrifolium (rosinweed)	SIIN2	VW-U	August
Silphium laciniatum (compass plant)	SILA3	KE-U, LP-R	July, August
Silphium perfoliatum (cup plant)	SIPE2	NC-U	August
Solidago altissima (tall goldenrod)	SOAL6	LP-R, WP-R, PP-R, NC-U	August
Solidago juncea (early goldenrod)	SOJU	VW-U	August
Solidago ptarmicoides (white upland aster)	SOPT4	WP-R	August
Solidago rigida (stiff goldenrod)	SORI2	WP-R	August
Solidago speciosa (showy goldenrod)	SOSP2	KE-U	August
Symphyotrichum novae-angliae (New England aster)	SYNO2	KE-U	August
Verbesina helianthoides (yellow crownbeard)	VEHE	NC-U	August
Verbesina virginica (white crownbeard)	VEVI3	NC-U	July, August

Table 1 continued. Focal forb species by family, USDA symbol, prairies found in, and months observed. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Vernonia baldwinii (western ironweed)	VEBA	KE-U	July
Vernonia fasciculata (prairie ironweed)	VEFA2	PP-R	August
Campanulaceae			
Lobelia siphilitica (blue lobelia)	LOSI	LP-R	August
Caryophyllaceae			
Silene regia (royal catchfly)	SIRE2	WP-R	July
Clusiaceae			
Hypericum prolificum (shrubby St. John's wort)	HYPR	VW-U	June, July, August
Commelinaceae			
Tradescantia ohiensis (smooth spiderwort)	TROH	LP-R, WP-R, KE-U, NC-U	May
Euphorbiaceae			
Euphorbia corollata (flowering spurge)	EUCO10	WP-R	August
Fabaceae			
Amorpha canescens (lead plant)	AMCA6	WP-R	June
Chamaecrista fasciculata (showy partridge pea)	CHFA2	VW-U	July, August
Dalea candida (white prairie clover)	DACA7	LP-R	June
Dalea purpurea (purple prairie clover)	DAPU5	WP-R	June
Desmodium canadense (showy tick trefoil)	DECA7	VW-U	August
Melilotus officinalis (yellow sweet clover)	MEOF	KE-U	May

Table 1 continued. Focal forb species by family, USDA symbol, prairies found in, and months observed. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Orbexilum pedunculatum (Sampson's snakeroot)	ORPE	PP-R	May
Trifolium pratense (red clover)	TRPR2	VW-U	May
Vicia villosa (winter vetch, hairy vetch)	VIVI	NC-U	May
Gentianaceae			
Sabatia campestris (prairie rose-gentian)	SACA3	WP-R	July
Lamiaceae			
Monarda fistulosa (wild bergamot)	MOFI	KE-U, NC-U	June
Physostegia angustifolia (false dragonhead)	PHAN6	WP-R, PP-R	June
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	LP-R, PP-R	June, July
Liliaceae			
Camassia scilloides (wild hyacinth)	CASC5	LP-R	May
Melanthium virginicum (bunchflower)	MEVI2	PP-R	June
Malvaceae			
Callirhoe involucrata (purple poppy mallow)	CAIN2	KE-U	June
Nyctaginaceae			
Mirabilis nyctaginea (wild four o'clock)	MINY	KE-U	May
Onagraceae			
Oenothera filiformis (large-flowered gaura)	OEFI2	LP-R	August
Plantaginaceae			

Table 1 continued. Focal forb species by family, USDA symbol, prairies found in, and months observed. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Penstemon digitalis (tall white beardtongue)	PEDI	LP-R, WP-R, PP-R, VW-U	May
Polemoniaceae			
Phlox divaricata (wild sweet William)	PHDI5	WP-R	May
Phlox glaberrima (smooth phlox)	PHGL4	PP-R	May
Ranunculaceae			
Delphinium carolinianum (prairie larkspur)	DECA3	WP-R	May
Rosaceae			
Rubus allegheniensis (Allegheny blackberry)	RUAL	NC-U	May
Verbenaceae			
Verbena stricta (hoary vervain)	VEST	VW-U	July

Table 2. Most common forb species per month in rural prairies and urban prairies.

Month	Found in	
	Rural	Urban
May	*Penstemon digitalis*	*Coreopsis lanceolata*
		Leucanthemum vulgare
		Tradescantia ohiensis
June	*Rudbeckia hirta*	*Erigeron strigosus*
		Monarda fistulosa
		Ratibida pinnata
		Rudbeckia hirta
July	*Eryngium yuccifolium*	*Cichorium intybus*
	Liatris pycnostachya	*Ratibida pinnata*
		Rudbeckia hirta
August	*Solidago altissima*	None

Table 3. Most common forb species per month per soil type.

Soil type	**Prairies**	Month	Most Common Forb
Hardpan	La Petite Gemme[1]	May	*Tradescantia ohiensis*
	Kickapoo Edge[2]	June	*Ratibida pinnata*
		July	*Silphium laciniatum*
		August	None
Mesic	Woods[1]	May	*Leucanthemum vulgare, Penstemon digitalis*
	Valley Water Mill[2]	June	*Rudbeckia hirta*
		July	None
		August	None
Wetland	Providence[1]	May	None
	Nature Center[2]	June	*Rudbeckia hirta*
		July	*Rudbeckia hirta*
		August	*Solidago altissima*

[1]Rural
[2]Urban

Focal forb species found in rural prairies varied in their spatial distributions and abundances (Appendices C-1-3), as did focal forb species found in urban prairies (Appendices C-4-6). The focal forb species varied in distribution and abundance across rural and urban prairies and across months (Appendices C-1-6).

Focal Forb Species Similarity of Rural and Urban Prairies

To further illustrate whether there was similarity in the blooming focal forb species between rural and urban prairies, Jaccard similarity indices (JSI) were constructed (Tables 4a-e). The JSI measures the proportion of the focal forb species that were shared across any two prairies. It is measured on a scale from 0-1, with 0 (0%) sharing no forb species and 1 (100%) having all species shared. Since there were three urban and three rural prairies, there are 15 possible JSI combinations. The JSI can be calculated combining all months (Table 4a) or calculated within a month (Tables 4b-4e).

I found that from May through August, focal forb species in rural prairies were more similar to each other than focal forb species in urban prairies were to each other (Table 4a). When I compared the mean JSI of individual rural prairies across urban prairies, I found very low similarity (Table 4a). For example, La Petite Gemme Prairie (LP-R) had 0.09 mean JSI (± standard deviation ±0.07, n=12); Woods Prairie (WP-R) had 0.08 mean JSI (±0.10, n=12); and Providence Prairie (PP-R) had 0.08 mean JSI (±0.12, n=12) across urban prairies (Table 4a). When I compared the mean JSI of rural prairies, urban prairies, and across rural and urban prairies, rural prairies were higher across all months and each individual month except May, when it tied with rural and urban prairies (Table 5).

Table 4a. Mean Jaccard similarity index of forb species between each prairie for May through August. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Mean	LP-R	WP-R	PP-R	KE-U	VW-U	NC-U
LP-R		0.18	0.36	0.08	0.09	0.11
WP-R			0.18	0.03	0.09	0.12
PP-R				0.03	0.14	0.08
KE-U					0.12	0.06
VW-U						0.09
NC-U						

Table 4b. Jaccard similarity index for forb species in May.

May	LP-R	WP-R	PP-R	KE-R	VW-U	NC-U
LP-R		0.25	0.11	0.11	0.11	0.11
WP-R			0.11	0.11	0.25	0.25
PP-R				0.11	0.43	0.00
KE-R					0.11	0.11
VW-U						0.11
NC-U						

Insect Pollinator Visits to Focal Forb Species

I recorded the number of visits to the focal forb species by five insect pollinator groups (see Table 6). I recorded a total of 10,113 insect visits during the study. The majority of the

Table 4c. Jaccard similarity index for forb species in June.

June	LP-R	WP-R	PP-R	KE-U	VW-U	NC-U
LP-R		0.11	0.25	0.11	0.25	0.11
WP-R			0.25	0.00	0.11	0.11
PP-R				0.00	0.11	0.11
KE-U					0.11	0.11
VW-U						0.25
NC-U						

Table 4d. Jaccard similarity index for forb species in July.

July	LP-R	WP-R	PP-R	KE-U	VW-U	NC-U
LP-R		0.25	0.67	0.11	0.00	0.11
WP-R			0.25	0.00	0.00	0.00
PP-R				0.00	0.00	0.11
KE-U					0.25	0.00
VW-U						0.00
NC-U						

visits were by bees, followed by butterflies and moths, together constituting 78.1% of the total visits (Table 6).

I found a difference in the sum of pollinator visits in rural and urban prairies. Overall, rural prairies received fewer insect pollinator visits than urban prairies (Table 7). Individually,

Table 4e. Jaccard similarity index for forb species in August.

Aug	LP-R	WP-R	PP-R	KE-U	VW-U	NC-U
LP-R		0.11	0.43	0.00	0.00	0.11
WP-R			0.11	0.00	0.00	0.11
PP-R				0.00	0.00	0.11
KE-U					0.00	0.00
VW-U						0.00
NC-U						

Table 5. Mean Jaccard similarity index of forb species in rural and urban prairies.

	Rural prairies			Urban prairies			Rural and urban prairies		
	N	Mean JSI	±SD	N	Mean JSI	±SD	N	Mean JSI	±SD
Across months	12	0.24	0.17	12	0.09	0.09	36	0.09	0.10
May	3	0.16	0.08	3	0.11	0.00	9	0.16	0.13
June	3	0.20	0.08	3	0.16	0.08	9	0.10	0.07
July	3	0.39	0.24	3	0.08	0.14	9	0.04	0.06
August	3	0.22	0.18	3	0.00	0.00	9	0.04	0.06

Table 6. Counts of insect pollinator visits and percent of total visits.

Insect group	Number of visits	Percent of total visits
Bees	5913	58.5
Butterflies/moths	1986	19.6
Wasps	908	9.0
Beetles	875	8.7
Flies	431	4.3

Table 7. Counts of rural and urban prairie insect pollinator visits and percent of total visits.

Prairie type	Prairie	Number of visits	Percent of visits
Rural	La Petite Gemme Prairie (LP-R)	1545	15.3
	Woods Prairie (WP-R)	1727	17.1
	Providence Prairie (PP-R)	702	6.9
Urban	Kickapoo Edge Prairie (KE-U)	2322	22.9
	Valley Water Mill Park Prairie (VW-U)	2040	20.2
	Nature Center Prairie (NC-U)	1777	17.6

each rural prairie received fewer insect pollinator visits than each urban prairie (Table 7). Rural prairies received 3,974 (39.3%) visits and urban prairies received 6,139 (60.7%) visits (Table 7).

Based on my ANOVA, insect visits were significantly different among rural/urban prairie types, insect groups, and months (Table 8) (Figure 3). There were no statistical differences between soil types.

I found significant interaction effects between rural/urban prairie types and insect groups, rural/urban prairies across months, and insect groups across months (Table 8). The interaction effects between rural/urban prairie types, insect groups, and months were not significant (Table 8).

I recorded which of the 66 focal forb species attracted the most insect pollinator visits (Appendix D). Five focal forb species received over 500 visits each, and are native to tallgrass prairies (Appendix D). Four of these five focal forb species are in the family Asteraceae, a generalist family (Czarnecka & Denisow, 2014), with the other in the family Lamiaceae, which has bilateral flowers most often visited by bees (Westerkamp & Claßen-Bockhoff, 2007) (Appendix D). Three of these five focal forb species were found in rural and urban prairies (Appendix D).

Table 8. ANOVA table for insect pollinator visits as a function of prairie location, insect group, and month.

Variable	Effect in ANOVA			
	N	df	*F*	P
Rural/urban	60	1, 80	7.05	0.010
Insect group	24	4, 80	38.04	<0.001
Month	30	3, 80	4.77	0.004
Rural/urban by insect group	12	4, 80	7.78	<0.001
Rural/urban by month	15	3, 80	3.38	0.022
Insect group by month	6	12, 80	4.74	<0.001
Rural/urban by insect group by month	3	12, 80	1.56	0.120

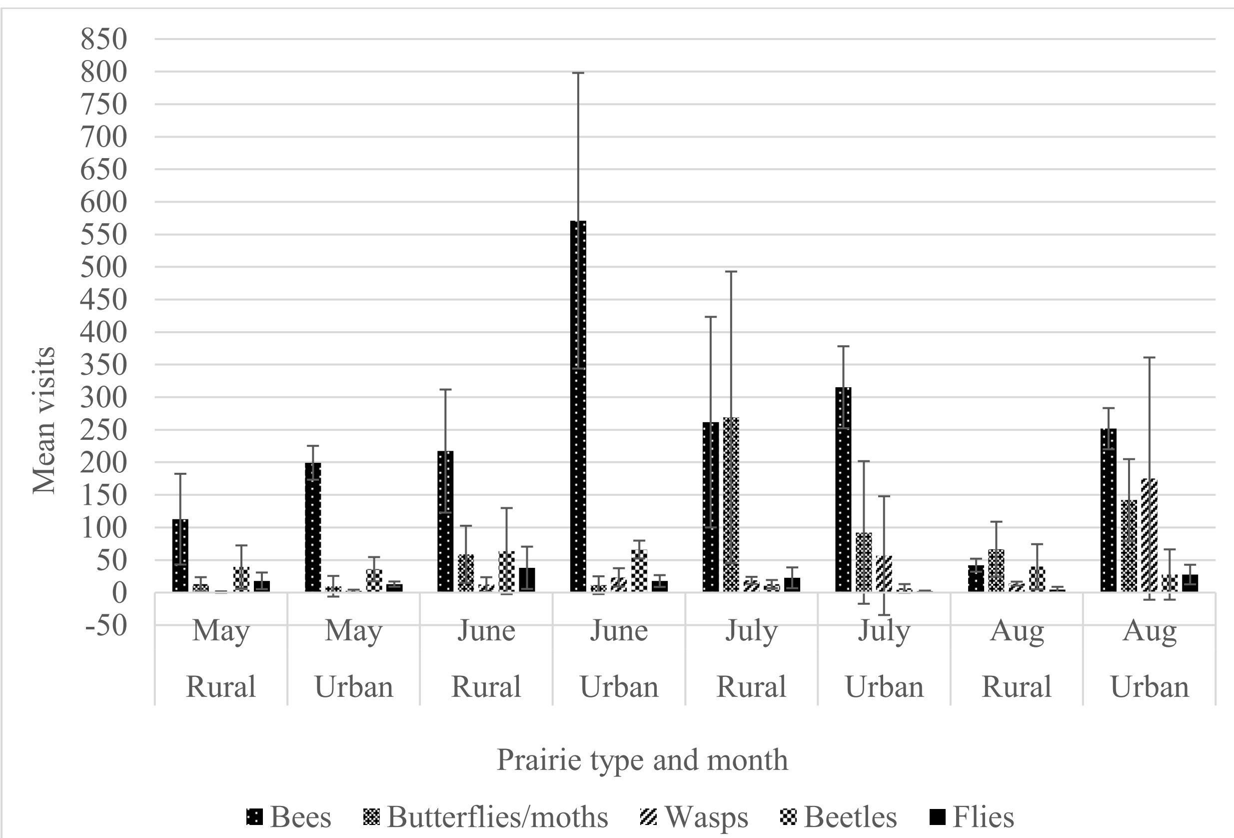


Figure 3. Mean (± SD) insect pollinator visits per month in rural and urban prairies.

The mean number of visits to focal forb species in rural prairies was 106.0 (±194.18, n=29) (Appendix D). The mean number of visits to focal forb species in urban prairies was 154.5 (±144.32, n=28) (Appendix D). The mean number of visits to focal forb species in rural and urban prairies was 301.4 (±223.16, n=9) (Appendix D).

The mean number of visits to focal forb species that are native to Missouri tallgrass prairies was 160.1 (±195.43, n=58) (Appendix D). The mean number of visits to focal forb species that are introduced to Missouri tallgrass prairies was 103.4 (±106.49, n=8) (Appendix D).

Based on chi-square tests, insect pollinator visits were significantly dependent upon prairie type across rural and urban prairies and rural prairies (Table 9). Insect pollinator visits were independent of prairie type in urban prairies (Table 9). With the Bonferroni correction, every test, except urban prairies in May, suggested significance.

Table 9. Chi-square test for association of insect pollinator visits as a function of prairie type and month.

	Rural and urban prairies			Rural prairies			Urban prairies		
	df	Pearson χ^2	P	df	Pearson χ^2	P	df	Pearson χ^2	P
Across months	10	912.32	<0.001	4	191.77	<0.001	4	176.01	<0.001
May	5	57.18	<0.001	2	16.65	<0.001	2	3.43	0.180
June	10	653.50	<0.001	4	204.85	<0.001	4	44.80	<0.001
July	10	1020.57	<0.001	4	298.02	<0.001	4	507.93	<0.001
August	10	283.80	<0.001	4	45.54	<0.001	4	165.37	<0.001

Insect Fidelity Comparisons in Rural and Urban Prairies

The results of the 2-sample t-test showed that there was not a significant difference in the means of insect fidelity in rural prairies (0.95, ±0.06) and insect fidelity in urban prairies (0.96,

±0.03), t(5)=-0.52, p=0.625 (Table 10). Mean insect fidelity was high across all groups throughout the four months (bees 98.1%, butterflies/moths 99.3%, wasps 92.6%, beetles 93.3%, flies 98.0%). Fidelity of all groups combined remained high in each month (May 98.6%, June 97.3%, July 98.1%, August 97.4%).

Table 10. Mean insect group fidelity in rural and urban prairies.

Insect group	Rural prairies	Urban prairies
Bees	98.6	97.9
Butterflies/moths	100.0	96.2
Wasps	85.0	94.5
Beetles	93.2	93.8
Flies	97.8	100.0

Surrounding Habitat Matrix in and Around Each Prairie

I estimated the percentage of impervious surface area around each prairie to see if this uninhabitable area played a role in insect pollinator visits (Appendices E-1-7) . The surrounding habitat matrix around rural prairies had a lower percentage of impervious surfaces than the urban prairies (Table 11).

Providence Prairie, the rural prairie that received the fewest insect pollinator visits, had the least amount of impervious surface surrounding the prairie (Table 11). Conversely, Kickapoo Edge Prairie, the urban prairie that received the most insect pollinator visits, had the greatest amount of impervious surface surrounding the prairie (Table 11).

Table 11. Percent impervious surface surrounding each prairie in an 8 km^2 radius.

Prairie type	Prairie	Percent impervious surface
Rural	La Petite Gemme Prairie (LP-R)	1.5
	Woods Prairie (WP-R)	0.9
	Providence Prairie (PP-R)	0.2
Urban	Kickapoo Edge Prairie (KE-U)	36.6
	Valley Water Mill Park Prairie (VW-U)	9.6
	Nature Center Prairie (NC-U)	13.2

DISCUSSION

Research on plant/pollinator interactions along gradients of rural areas to urban areas is growing (Ahrné *et al.*, 2009; Bates *et al.*, 2011; Geslin *et al.*, 2013; Sirohi *et al.*, 2015), as well as plant/pollinator interactions in various urban environments (Lowenstein *et al.*, 2015; Plascencia and Philpott, 2017). This is the first study on plant/pollinator interactions comparing rural prairies with urban prairies. Key findings are that similarity between focal forb species in rural prairies and urban prairies was low. Insect visitation was significantly dependent on prairie type (rural/ urban), month, insect group, and the interactions between them. Insect fidelity did not significantly differ between rural and urban prairies. The percentage of impervious surfaces in and around prairie types, as well as urban habitat matrices, did not negatively impact insect pollinator visits.

Focal Forb Species Similarity

This experiment's results did not support my hypothesis that dominant blooming forb species would be similar across rural and urban prairies. Edaphic factors may contribute to certain forb species success over other species, for example, hardpan clay-based soil may be difficult for roots to penetrate. Packard *et al.* (2015) explained that grasses tend to dominate in restored prairies, thus is a recognizable feature of the age of restorations. In newer restorations, the grass roots have ample space to flourish due to less root accumulation by forbs competing for space underground; in time, succession balances the grass/forb ratio. Recently established native forb species can also be more aggressive than other forbs, for example, *Ratibida pinnata* (gray-headed coneflower), or *Physostegia angustifolia* (false dragonhead), which are known for not staying where planted. Competition from aggressive forb species in newer urban prairies can limit the opportunity for neighboring forb species to establish. Could this "monopoly" of aggressive forbs in recently established urban prairies become a recognizable feature where experts could gauge the succession of urban prairies, and in time, set potential biodiversity load expectations?

The lack of overlap of focal forb species across rural and urban prairies in my study may be attributed to edge effects in urban prairies. Gieselman *et al.* (2013) and Neame *et al.* (2013) found that edges change the community composition in grasslands. Gieselman *et al.* (2013) found significantly less native plants and significantly more introduced plants 25-30 meters from man-made grassland edges. This might also explain the higher number of introduced focal forb species in the urban prairies, especially since it is known that each urban prairie received native seed mixes or starts from native seed from local rural prairies. Gieselman *et al.* (2013) also reported finding significantly less native plant species along edges.

Restraints on scheduling, manpower, and weather conditions could have attributed spatio-temporal limitations to the low similarity in the focal forb species lists. Only visiting each prairie once per month limited my opportunity for viewing conspecific blooms across both prairie types. Rain and/or high wind events delayed some of my visits, decreasing the likelihood of documenting concurrent blooming.

Insect Pollinator Visits

In contrast to much of the findings in the literature of decreasing abundance, diversity, and richness of insect pollinators in urban ecosystems compared to rural ecosystems (Ahrné *et al.*, 2009; Bates *et al.*, 2011; Geslin *et al.*, 2013; Plascencia and Philpott, 2017), my research found that urban prairies can be effective at attracting insect pollinators as can rural prairies. My hypothesis that rural prairies would receive more insect pollinator visits than urban prairies was not supported. This is surprising, because each of the rural prairies are old-growth prairies, with hectares of diverse forb communities blooming throughout the growing season. This high ecosystem function is known to support varying specializations of insect pollinators (Allan *et al.*, 2011; Blaauw and Isaacs, 2014; Kammerer *et al.*, 2016; Mallinger *et al.*, 2016).

I found interesting trends in my insect pollinator visit data (Figure 3). Although bee visitation peaked in June, overall, bees had the greatest number of visits of all insect pollinators in my study. Equally interesting was how the number of visits for butterflies/moths and wasps increased through the study. Increases in butterfly/moth visits in rural prairies in June and July coincided with blooming focal forb species, *Liatris pycnostachya*. Wasp's greatest number of visits coincided with blooming *Solidago* species in August. Surprisingly, beetle and fly visits remained low across both prairie types and months, even though both groups are important generalist pollinators.

Current research and reviews suggest that urban areas are capable of supporting beneficial plant/pollinator ecosystem services (Potts *et al.*, 2010; Lowenstein *et al.*, 2015; Senapathi *et al.*, 2017). Bates *et al.* (2011) suggested that urban gardens can support a diversity of pollinating insects, and may even aid in pollinating surrounding agricultural areas. Bates *et al.* (2011) also pointed out that generalist insect pollinators are often resilient to urbanization and land use change. Blaauw and Isaacs (2014), Plascencia and Philpott (2017), and Senapathi *et al.* (2017), agree that managing for high-quality ecosystems in urban areas is of utmost importance for maintaining high levels of plant/pollinator interactions.

Habitat connectivity may help explain why rural prairies received less insect pollinator visits than rural prairies. The rural prairies are surrounded by mostly agriculture, for example cropland, livestock, or haying. Inadequate foraging resources in these adjacent environments, especially in intensive industrial farming, could limit connectivity (Potts *et al.*, 2016). Travel distance for insect pollinators varies based on size and energy requirements (Mader *et al.*, 2011). For example, the average sweat bee (Halictidae) can only travel around 184 meters before it must feed and drink to counteract energy expenditures (Mader *et al.*, 2011). Smaller insect pollinators are therefore more sensitive to landscape configuration (Geslin *et al.*, 2013). Urban areas, although highly fragmented with increased levels of uninhabitable areas (buildings, parking lots, roads, etc.), may provide higher connectivity for insect pollinators (Bates *et al.*, 2011; Geslin, *et al.*, 2013; Senapathi *et al.*, 2017). Urban neighborhoods can have abundant flowering resources by which insect pollinators can forage, rest, and nest (Bates *et al.*, 2011; Neame *et al.*, 2013; Sirohi *et al.*, 2015). Bates *et al.* (2011) and Sirohi *et al.* (2011) agree that further research is needed in urban areas, since developmental histories and habitat differences can provide differing results.

Another possible contributing factor to fewer insect pollinator visits in the rural prairies is the increasing use of pesticides (including herbicides, fungicides, molluscicides, etc.) (Potts *et al.*, 2016; Moeller, 2019). Globally, herbicides are the highest used pesticide on farms (Bohnenblust *et al.*, 2016). A 2012 United States Environmental Protection Agency report showed, from 2005 to 2012, that almost 90% of pesticide use in the United States was in the agriculture sector (Atwood and Paisley-Jones, 2017). Although one would reason that herbicides would not affect pollinators, only compromise available food resources, Bohnenblust *et al.* (2016) found that some herbicides can kill or have negative effects on pollinators. Topical applications of the herbicide paraquat are extremely toxic (Bohnenblust *et al.*, 2016). Brood development is negatively impacted with herbicides 2,4-D and 2,4-trichlorophenoxyacetic acid (Bohnenblust *et al.*, 2016).

In Lawrence County, MO, an aerial crop-dusting operation is within 6.89-kilometer (km) flight distance from Providence Prairie and 23.8 km flight distance from Woods Prairie ("Google Map Developers"). This business sprays pesticides on crop fields from March until August throughout the region (Clayton, 2014). Pesticide "drifts" from these aerial applications could settle on adjacent or nearby fields or prairies (Moeller, 2019). One study on Dicamba, an herbicide, found that pollinator visitation was 50% less to plants exposed to drift than to the control plants (Bohnenblust *et al.*, 2016).

Forb Qualities That Attract Insect Pollinators

Differing forbs have varying traits (pollination syndromes) that attract insect pollinators (Mader *et al.*, 2011). Many of the forb species in my study that received the most insect pollinator visits were generalist-type flowers that received visits from a multitude of insect pollinator groups. Similarly, Czarnecka and Denisow (2014) reported visits from bees, flies, butterflies and beetles on *Senecio macrophyllus* (family Asteraceae). Forbs in the Asteraceae family have heads consisting of many flowers with large amounts of surface area on which an insect pollinator can land and rest while feeding on nectar (Czarnecka and Denisow, 2014). This large surface area also provides ample pollen for collection (Czarnecka and Denisow, 2014). Colors of the most visited forbs in my study were also consistent with pollinator syndromes that attract bees: blue, yellow, and purple (Mader *et al.*, 2011).

Insect Fidelity Comparisons in Rural and Urban Prairies

Cappellari *et al.* (2013) posed that since crown group bees formed around the same time as eudicots, each clade co-evolved to create a highly productive mutualistic relationship. This basis is consistent with my findings that each insect pollinator group had high fidelity, regardless of its surroundings (rural or urban prairies). Results support my hypothesis that insect group fidelity would not differ in rural and urban prairies. It is interesting that my results differed entirely from findings of Pohl *et al.* (2011), where they described no constancy of butterfly fidelity. It is not known exactly why or how insect pollinators choose conspecific flowers over other abundantly advertised floral resources (Grüter and Ratnieks, 2011). Some researchers conclude that limited nervous systems cause insects to have fidelity, whereas others posit that insects can only search for one flower type at a time (Grüter and Ratnieks, 2011). Grüter and Ratnieks (2011) suggest that fidelity is an adaptive behavior. Jaworski *et al.* (2015) found that bumble bee flower constancy was a learned behavior attributed to floral type. Further research on insect pollinator group fidelity could help close the information gap.

Surrounding Habitat Matrix in and Around Rural and Urban Prairies

Plascencia and Philpott (2017) explain that increased impervious surfaces reduce available nesting for bees and require bees to travel farther to forage. Geslin *et al.* (2016) reported that increases in impervious surface decreased bee abundance and species richness. However, my results do not support my hypothesis that rural prairies, with less impervious surfaces, would receive greater numbers of pollinator visits than would urban prairies. The urban prairies are all highly managed, and are probably capable of supporting plant/pollinator interactions, regardless of percent of impervious surfaces or varying degrees of surrounding land use. Bates *et al.* (2011) offers that buildings, parks and gardens are potential refuge spaces, nesting and overwintering grounds, and forage opportunities for insect pollinators. Ahrné *et al.* (2009) found management quality affects bumble bee abundance more than surrounding landscape. Neame *et al.* (2013) suggests that insect pollinators can benefit from urban fragmentation because of the close proximity to garden-dwelling neighborhoods. Mallinger *et al.* (2016) warns of categorization of land use as habitable and inhabitable, as wild bees have been well-documented in diverse landscapes, from urban, to woodlands, to grasslands. Further studies of land use in a variety of urban habitats would benefit knowledge of urban land management.

I found answers to my five main questions comparing rural prairies to urban prairies. However, long-term research might answer further questions and provide an additional knowledge base. If funding, time, and manpower were available, I would have liked to continue this study across more growing seasons. Documenting dominating focal forb species over several years might reveal beneficial patterns for urban prairie management. More manpower could allow visits to all prairies on the same day or same week to document concurrent blooming across prairies, reducing spatio/temporal limitations. Although I answered that urban prairies are as effective at attracting insect pollinators as are rural prairies, it leads to another question. Does the difference in prairie size between large rural prairies and smaller urban prairies account for more visits to urban prairies, since insect pollinators in urban prairies concentrate their foraging across a decreased area? I determined which forbs attracted the most insect pollinators in rural and urban prairies in my study. It was encouraging to find that each group of visiting insect pollinators in urban compared to rural prairies had high fidelity from visiting conspecific plants consecutively, and increasing the potential of pollination. I found surprising answers how the habitat matrix in and around rural and urban prairies can have an influence on plant/pollinator interactions.

Rural prairies have been effectively managed for decades. Expanding urbanization and increasing agricultural pesticide use brings continual challenges to rural prairie management. My only recommendation would be that if land surrounding the rural prairies becomes available (and a means to acquire the land is available), to use that land as a buffer between the remnant prairie and surrounding property to offset edge effects to the perimeter of the prairies.

Based on this study, I offer recommendations to urban prairie managers. With the higher ratio of edge in urban prairies, edge effects could be more prevalent, allowing more populations of introduced species to establish. Continued intensive eradication of introduced species to Missouri tallgrass prairies could reduce changes in community composition that occur with introduced species. If it is feasible, and applicable, thin out any aggressive native species to allow room for other native species to compete for space. Each urban prairie has existing solid management in place that is effectively maintaining a functional and appealing prairie ecosystem.

The growing trend of planting native forbs and grasses in urban areas is promising, as my research demonstrated that urban prairies can sustain themselves through pollination services. Effort put forth to plant urban prairies provides wildlife with habitat and connectivity, and holds the potential to shift public perspective to inclusion of natural diversity. With the ever-increasing global urbanization and decrease in insect pollinators, the potential benefits of well-managed urban prairie plots may help counteract such declines.

REFERENCES

AHRNÉ, K., J. BENGTSSON AND T. ELMQVIST. 2009. Bumble bees (Bombus spp) along a gradient of increasing urbanization. *PLoS One*, **4**.

ALLAN, E., W. WEISSER, A. WEIGELT, C. ROSCHER, M. FISCHER AND H. HILLEBRAND. 2011. More diverse plant communities have higher functioning over time due to turnover in complementary dominant species. *Proc. Natl. Acad. Sci.*, doi: 10.1073/pnas.1104015108.

ANDERSON C., R. ARNDT, J. AUCKLEY, A. BENSON, J. BOWMASTER, K. COOPER, B. DAVIT, C. DAVIT, D. DARROW, S. DUCKWORTH, J. GEBHART, G. GREMAUD, L. HOUF, M. HUTCHINGS, M. JACKSON, T. JOHNSON, K. KORTHAS, D. KURZ, D. LADD, K. MCCARTY, D. MCDEVITT, T. NAGEL, G. NICHOLS, D. NOWAT, S. PARRISH, J. SHATFORD, M. SKINNER, S. SMITH, D. SWEARINGEN, S. THIESS, R. THOM, AND J. TRAGER. 1999. Public Prairies of Missouri, 3rd ed. Missouri Department of Conservation, Jefferson City, MO. 43 pp.

ARONSON, M. F., C. A. LEPCZYK, K. L. EVANS, M. A. GODDARD, S. B. LERMAN, J. S. MACIVOR, C. H. NILON AND T. VARGO. 2017. Biodiversity in the city: key challenges for urban green space management. *Front. Ecol. Environ.*, **15**:189–196.

ATWOOD, D. AND C. PAISLEY-JONES. 2017. Pesticides Industry Sales and Usage 2008 –2012 Market Estimates. https://www.epa.gov/sites/production/files/2017-01/documents/pesticides-industry-sales-usage-2016_0.pdf. Accessed 21 Jul. 2019.

BALDOCK, K. C. R., M. A. GODDARD, D. M. HICKS, W. E. KUNIN, N. MITSCHUNAS, L. M. OSGATHORPE, S. G. POTTS, K. M. ROBERTSON, A. V. SCOTT, G. N. STONE, I. P. VAUGHAN AND J. MEMMOTT. 2015. Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proc. R. Soc. B Biol. Sci.*, **282**:20142849–20142849.

BATES, A. J., J. P. SADLER, A. J. FAIRBRASS, S. J. FALK, J. D. HALE, AND T. J. MATTHEWS. 2011. Changing bee and hoverfly pollinator assemblages along an urban-rural gradient. *PLoS One*, **6**: 0023459.

BLAAUW, B. R. AND R. ISAACS. 2014. Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. *J. Appl. Ecol.*, doi: 10.1111/1365-2664.12257.

BOHNENBLUST, E. W., A. D. VAUDO, J. F. EGAN, D. A. MORTENSEN AND J. F. TOOKER. 2016. Effects of the herbicide dicamba on nontarget plants and pollinator visitation. *Environ. Toxicol. Chem.*, **35**:144–151.

BONARI, G., K. FAJMON, I. MALENOVSKÝ, D. ZELENÝ, J. HOLUŠA, I. JONGEPIEROVÁ, P. KOČÁREK, O. KONVIČKA, J. UŘIČÁŘ AND M. CHYTRÝ. 2017. Management of semi-natural grasslands benefiting both plant and insect diversity: The importance of heterogeneity and tradition. *Agric. Ecosyst. Environ.*, **246**:243–252.

CAPPELLARI, S. C., H. SCHAEFER AND C. C. DAVIS. 2013. Evolution: Pollen or Pollinators — Which Came First? *Curr. Biol.*, **23**:R316–R318.

CLAYTON, CHRIS. 2014. Building Business From The Ground Up. *Progressive Farmer*. http://dtnpf-digital.com/article/Building+Business+From+The+Ground+Up/1766213/218347/article.html. Accessed 4 Jul. 2019.

CZARNECKA, B. AND B. DENISOW. 2014. Floral biology of Senecio macrophyllus M. BIEB. (Asteraceae), a rare Central European steppe plant. *Acta Soc. Bot. Pol.*, **83**:17–27.

GESLIN, B., V. LE FÉON, M. FOLSCHWEILLER, F. FLACHER, D. CARMIGNAC, E. MOTARD, S. PERRET AND I. DAJOZ. 2016. The proportion of impervious surfaces at the landscape scale structures wild bee assemblages in a densely populated region. *Ecol. Evol.*, **6**:6599–6615.

GIESELMAN, T. M., K. E. HODGES AND M. VELLEND. 2013. Human-induced edges alter grassland community composition., doi: 10.1016/j.biocon.2012.08.019.

GOOGLE MAP DEVELOPERS. Mileage Calculator: Calculate the mileage of a flight between airports or the mileage of a car between addresses. https://www.mapdevelopers.com/mileage_calculator.php. Accessed 4 Jul. 2019.

GRÜTER, C. AND F. L. W. RATNIEKS. 2011. Flower constancy in insect pollinators: Adaptive foraging behaviour or cognitive limitation? *Commun. Integr. Biol.*, **4**:633–6.

HALLMANN, C. A., M. SORG, E. JONGEJANS, H. SIEPEL, N. HOFLAND, H. SCHWAN, W. STENMANS, A. MÜLLER, H. SUMSER, T. HÖRREN, D. GOULSON AND H. DE KROON. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One*, **12**:e0185809. Public Library of Science.

HATTEN, T. D., C. LOONEY, J. P. STRANGE AND N. A. BOSQUE-PÉREZ. 2013. Bumble Bee Fauna of Palouse Prairie: Survey of Native Bee Pollinators in a Fragmented Ecosystem. *J. Insect Sci.*, **13**:1–19.

HELDEN, A. J., R. MCKENZIE, G. COBBOLD, P. V. GRICE, G. Q. A. ANDERSON AND M. A. MACDONALD. 2015. Field-based grassland management for cirl buntings (*Emberiza cirlus* L.) and its effect on plant- and leafhoppers (Hemiptera: Auchenorrhyncha). *Insect Conserv. Divers.*, **8**:272–281. John Wiley & Sons, Ltd (10.1111).

JAWORSKI, C. C., C. ANDALO, C. RAYNAUD, V. SIMON, C. THÉBAUD AND J. CHAVE. 2015. The Influence of Prior Learning Experience on Pollinator Choice: An Experiment Using Bumblebees on Two Wild Floral Types of Antirrhinum majus. *PLoS One*, **10**:e0130225.

KAMMERER, M. A., D. J. BIDDINGER, E. G. RAJOTTE AND D. A. MORTENSEN. 2016. Local Plant Diversity Across Multiple Habitats Supports a Diverse Wild Bee Community in Pennsylvania Apple Orchards. *Environ. Entomol.*, **45**:32–38.

LOWENSTEIN, D. M., K. C. MATTESON AND E. S. MINOR. 2015. Diversity of wild bees supports pollination services in an urbanized landscape. *Oecologia*, **179**.

MADER E, M. SHEPHERD, M. VAUGHAN, S. BLACK, AND G. LEBUHN. 2011. Attracting Native Pollinators: Protecting North America's Bees and Butterflies. Storey Publishing, North Adams, MA. 371 pp.

MAGRACH, A., A. HOLZSCHUH, I. BARTOMEUS, V. RIEDINGER, S. P. M. ROBERTS, M. RUNDLOF, A. VUJIC, J. B. WICKENS, V. J. WICKENS, R. BOMMARCO, J. P. GONZALEZ-VARO, S. G. POTTS, H. G. SMITH, I. STEFFAN-DEWENTER AND M. VILA. 2017. Plant-pollinator networks in semi-natural grasslands are resistant to the loss of pollinators during blooming of mass-flowering crops. *Ecography (Cop.)*., doi: 10.1111/ecog.02847.

MALLINGER, R. E., J. GIBBS AND C. GRATTON. 2016. Diverse landscapes have a higher abundance and species richness of spring wild bees by providing complementary floral resources over bees' foraging periods. *Landsc. Ecol.*, **31**.

MOELLER, D. L. 2019. Superfund, Pesticide Regulation, and Spray Drift: Rethinking the Federal Pesticide Regulatory Framework to Provide Alternative Remedies for Pesticide Damage - Iowa Law Review - The University of Iowa College of Law. *Iowa Law Rev.*, **104**:1523–1550.

MOUNT VERNON, MISSOURI. Maps and Population. 2006. http://www.mtvernon-cityhall.org/index.cfm?content=46. Accessed 4 Jul. 2019.

NEAME, L. A., T. GRISWOLD AND E. ELLE. 2013. Pollinator nesting guilds respond differently to urban habitat fragmentation in an oak-savannah ecosystem. *Insect Conserv. Divers.*, **6**:57–66.

OLLERTON, J. 2017. Pollinator Diversity: Distribution, Ecological Function, and Conservation. *Annu. Rev. Ecol. Evol. Syst.*, **48**:353–376. Annual Reviews.

PACKARD S., C.F. MUTEL, SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL. 2005. The Tallgrass Restoration Handbook: for Prairies, Savannas, and Woodlands, 2nd ed. Island Press, Washington, DC. 463 pp.

PLASCENCIA, M. AND S. M. PHILPOTT. 2017. Floral abundance, richness, and spatial distribution drive urban garden bee communities. *Bull. Entomol. Res.*, **107**:658–667.

POHL, N. B., J. VAN WYK AND D. R. CAMPBELL. 2011. Butterflies show flower colour preferences but not constancy in foraging at four plant species. *Ecol. Entomol.*, **36**:290–300.

POTTS, S. G., J. C. BIESMEIJER, C. KREMEN, P. NEUMANN, O. SCHWEIGER AND W. E. KUNIN. 2010. Global pollinator declines: trends, impacts and drivers. *Trends Ecol. Evol.*, **25**:345–353.

POTTS, S. G., V. IMPERATRIZ-FONSECA, H. T. NGO, M. A. AIZEN, J. C. BIESMEIJER, T. D. BREEZE, L. V. DICKS, L. A. GARIBALDI, R. HILL, J. SETTELE AND A. J. VANBERGEN. 2016. Safeguarding pollinators and their values to human well-being. *Nature*, **540**:220–229.

PROBER, S. M., K. R. THIELE, I. D. LUNT AND T. B. KOEN. 2005. Restoring ecological function in temperate grassy woodlands: manipulating soil nutrients, exotic annuals and native perennial grasses through carbon supplements and spring burns. *J. Appl. Ecol.*, **42**:1073–1085. John Wiley & Sons, Ltd (10.1111).

ROWE, H. I., J. FARGIONE AND J. D. HOLLAND. 2013. Prairie restorations can protect remnant tallgrass prairie plant communities. *Am. Midl. Nat.*, **170**:26–38.

SCHMITHALS, A. AND N. KÜHN. 2014. To burn or not to burn? Effect of management strategy on North American prairie vegetation for public urban areas in Germany. *PLoS One*, **9**:e108588.

SENAPATHI, D., M. A. GODDARD, W. E. KUNIN, AND K. C. R. BALDOCK. 2017. Landscape impacts on pollinator communities in temperate systems: evidence and knowledge gaps. *Funct. Ecol.*, **31**:26–37.

SIROHI, M. H., J. JACKSON, M. EDWARDS AND J. OLLERTON. 2015. Diversity and abundance of solitary and primitively eusocial bees in an urban centre: a case study from Northampton (England). *J. Insect Conserv.*, **19**.

SMITH, L. M. AND R. CHERRY. 2014. Effects of Management Techniques on Grassland Butterfly Species Composition and Community Structure. *Am. Midl. Nat.*, **172**:227–235.

STEYERMARK, J. A., G. A. YATSKIEVYCH, MISSOURI DEPARTMENT OF CONSERVATION AND MISSOURI BOTANICAL GARDEN. 1999. Steyermark's Flora of Missouri, Volume 1. Missouri Dept. of Conservation in cooperation with Missouri Botanical Garden Press, Jefferson City, MO. 991 pp.

STEYERMARK, J. A., G. A. YATSKIEVYCH, MISSOURI DEPARTMENT OF CONSERVATION AND MISSOURI BOTANICAL GARDEN. 2006. Steyermark's Flora of Missouri, Volume 2. Missouri Dept. of Conservation in cooperation with Missouri Botanical Garden Press, Jefferson City, MO. 1200 pp.

STEYERMARK, J. A., G. A. YATSKIEVYCH, MISSOURI DEPARTMENT OF CONSERVATION AND MISSOURI BOTANICAL GARDEN. 2013. Steyermark's Flora of Missouri, Volume 3. Missouri Dept. of Conservation in cooperation with Missouri Botanical Garden Press, Jefferson City, MO. 1382 pp.

SWENGEL, A. B. AND S. R. SWENGEL. 2013. Decline of Hesperia ottoe (lepidoptera: Hesperiidae) in northern tallgrass prairie preserves. *Insects*, **4**:663–682.

THEISS, K., S. KEPHART, AND C. IVEY. 2007. Pollinator Effectiveness on Co-Occurring Milkweeds (Asclepias; Apocynaceae, Asclepiadoideae). *Ann. Missouri Bot. Gard.*, **94**:505–516.

THOMAS, A. L., S. GIBSON, AND N. J. HOLMBERG. 2004. The flora and natural history of Woods Prairie, a nature reserve in Southwestern Missouri. *Missouriensis*, **25**:1–19.

US CENSUS BUREAU. QuickFacts. 2018. https://www.census.gov/quickfacts/fact/table/greenecountymissouri,springfieldcitymissouri,lawrencecountymissouri,polkcountymissouri/PST045218. Accessed 4 Jul. 2019.

VELDMAN, J. W., E. BUISSON, G. DURIGAN, G. W. FERNANDES, S. LE STRADIC, G. MAHY, D. NEGREIROS, G. E. OVERBECK, R. G. VELDMAN, N. P. ZALOUMIS, F. E. PUTZ, AND W. J. BOND. 2015. Toward an old-growth concept for grasslands, savannas, and woodlands. *Front. Ecol. Environ.*, **13**:154–162.

WESTERKAMP, C. AND R. CLAßEN-BOCKHOFF. 2007. Bilabiate Flowers: The Ultimate Response to Bees? *Ann. Bot.*, **100**:361–374.

WIDHIONO, I., E. SUDIANA AND D. DARSONO. 2017. Diversity of Wild Bees along Elevational Gradient in an Agricultural Area in Central Java, Indonesia. *Psyche A J. Entomol.*, **2017**:1–5.

APPENDICES

Appendix A-1: Data on focal forb species found in rural prairies that are native to tallgrass prairies

Focal forb species by family, USDA code, prairies found in, and month found. Prairies are shown as code-R (rural), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, and PP-R = Providence Prairie.

Species by family	USDA code	Prairies present	Month found
Eryngium yuccifolium (rattlesnake master)	ERYU	LP-R, WP-R, PP-R	July
Achillea millefolium (common yarrow)	ACMI2	LP-R	May
Berlandiera texana (Texas green eyes)	BEBE4	WP-R	July, August
Cirsium discolor (field thistle)	CIDI	LP-R, PP-R	August
Coreopsis grandiflora (bigflower coreopsis)	COGR5	LP-R	May
Echinacea pallida (pale purple coneflower)	ECPA	WP-R	June
Eupatorium serotinum (late boneset)	EUSE2	PP-R	August
Helenium flexuosum (purple-headed sneezeweed)	HEFL	PP-R	June, July
Helianthus mollis (ashy sunflower)	HEMO2	LP-R, PP-R	August
Liatris pycnostachya (gayfeather, blazing star)	LIPY	LP-R, WP-R, PP-R	June, July
Solidago rigida (stiff goldenrod)	SORI2	WP-R	August
Solidago ptarmicoides (white upland aster)	SOPT4	WP-R	August
Vernonia fasciculata (prairie ironweed)	VEFA2	PP-R	August
Lobelia siphilitica (blue lobelia)	LOSI	LP-R	August
Silene regia (royal catchfly)	SIRE2	WP-R	July
Euphorbia corollata (flowering spurge)	EUCO10	WP-R	August

Focal forb species found in rural prairies that are native to tallgrass prairies continued. Species by family, USDA code, prairies found in, and month found. Prairies are shown as code-R (rural), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, and PP-R = Providence Prairie.

Species by family	**USDA code**	**Prairies present**	**Month found**
Amorpha canescens (lead plant)	AMCA6	WP-R	June
Dalea candida (white prairie clover)	DACA7	LP-R	June
Dalea purpurea (purple prairie clover)	DAPU5	WP-R	June
Orbexilum pedunculatum (Sampson's snakeroot)	ORPE	PP-R	May
Sabatia campestris (prairie rose-gentian)	SACA3	WP-R	July
Physostegia angustifolia (false dragonhead)	PHAN6	WP-R, PP-R	June
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	LP-R, PP-R	June, July
Camassia scilloides (wild hyacinth)	CASC5	LP-R	May
Melanthium virginicum (bunchflower)	MEVI2	PP-R	June
Oenothera filiformis (large-flowered gaura)	OEFI2	LP-R	August
Phlox divaricata (wild sweet William)	PHDI5	WP-R	May
Phlox glaberrima (smooth phlox)	PHGL4	PP-R	May
Delphinium carolinianum (prairie larkspur)	DECA3	WP-R	May

Appendix A-2: Data on focal forb species found in urban prairies that are native to tallgrass prairies

Focal forb species by family, USDA code, prairies found in, and month found. Prairies are shown as code-U (urban), with KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Asclepias syriaca (common milkweed)	ASSY	NC-U	June
Coreopsis tinctoria (plains coreopsis)	COTI3	VW-U	June
Erigeron annuus (annual fleabane)	ERAN	KE-U	May
Heliopsis helianthoides (oxeye sunflower)	HEHE5	KE-U	June, July, August
Rudbeckia triloba (brown-eyed Susan)	RUTR2	NC-U	July, August
Silphium integrifolium (rosinweed)	SIIN2	VW-U	August
Silphium perfoliatum (cup plant)	SIPE2	NC-U	August
Solidago juncea (early goldenrod)	SOJU	VW-U	August
Solidago speciosa (showy goldenrod)	SOSP2	KE-U	August
Symphyotrichum novae-angliae (New England aster)	SYNO2	KE-U	August
Verbesina helianthoides (yellow crownbeard)	VEHE	NC-U	August
Verbesina virginica (white crownbeard)	VEVI3	NC-U	July, August
Vernonia baldwinii (western ironweed)	VEBA	KE-U	July
Hypericum prolificum (shrubby St. John's wort)	HYPR	VW-U	June, July, August
Chamaecrista fasciculata (showy partridge pea)	CHFA2	VW-U	July, August
Desmodium canadense (showy tick trefoil)	DECA7	VW-U	August
Monarda fistulosa (wild bergamot)	MOFI	KE-U, NC-U	June
Callirhoe involucrata (purple poppy mallow)	CAIN2	KE-U	June

Focal forb species found in urban prairies that are native to tallgrass prairies continued. Species by family, USDA code, prairies found in, and month found. Prairies are shown as code-U (urban), with KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies present	Month found
Mirabilis nyctaginea (wild four o'clock)	MINY	KE-U	May
Rubus allegheniensis (Allegheny blackberry)	RUAL	NC-U	May
Verbena stricta (hoary vervain)	VEST	VW-U	July

Appendix A-3: Data on focal forb species found in rural and urban prairies that are native to tallgrass prairies

Focal forb species by family, USDA code, prairies found in, and month found. Prairies are shown as code-R (rural) and code-U (urban), with LP-R = La Petite Gemme Prairie, WP-R = Woods Prairie, PP-R = Providence Prairie, KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies found	Month found
Coreopsis lanceolata (tickseed coreopsis)	COLA5	PP-R, KE-U, VW-U	May
Erigeron strigosus (daisy fleabane)	ERST3	PP-R, VW-U, NC-U	May, June, July
Ratibida pinnata (gray-headed coneflower)	RAPI	LP-R, KE-U, VW-U	June, July
Rudbeckia hirta (black-eyed Susan)	RUHI2	LP-R, WP-R, PP-R, VW-U, NC-U	June, July
Silphium laciniatum (compass plant)	SILA3	LP-R, KE-U	July, August
Solidago altissima (tall goldenrod)	SOAL6	LP-R, WP-R, PP-R, NC-U	August
Tradescantia ohiensis (smooth spiderwort)	TROH	LP-R, WP-R, KE-U, NC-U	May
Penstemon digitalis (tall white beardtongue)	PEDI	LP-R, WP-R, PP-R, VW-U	May

Appendix B: Data on focal forb species found in urban prairies that are introduced species to tallgrass prairies

Focal forb species by family, USDA code, prairies found in, and month found. Prairies are shown as code-U (urban), with KE-U = Kickapoo Edge Prairie, VW-U = Valley Water Mill Park Prairie, and NC-U = Nature Center Prairie.

Species by family	USDA code	Prairies found	Month found
Conium maculatum (poison hemlock)	COMA2	NC-U	May
Daucus carota (Queen Anne's lace)	DACA6	NC-U	June, July
Torilis arvensis (field hedge parsley)	TOAR	KE-U	June
Cichorium intybus (common chickory)	CIIN	KE-U, VW-U	July, August
Melilotus officinalis (yellow sweet clover)	MEOF	KE-U	May
Trifolium pratense (red clover)	TRPR2	VW-U	May
Vicia villosa (winter vetch, hairy vetch)	VIVI	NC-U	May

Appendix C-1: Data on distribution and abundance of focal forb species found in La Petite Gemme Prairie (LP-R)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Achillea millefolium (common yarrow)	ACMI2	May	C	2
Camassia scilloides (wild hyacinth)	CASC5	May	E	1
Coreopsis grandiflora (bigflower coreopsis)	COGR5	May	C	1
Penstemon digitalis (tall white beardtongue)	PEDI	May	R	1
Tradescantia ohiensis (smooth spiderwort)	TROH	May	C	1
Dalea candida (white prairie clover)	DACA7	Jun	E	2

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Liatris pycnostachya (gayfeather, blazing star)	LIPY	Jun	E	2
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	Jun	E	2
Ratibida pinnata (gray-headed coneflower)	RAPI	Jun	C	1
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jun	C	1
Eryngium yuccifolium (rattlesnake master)	ERYU	Jul	C	1
Liatris pycnostachya (gayfeather, blazing star)	LIPY	Jul	E	3
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	Jul	E	3
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jul	C	1
Silphium laciniatum (compass plant)	SILA3	Jul	R	1
Cirsium discolor (field thistle)	CIDI	Aug	R	1
Helianthus mollis (ashy sunflower)	HEMO2	Aug	C	1
Lobelia siphilitica (blue lobelia)	LOSI	Aug	C	1
Oenothera filiformis (large-flowered gaura)	OEFI2	Aug	E	3
Solidago altissima (tall goldenrod)	SOAL6	Aug	C	1

Appendix C-2: Data on distribution and abundance of focal forb species found in Woods Prairie (WP-R)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Delphinium carolinianum (prairie larkspur)	DECA3	May	E	1
Leucanthemum vulgare (ox-eye daisy)	LEVU	May	R	1
Penstemon digitalis (tall white beardtongue)	PEDI	May	E	2
Phlox divaricata (wild sweet William)	PHDI5	May	E	3
Tradescantia ohiensis (smooth spiderwort)	TROH	May	C	1
Amorpha canescens (lead plant)	AMCA6	Jun	E	2
Dalea purpurea (purple prairie clover)	DAPU5	Jun	C	2
Echinacea pallida (pale purple coneflower)	ECPA	Jun	E	1
Physostegia angustifolia (false dragonhead)	PHAN6	Jun	E	1
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jun	R	1
Berlandiera texana (Texas green eyes)	BEBE4	Jul	R	2
Eryngium yuccifolium (rattlesnake master)	ERYU	Jul	C	2
Liatris pycnostachya (gayfeather, blazing star)	LIPY	Jul	C	2
Sabatia campestris (prairie rose-gentian)	SACA3	Jul	C	1
Silene regia (royal catchfly)	SIRE2	Jul	C	1
Berlandiera texana (Texas green eyes)	BEBE4	Aug	C	2
Euphorbia corollata (flowering spurge)	EUCO10	Aug	C	1
Solidago altissima (tall goldenrod)	SOAL6	Aug	C	1

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Solidago ptarmicoides (white upland aster)	SOPT4	Aug	C	1
Solidago rigida (stiff goldenrod)	SORI2	Aug	C	1

Appendix C-3: Data on distribution and abundance of focal forb species found in Providence Prairie (PP-R)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Coreopsis lanceolata (tickseed coreopsis)	COLA5	May	R	1
Erigeron strigosus (daisy fleabane)	ERST3	May	R	1
Orbexilum pedunculatum (Sampson's snakeroot)	ORPE	May	R	1
Penstemon digitalis (tall white beardtongue)	PEDI	May	R	1
Phlox glaberrima (smooth phlox)	PHGL4	May	R	1
Helenium flexuosum (purple-headed sneezeweed)	HEFL	Jun	R	2
Melanthium virginicum (bunchflower)	MEVI2	Jun	R	1
Physostegia angustifolia (false dragonhead)	PHAN6	Jun	R	1
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	Jun	R	1
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jun	C	1
Eryngium yuccifolium (rattlesnake master)	ERYU	Jul	C	1

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Helenium flexuosum (purple-headed sneezeweed)	HEFL	Jul	C	1
Liatris pycnostachya (gayfeather, blazing star)	LIPY	Jul	E	3
Pycnanthemum tenuifolium (slender mountain mint)	PYTE	Jul	E	2
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jul	C	1
Cirsium discolor (field thistle)	CIDI	Aug	R	1
Eupatorium serotinum (late boneset)	EUSE2	Aug	R	1
Helianthus mollis (ashy sunflower)	HEMO2	Aug	C	1
Solidago altissima (tall goldenrod)	SOAL6	Aug	E	1
Vernonia fasciculata (prairie ironweed)	VEFA2	Aug	R	1

Appendix C-4: Data on distribution and abundance of focal forb species found in Kickapoo Edge Prairie (KE-U)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Coreopsis lanceolata (tickseed coreopsis)	COLA5	May	R	1
Erigeron annuus (annual fleabane)	ERAN	May	R	1
Melilotus officinalis (yellow sweet clover)	MEOF	May	C	1
Mirabilis nyctaginea (wild four o'clock)	MINY	May	C	1

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Tradescantia ohiensis (smooth spiderwort)	TROH	May	C	1
Callirhoe involucrata (purple poppy mallow)	CAIN2	Jun	R	1
Heliopsis helianthoides (oxeye sunflower)	HEHE5	Jun	C	2
Monarda fistulosa (wild bergamot)	MOFI	Jun	C	2
Ratibida pinnata (gray-headed coneflower)	RAPI	Jun	C	3
Torilis arvensis (field hedge parsley)	TOAR	Jun	E	3
Cichorium intybus (common chickory)	CIIN	Jul	C	1
Heliopsis helianthoides (oxeye sunflower)	HEHE5	Jul	C	2
Ratibida pinnata (gray-headed coneflower)	RAPI	Jul	C	1
Silphium laciniatum (compass plant)	SILA3	Jul	R	1
Vernonia baldwinii (western ironweed)	VEBA	Jul	R	1
Cichorium intybus (common chickory)	CIIN	Aug	C	1
Heliopsis helianthoides (oxeye sunflower)	HEHE5	Aug	C	2
Silphium laciniatum (compass plant)	SILA3	Aug	R	1
Solidago speciosa (showy goldenrod)	SOSP2	Aug	C	2
Symphyotrichum novae-angliae (New England aster)	SYNO2	Aug	R	1

Appendix C-5: Data on distribution and abundance of focal forb species found in Valley Water Mill Park Prairie (VW-U)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Coreopsis lanceolata (tickseed coreopsis)	COLA5	May	C	1
Erigeron strigosus (daisy fleabane)	ERST3	May	R	1
Leucanthemum vulgare (ox-eye daisy)	LEVU	May	C	2
Penstemon digitalis (tall white beardtongue)	PEDI	May	R	2
Trifolium pratense (red clover)	TRPR2	May	C	2
Coreopsis tinctoria (plains coreopsis)	COTI3	Jun	R	1
Erigeron strigosus (daisy fleabane)	ERST3	Jun	E	3
Hypericum prolificum (shrubby St. John's wort)	HYPR	Jun	C	1
Ratibida pinnata (gray-headed coneflower)	RAPI	Jun	C	3
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jun	C	2
Chamaecrista fasciculata (showy partridge pea)	CHFA2	Jul	C	1
Cichorium intybus (common chickory)	CIIN	Jul	C	1
Hypericum prolificum (shrubby St. John's wort)	HYPR	Jul	C	1
Ratibida pinnata (gray-headed coneflower)	RAPI	Jul	C	3
Verbena stricta (hoary vervain)	VEST	Jul	C	1
Chamaecrista fasciculata (showy partridge pea)	CHFA2	Aug	C	1
Desmodium canadense (showy tick trefoil)	DECA7	Aug	R	1
Hypericum prolificum (shrubby St. John's wort)	HYPR	Aug	R	1

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Silphium integrifolium (rosinweed)	SIIN2	Aug	R	1
Solidago juncea (early goldenrod)	SOJU	Aug	C	1

Appendix C-6: Data on distribution and abundance of focal forb species found in Nature Center Prairie (NC-U)

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Conium maculatum (poison hemlock)	COMA2	May	C	1
Leucanthemum vulgare (ox-eye daisy)	LEVU	May	R	1
Rubus allegheniensis (Allegheny blackberry)	RUAL	May	C	2
Tradescantia ohiensis (smooth spiderwort)	TROH	May	C	1
Vicia villosa (winter vetch, hairy vetch)	VIVI	May	E	4
Asclepias syriaca (common milkweed)	ASSY	Jun	C	3
Daucus carota (Queen Anne's lace)	DACA6	Jun	R	1
Erigeron strigosus (daisy fleabane)	ERST3	Jun	R	2
Monarda fistulosa (wild bergamot)	MOFI	Jun	R	1
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jun	R	1
Daucus carota (Queen Anne's lace)	DACA6	Jul	R	1

Focal forb species by family, USDA code, month found, spatial distribution, and abundance class continued. (Distribution codes: R=random, C=clumped, E=even) (Abundance of prairie codes: 1=<5% cover, 2=5-25% cover, 3=25-50% cover, 4=50-75% cover, 5=75-95% cover, 6=95-100% cover).

Species by family	USDA code	Month	Spatial distribution	Abundance class
Erigeron strigosus (daisy fleabane)	ERST3	Jul	R	1
Rudbeckia hirta (black-eyed Susan)	RUHI2	Jul	C	2
Rudbeckia triloba (brown-eyed Susan)	RUTR2	Jul	E	5
Verbesina virginica (white crownbeard)	VEVI3	Jul	C	1
Rudbeckia triloba (brown-eyed Susan)	RUTR2	Aug	C	4
Silphium perfoliatum (cup plant)	SIPE2	Aug	R	1
Solidago altissima (tall goldenrod)	SOAL6	Aug	R	1
Verbesina helianthoides (yellow crownbeard)	VEHE	Aug	C	4
Verbesina virginica (white crownbeard)	VEVI3	Aug	C	3

Appendix D: Data on focal forb species and number of insect pollinator visits to each

Focal forb species, arranged by descending counts of insect pollinator visits found in rural, urban, or rural/urban prairies, and the insect pollinator group that visited each forb species the most. For any focal forb species that were found in both prairie types, the number of visits listed first are to the forbs found in rural prairies, separated by a forward slash (/), followed by the number of visits to the forbs found in urban prairies. For insect pollinator group visits to forb species found in both prairie types, insect groups listed first were in the rural prairies, separated by a /, followed by insect groups in urban prairies. Insect pollinator groups followed by an asterisk (*) indicates equal counts of visits. An I in parenthesis (I) after the forb species' common name indicates that the forb is an introduced species to tallgrass prairies.

Forb species	Number of visits	Found in	Insect pollinator group most visited
Liatris pycnostachya (gayfeather, blazing star)	1031	Rural	Bumble bees
Silphium laciniatum (compass plant)	278/351	Rural/Urban	Sweat bees/Sweat bees
Ratibida pinnata (gray-headed coneflower)	15/563	Rural/Urban	Beetles/Bumble bees
Rudbeckia hirta (black-eyed Susan)	182/355	Rural/Urban	Larger butterflies/Sweat bees
Monarda fistulosa (wild bergamot)	531	Urban	Carpenter bees
Solidago juncea (early goldenrod)	481	Urban	Wasps
Cichorium intybus (common chickory) (I)	338	Urban	Sweat bees
Silphium integrifolium (rosinweed)	310	Urban	Skippers
Tradescantia ohiensis (smooth spiderwort)	173/137	Rural/Urban	Honey bees/Honey bees
Heliopsis helianthoides (oxeye sunflower)	307	Urban	Solitary bees
Verbesina virginica (white crownbeard)	302	Urban	Wasps
Pycnanthemum tenuifolium (slender mountain mint)	295	Rural	Beetles* Flies*
Asclepias syriaca (common milkweed)	251	Urban	Bumble bees
Chamaecrista fasciculata (showy partridge pea)	247	Urban	Bumble bees

Focal forb species, arranged by descending counts of insect pollinator visits found in rural, urban, or rural/urban prairies, and the insect pollinator group that visited each forb species the most continued. For any focal forb species that were found in both prairie types, the number of visits listed first are to the forbs found in rural prairies, separated by a forward slash (/), followed by the number of visits to the forbs found in urban prairies. For insect pollinator group visits to forb species found in both prairie types, insect groups listed first were in the rural prairies, separated by a /, followed by insect groups in urban prairies. Insect pollinator groups followed by an asterisk (*) indicates equal counts of visits. An I in parenthesis (I) after the forb species' common name indicates that the forb is an introduced species to tallgrass prairies.

Forb species	Number of visits	Found in	Insect pollinator group most visited
Penstemon digitalis (tall white beardtongue)	56/183	Rural/Urban	Carpenter bees/Bumble bees
Eryngium yuccifolium (rattlesnake master)	232	Rural	Sweat bees
Vernonia baldwinii (western ironweed)	228	Urban	Larger butterflies
Berlandiera texana (Texas green eyes)	195	Rural	Sweat bees
Dalea purpurea (purple prairie clover)	179	Rural	Bumble bees
Rudbeckia triloba (brown-eyed Susan)	174	Urban	Honey bees
Silene regia (royal catchfly)	167	Rural	Larger butterflies
Physostegia angustifolia (false dragonhead)	165	Rural	Carpenter bees
Vicia villosa (winter vetch, hairy vetch) (I)	161	Urban	Carpenter bees
Hypericum prolificum (shrubby St. John's wort)	140	Urban	Sweat bees
Coreopsis lanceolata (tickseed coreopsis)	35/85	Rural/Urban	Sweat bees/Beetles
Solidago speciosa (showy goldenrod)	115	Urban	Beetles
Coreopsis grandiflora (bigflower coreopsis)	114	Rural	Sweat bees
Erigeron strigosus (daisy fleabane)	24/87	Rural/Urban	Beetles* Flies*/Sweat bees
Verbesina helianthoides (yellow crownbeard)	109	Urban	Carpenter bees

Focal forb species, arranged by descending counts of insect pollinator visits found in rural, urban, or rural/urban prairies, and the insect pollinator group that visited each forb species the most continued. For any focal forb species that were found in both prairie types, the number of visits listed first are to the forbs found in rural prairies, separated by a forward slash (/), followed by the number of visits to the forbs found in urban prairies. For insect pollinator group visits to forb species found in both prairie types, insect groups listed first were in the rural prairies, separated by a /, followed by insect groups in urban prairies. Insect pollinator groups followed by an asterisk (*) indicates equal counts of visits. An I in parenthesis (I) after the forb species' common name indicates that the forb is an introduced species to tallgrass prairies.

Forb species	Number of visits	Found in	Insect pollinator group most visited
Solidago altissima (tall goldenrod)	73/34	Rural/Urban	Beetles/Wasps
Callirhoe involucrata (purple poppy mallow)	102	Urban	Honey bees
Melilotus officinalis (yellow sweet clover) (I)	95	Urban	Sweat bees
Echinacea pallida (pale purple coneflower)	92	Rural	Bumble bees
Silphium perfoliatum (cup plant)	84	Urban	Larger butterflies
Leucanthemum vulgare (ox-eye daisy) (I)	64/18	Rural/Urban	Beetles/Beetles
Coreopsis tinctoria (plains coreopsis)	80	Urban	Sweat bees
Cirsium discolor (field thistle)	75	Rural	Bumble bees
Daucus carota (Queen Anne's lace) (I)	75	Urban	Beetles
Lobelia siphilitica (blue lobelia)	73	Rural	Sulfur butterflies
Helianthus mollis (ashy sunflower)	69	Rural	Bumble bees
Dalea candida (white prairie clover)	65	Rural	Sweat bees* Wasps*
Solidago ptarmicoides (white upland aster)	57	Rural	Sulfur butterflies
Torilis arvensis (field hedge parsley) (I)	56	Urban	Sweat bees
Helenium flexuosum (purple-headed sneezeweed)	44	Rural	Bumble bees

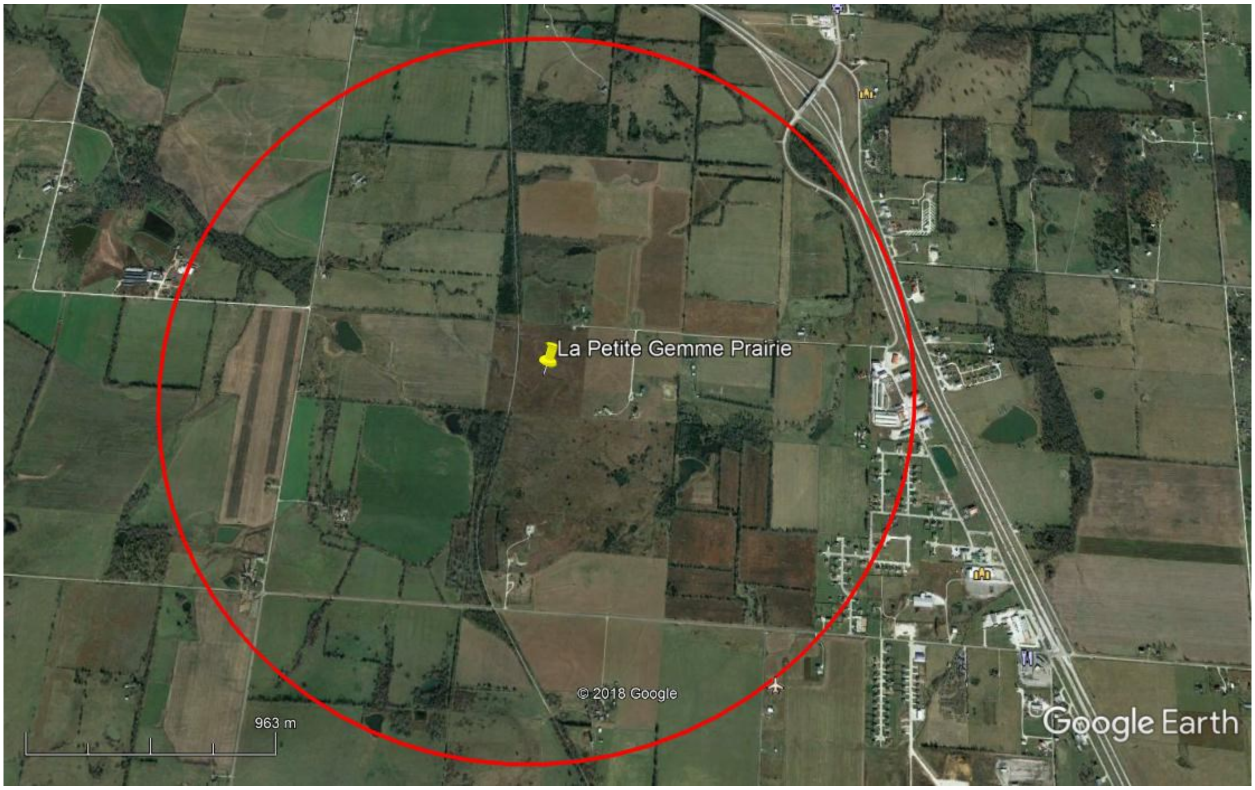
Focal forb species, arranged by descending counts of insect pollinator visits found in rural, urban, or rural/urban prairies, and the insect pollinator group that visited each forb species the most continued. For any focal forb species that were found in both prairie types, the number of visits listed first are to the forbs found in rural prairies, separated by a forward slash (/), followed by the number of visits to the forbs found in urban prairies. For insect pollinator group visits to forb species found in both prairie types, insect groups listed first were in the rural prairies, separated by a /, followed by insect groups in urban prairies. Insect pollinator groups followed by an asterisk (*) indicates equal counts of visits. An I in parenthesis (I) after the forb species' common name indicates that the forb is an introduced species to tallgrass prairies.

Forb species	**Number of visits**	**Found in**	**Insect pollinator group most visited**
Sabatia campestris (prairie rose-gentian)	43	Rural	Solitary bees
Erigeron annuus (annual fleabane)	33	Urban	Solitary bees
Vernonia fasciculata (prairie ironweed)	30	Rural	Sulfur butterflies
Achillea millefolium (common yarrow)	29	Rural	Beetles
Desmodium canadense (showy tick trefoil)	27	Urban	Sweat bees
Solidago rigida (stiff goldenrod)	26	Rural	Beetles
Camassia scilloides (wild hyacinth)	24	Rural	Sweat bees
Eupatorium serotinum (late boneset)	23	Rural	Wasps
Phlox glaberrima (smooth phlox)	22	Rural	Skippers
Symphyotrichum novae-angliae (New England aster)	21	Urban	Sweat bees
Verbena stricta (hoary vervain)	20	Urban	Sweat bees
Rubus allegheniensis (Allegheny blackberry)	14	Urban	Beetles
Conium maculatum (poison hemlock) (I)	10	Urban	Beetles
Trifolium pratense (red clover) (I)	10	Urban	Bumble bees* Beetles*
Orbexilum pedunculatum (Sampson's snakeroot)	9	Rural	Solitary bees

Focal forb species, arranged by descending counts of insect pollinator visits found in rural, urban, or rural/urban prairies, and the insect pollinator group that visited each forb species the most continued. For any focal forb species that were found in both prairie types, the number of visits listed first are to the forbs found in rural prairies, separated by a forward slash (/), followed by the number of visits to the forbs found in urban prairies. For insect pollinator group visits to forb species found in both prairie types, insect groups listed first were in the rural prairies, separated by a /, followed by insect groups in urban prairies. Insect pollinator groups followed by an asterisk (*) indicates equal counts of visits. An I in parenthesis (I) after the forb species' common name indicates that the forb is an introduced species to tallgrass prairies.

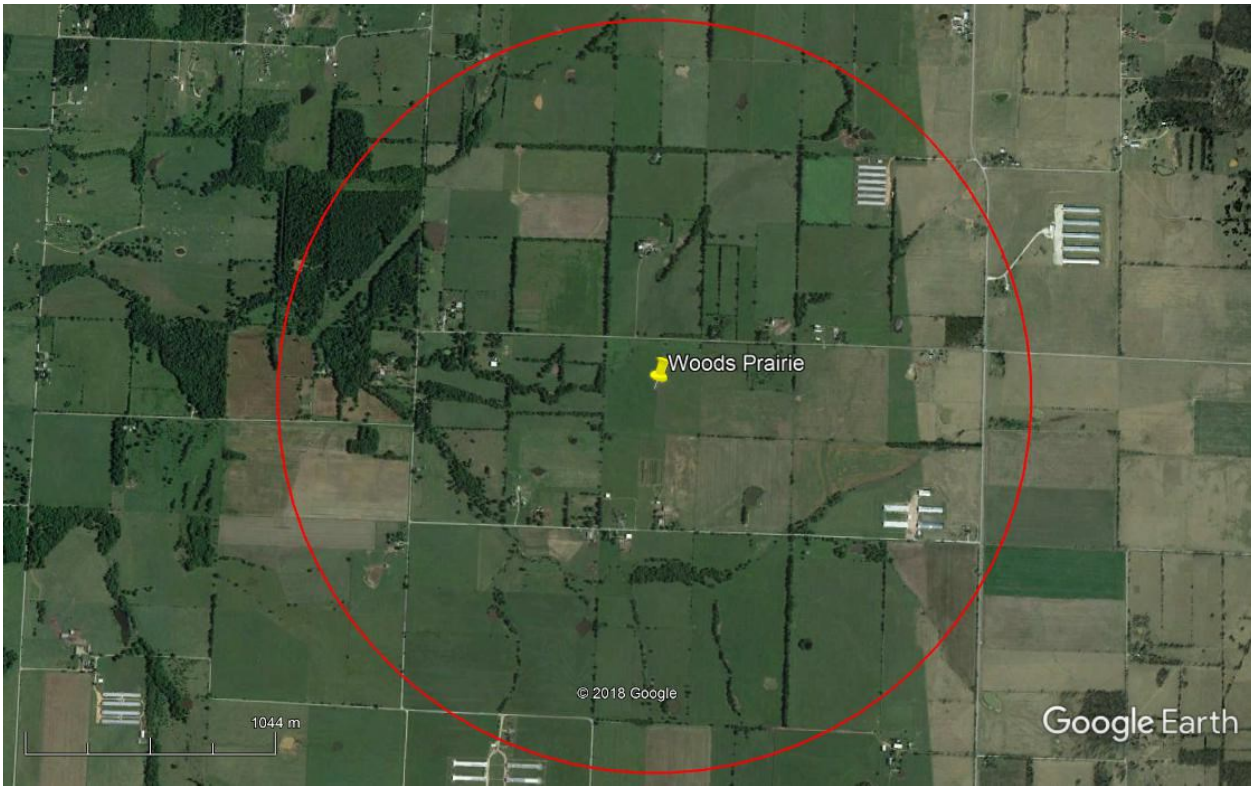
Forb species	**Number of visits**	**Found in**	**Insect pollinator group most visited**
Melanthium virginicum (bunchflower)	8	Rural	Beetles
Mirabilis nyctaginea (wild four o'clock)	5	Urban	Flies
Amorpha canescens (lead plant)	4	Rural	Sweat bees* Solitary bees* Carpenter bees* Flies*
Euphorbia corollata (flowering spurge)	3	Rural	Skippers* Beetles* Flies*
Delphinium carolinianum (prairie larkspur)	0	Rural	No visitors
Oenothera filiformis (large-flowered gaura)	0	Rural	No visitors
Phlox divaricata (wild sweet William)	0	Rural	No visitors

APPENDIX E-1: MAP OF LA PETITE GEMME PRAIRIE (LP-R)



Aerial view of La Petite Gemme Prairie (LP-R). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-2: MAP OF WOODS PRAIRIE (WP-R)

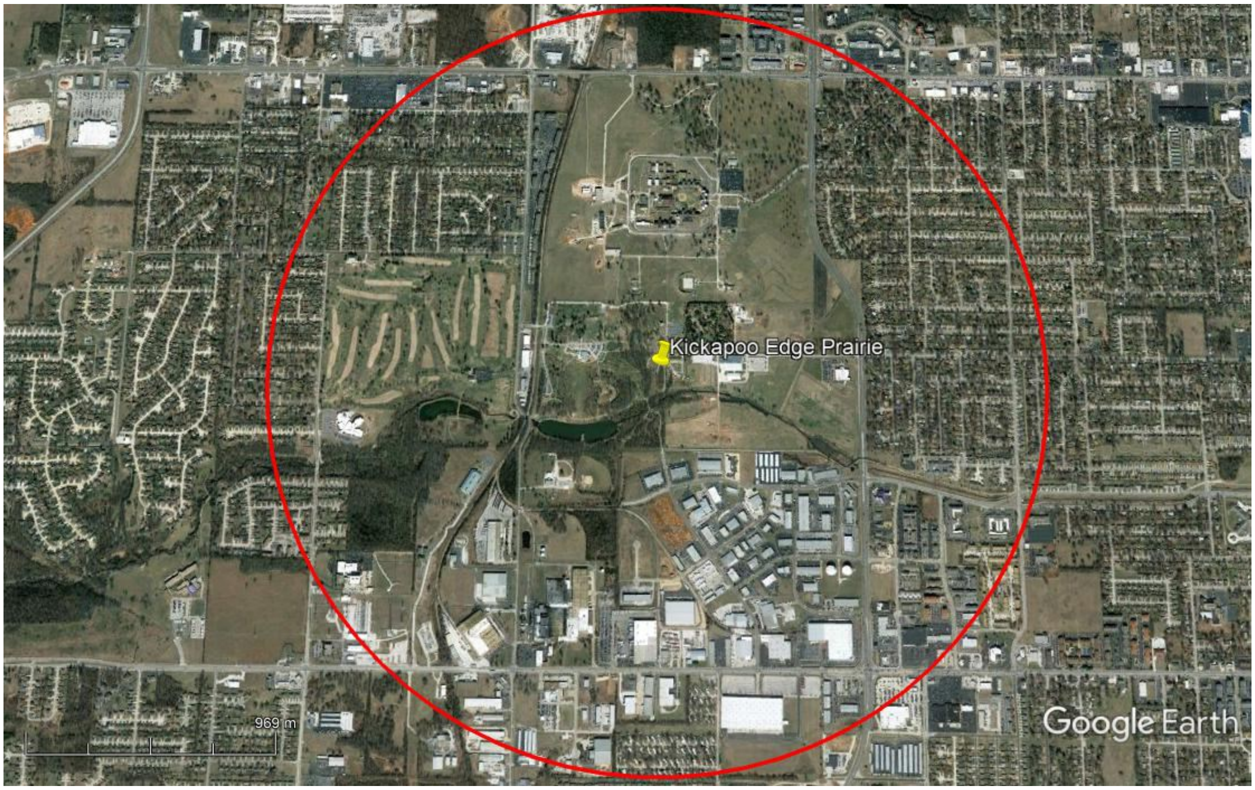


Aerial view of Woods Prairie (WP-R). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-3: MAP OF PROVIDENCE PRAIRIE (PP-R)

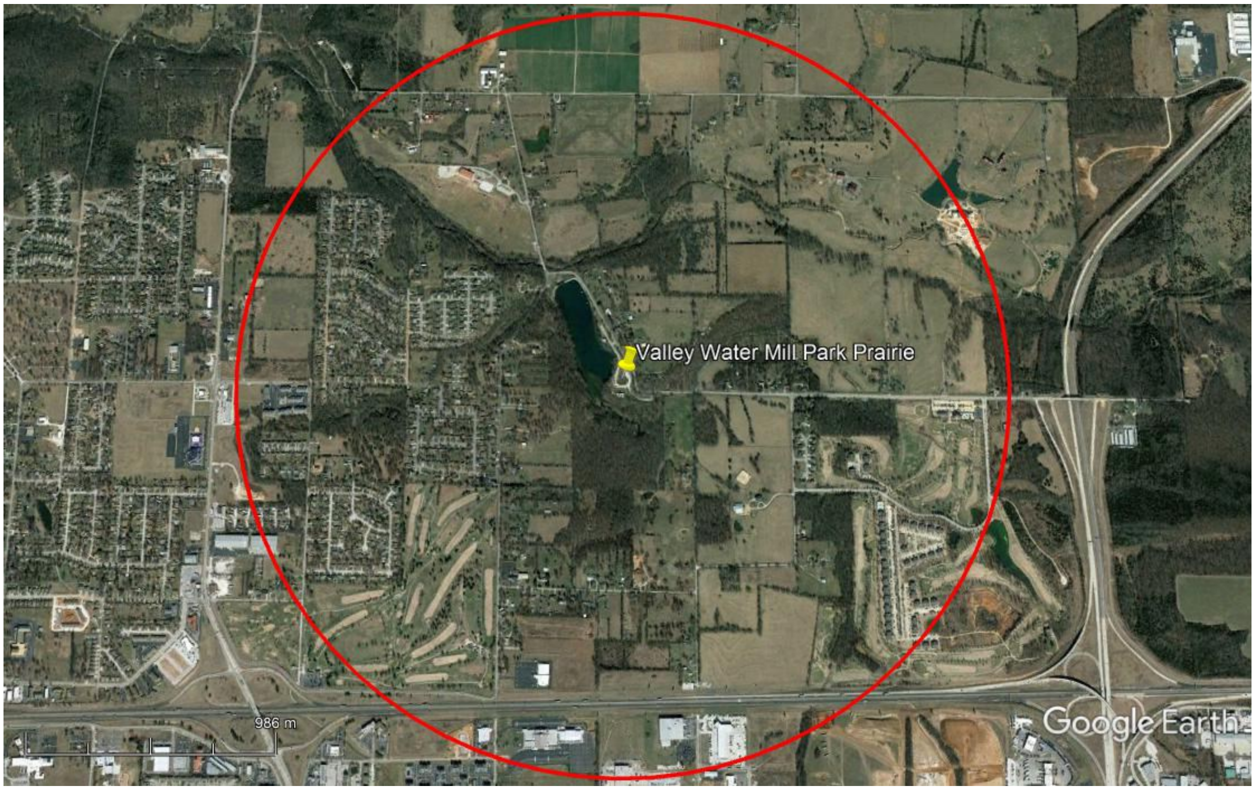
Aerial view of Providence Prairie (PP-R). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-4: MAP OF KICKAPOO EDGE PRAIRIE (KE-U)



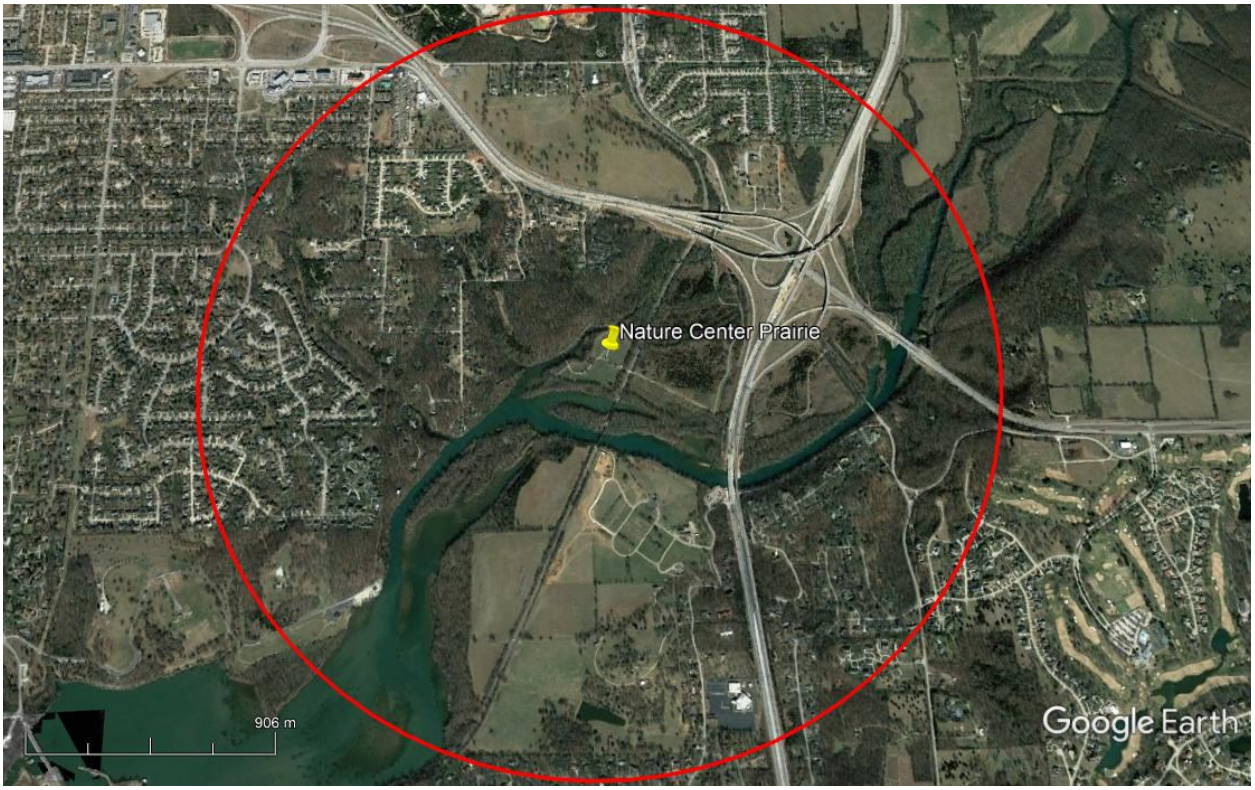
Aerial view of Kickapoo Edge Prairie (KE-U). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-5: MAP OF VALLEY WATER MILL PARK PRAIRIE (VW-U)



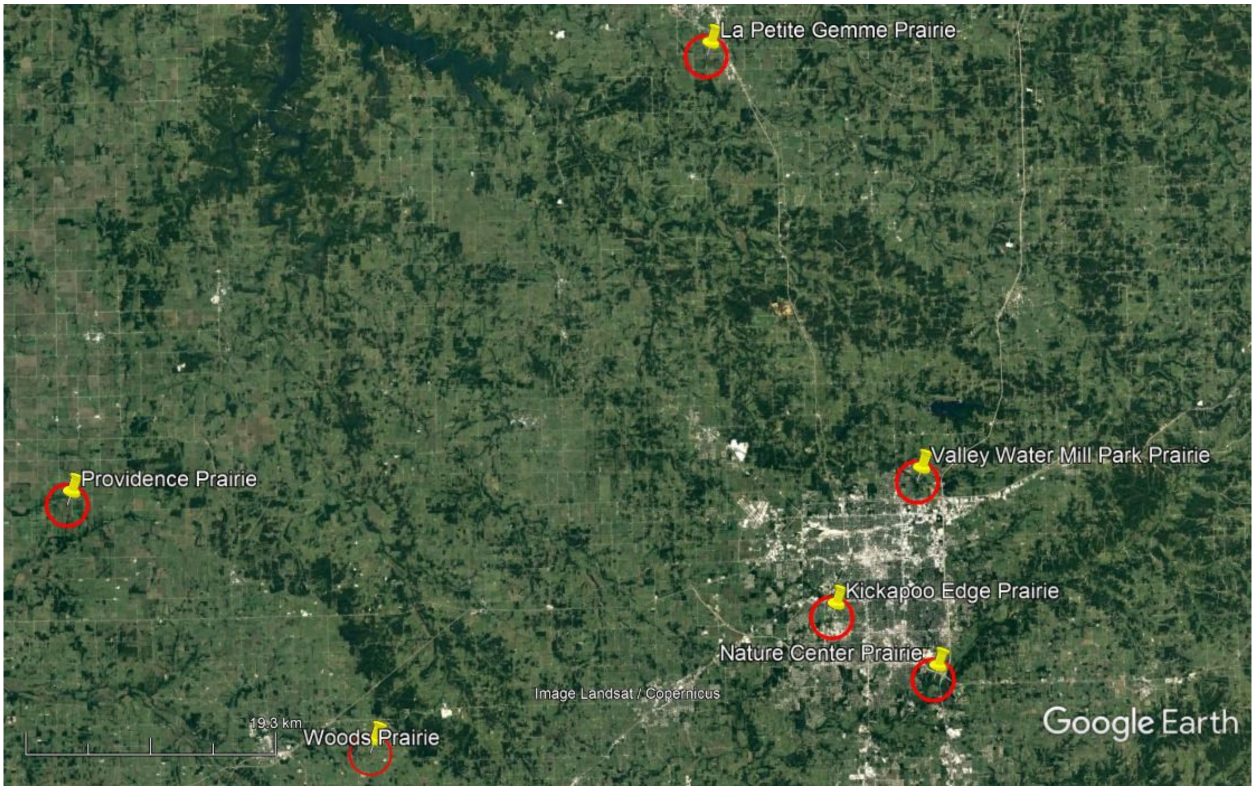
Aerial view of Valley Water Mill Park Prairie (VW-U). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-6: MAP OF NATURE CENTER PRAIRIE (NC-U)



Aerial view of Nature Center Prairie (NC-U). The red outline is the boundary of the 8 km^2 area surrounding the prairie.

APPENDIX E-7: MAP OF ENTIRE STUDY SITES



Aerial view of the three rural and three urban prairies in southwest Missouri. The red circles are the boundaries of the 8 km^2 areas surrounding each prairie.