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We respect Indigenous people and their roles in protecting the natural world for they represent only 5% of the world's population while preserving 80% of the world's biodiversity on their territorial lands (Ogar et al., 2020, Johnston, 2022).

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Abstract

Turfgrass landscapes have expanded rapidly in the United States and are a dominant land cover in urban ecosystems, predicted to expand as urban areas increase. If turfgrass is a dominating land cover, then this homogenization in plant species diversity (quality) and biomass (quantity) could result in negative impacts on multiple ecosystem functions (ecosystem multifunctionality [EMF]), both above- and belowground. Our study compares multiple ecosystem response variables across three habitat types, 1) bermudagrass turfs (BG), 2) pollinator gardens (PG), and 3) remnant prairies (RP) (N=18, n=6). We measured above- and belowground variables for relative EMF between habitats. We assess whether there is a distinguishable difference between functions of these urban (BG, PG) and native (RP) grassland habitats and if aboveground variables can be used as predictors for belowground biotic and abiotic properties. Our results indicate that PG function similarly to RP in promoting pollinators, pest regulation, and plant production. In addition, PG differ in function compared to RP in nutrient cycling, biodiversity, and all habitats are similar in water cycling. Our analysis indicates that BG significantly differ, and are lower in function, compared to PG and RP.

Keywords: plant, pollinator, soil, ecosystem, biodiversity, multifunctionality, habitats, native, urban, management, blooming

INTRODUCTION

Land cover change through habitat reduction and fragmentation have negatively impacted biodiversity through extirpation, extending to extinction (Larsen et al., 2005; Newbold et al., 2016; Thomas et al., 2004). Declines in biodiversity are a result of ecosystem degradation caused by several contributors, including climate change, overharvesting, and the intensification of land use. These effects are coupled with the introduction of invasive species, such as plants. Invasive plant species often pose negative ecological impacts on ecosystem structure (native soil, plant, and insect populations) and functions through impacting critical abiotic and biotic interactions, such as plant-soil nutrient cycling and plant-insect mutualist relationships (Giling et al., 2019; Hooper et al., 2005; Manning et al., 2018; Newbold et al., 2016). Ecological functions provide essential, life-supporting processes that contribute to humans (Giling et al., 2019; Hooper et al., 2005; Manning et al., 2018). These functions are provided by the biotic community, abiotic mechanisms, and climate (Giling et al., 2019; Hooper et al., 2005). Given the interconnection of ecosystem functions and organisms, disturbances, such as land use change and intensification, can negatively affect multiple organisms and multiple ecosystem functions (Hooper et al., 2005; Newbold et al., 2015).

Efforts to preserve or restore ecosystem function have been implemented by using various management techniques and interventions (Novotny & Goodell, 2020; Suding, 2011; Thompson & Kao-Kniffin, 2017). However, such efforts often target one or two ecosystem functions at a time, and studies on the effectiveness of such intervention efforts likewise tend to only measure their specific targeted functions, such as soil erosion or pollination. Restoration efforts with one target in mind will inevitably affect other non-target processes, such as those occurring both above- and below-ground (Bakker & Wilson, 2004; Kumar et al., 2018; O'Riordan et al., 2021; Millennium Ecosystem Assessment, 2005). A multifunctional approach to studying biodiversity and abiotic mechanisms is known as ecosystem multifunctionality (Hooper et al., 2005). Ecosystem multifunctionality (EMF) attempts to holistically study biotic and abiotic mechanisms that are simultaneously interacting within and between themselves to provide essential functions with the goal to advise land management practices (Giling et al., 2019; Manning et al., 2018).

A multifunctionality framework can be applied to examine impacts of habitat conversion and subsequent restoration in native grasslands which are among the world's most vulnerable biomes (Comer et al., 2018). Worldwide only 4.6% of grasslands are protected from habitat conversion (Hoekstra et al., 2005). In the North American Great Plains, more than 50% of native, temperate grasslands and prairies have been lost due to drastic changes in land use (Hoekstra et al., 2005; Newbold et al., 2016), namely conversion to agriculture and urbanization (Comer et al., 2018; Hoekstra et al., 2005; Milesi et al., 2005; Newbold et al., 2016). The greatest losses from land conversion have been in the tall grass prairies, where as little as 2% to 8% of their historical extent remains (Comer et al., 2018).

Grasslands are essential ecosystems that have a major role in the global carbon cycle, acting as carbon sinks that amount from 10% to 30% of the world's carbon stocks (Scurlock & Hall, 1998). Prairies, especially tallgrass prairies, have higher water holding capacity due to clay and fine sediment to a rich variety of plant diversity that supports both above- and belowground biodiversity (Kumar et al., 2018). Plant diversity promotes EMF (Allan et al., 2015; Hooper et al., 2005; Meissen et al., 2020; Thompson & Kao-Kniffin, 2017; Wratten et al., 2012) and grasslands

are far from uniform (Scurlock & Hall, 1998), being made up of primarily herbaceous plant species ranging in species and function from graminoids to forbs, including nitrogen fixers. In the United States of America (U.S.), land conversion that took place within the past two centuries included the removal of native plant populations followed by the introduction of homogenous plant communities, or monocultures. These monocultures are made up of staple crops (corn, wheat, and soy) in agricultural areas covering 4,058,104 km^2 of land (Agricultural land (sq. km) - United States. World Bank Open Data, 2021) and turf grasses, including exotic and invasive species such as bermudagrass (*Cynodon dactylon*) that are most common in warmer climates (Thompson & Kao-Kniffin, 2017). As of 2005, an estimated 163,800 km^2 of land cover in the U.S. are made up of turf grasses and this area is expected to increase in tandem with urban development and expansion (Milesi et al., 2005; Thompson & Kao-Kniffin, 2017) which, as of 2015, has increased to 186,576 km^2 (Center for International Earth Science Information Network, 2013).

The approach to managing turf grasses in urban areas is known to 1) decrease multiple ecosystem functions, such as reducing biodiversity and causing nutrient runoff (Thompson & Kao-Kniffin, 2017), and 2) increase the uses of chemical herbicides and fossil fuel mowers leading to enhanced chemical run-off and carbon emissions, respectively (Milesi et al., 2005; Thompson & Kao-Kniffin, 2017). An alternative to turf grass that has been promoted and is gaining momentum, is the establishment of forb-dominant pollinator habitats, also known as pollinator gardens (Coleman & Wait, 2022; Meissen et al., 2020; Novotny & Goodell, 2020; T. L. Watson et al., 2022; Wratten et al., 2012). The evidence is clear that pollinator gardens enhance pollen- and nectar-resource availability for pollinators (Coleman & Wait, 2022; Nichols et al., 2022; Winfree et al., 2011; Wratten et al., 2012). However, other than provisioning for pollinators (Liang et al., 2022, Baldock 2020; Buchholz & Egerer 2020; Wenzel et al., 2020; Ayers & Rehan 2021; Maruyama et al., 2021; Silva et al., 2021) few studies have investigated the effects pollinator garden management has on EMF when they are maintained in urban areas (Jha et al., 2023).

In this study, we address EMF in grasslands that are native to the region and those that were installed by humans in urban areas throughout Central Oklahoma. The grasslands of this region are historically defined as the tall to mixed-grass prairies. To assess land conversion effects on EMF, we tested multiple above- and belowground variables from native grassland conversion to turfs to pollinator gardens. We surveyed plant and invertebrate functionality and diversity with soil physical and chemical properties of three managed habitats to broaden the understanding of whether conversion from prairies to bermudagrass turfs impact EMF and whether conversion to pollinator gardens restores EMF. In this study, we consider the following question: Do urban pollinator gardens have high EMF, comparable to native prairie habitats, and do bermudagrass turfs have lower EMF? Our hypothesis is that EMF is driven by plant community composition derived by management. We predict that above- and below-ground functions are enhanced with a higher number of plant species contributing to enhanced multifunctionality (Allan et al., 2015; Byrnes et al., 2014; Hector & Bagchi, 2007; Isbell et al., 2017; Meissen et al., 2020).

Our study assesses how land-use influences EMF, from native to urban grassland communities here on referred to as habitat type(s), that include remnant prairies, pollinator gardens, and bermudagrass turfs. We assess the culture of human-managed habitats working to maintain an abundance of seasonal blooming forbs to promote pollinators (Bożek, 2019; Cariveau et al., 2020). In addition, we assess the goal to sequester carbon and retain water in urban areas through managed

green spaces (Milesi et al., 2005; Thompson & Kao-Kniffin, 2017). As global change intensifies (Giling et al., 2019) and human development increases, it is increasingly important to quantify the effects of urban managed habitats on multifunctionality (Jha et al., 2023; O'Riordan et al., 2021; Engström et al., 2018).

METHODS

Study Design

In this 2023 study, we explored the proposed question with a spatially matched design that quantified multiple plant, invertebrate, and soil variables in three habitat types: (I) graminoid-dominant bermudagrass turf, (II) forb-dominant pollinator gardens, and (III) graminoid- and forb-mixed remnant prairies (*n*=6 of each habitat type) located within and near the urban areas of Central Oklahoma along I-35 (Figure 1, Table S1). This region of Oklahoma is within the historically tall to mixed-grass prairie ecoregion of the U.S. Central Great Plains and the ancestral territories of the Native American Nations who are the Gáuigú (Kiowa), ϟΛȤΛȤα ɮOƧ∩ ᑕ∩ᓚα ᑭΛ^ȤΛ^(Osage), Wichita, Nʉmʉnʉʉ Sookobitʉ (Comanche), Kiikaapoi (Kickapoo), and current day territory of the Chickasaw Nation.

The study sites were between 30-m^2 and 400-m^2, determined by layout of the vegetation (Figure 2). The sites with a large area were set up as 400-m^2 (20m x 20m), most often in BG and RP sites, but occasionally were smaller due to the layout of PG, which often had smaller ranges of area that were occupied by forb species. To identify each site's area for survey and collection, all sites were laid out in a grid starting from the NW corner made up of 1-m^2 grids. We labeled the northern-most W to E edge of each site by letters (A to T, at the max) and the western-most N to S edge by numbers (starting chronologically at 1).

Furthermore, we surveyed land management from each site to gather data for site characteristics (Table S2). We collected data about how each site is managed. The data collected included land cover history, use of mower or brush hog or clipping, irrigation, seeds added, plants added, soil additives used (i.e., compost, mulch, or chemical fertilizers), and chemical usage (i.e., herbicides or pesticides). This survey was conducted using a questionnaire that asked questions relating to the management process for each site in which land managers responded using multiple choice and short answers.

Plants

We conducted plant surveys and collections from ten randomly generated quadrats (the same quadrats used for soil collections, see below). Each site had ten total 1-m^2 randomly placed, fixed quadrats totaling 172 samples collected in July (less six samples due to one site's conservation concern and two missing samples from 2 different sites; Appendices Figure S1).

I. Site-level Dominant Species & Blooming Forbs

In early May of 2023, we surveyed the top 3-6 dominant plant species using ranked cover rates at the site level. To identify the most dominant plant species, we walked the full area of each site. If a plant species occupied 15% of the site's total area or more, it was identified as a dominant plant species. We identified the dominant plant species' functional type (forb, legume, graminoid, or woody) and reported their ranked cover rate. The ranked cover rates were determined from 1 to 5 using the following scale: 1: 0-15%, 2: 15-25%, 3: 25-50%, 4: 50-75%, 5: 75-100%.

Specific leaf area (SLA; mm^2/mg) is an indicator of plant life strategies that are acquisitive (fast) or conservative (slow growing). To calculate SLA for species-level traits, we collected ten fully formed leaves from ten individuals of each dominant plant species from outside of the site perimeter for BG and RP which occupied larger areas, and from inside the perimeter for PG which occupied smaller areas. We digitally scanned the surface area of every leaf. We oven-dried the leaves in coin envelopes at 70°C for 48 hours and measured the leaf dry weight. The following equation was used to calculate SLA:

$$\frac{leaf\ area\ (mm^2)}{leaf\ dry\ mass\ (mg)} = SLA\ (\frac{mm^2}{mg})$$

The Southern U.S. experiences more precipitation in the spring and decreased precipitation in the summer (Hajek and Knapp, 2022). Due to the onset of our study and the ideal conditions seasonal precipitation provide to blooming forbs in the early summer (Hajek and Knapp 2022), we took one full site measure of blooming forbs from each site in early May of 2023. We surveyed the blooming plant (forb and legume) cover at each site. To account for each site's blooming plant cover, we walked the sites' full area with a grided map that had a customized outline of the individual sites in which each grid represented a 1-m^2 quadrat. We took note of the areas that had blooming plants by shading in the areas on the grided map that corresponded to our location within the site with a pencil (Appendices Figure S2). Throughout the remainder of our study, we accounted for blooming forbs, or no blooming forbs, at the quadrat level using a maximum of ten and minimum of four random and unfixed quadrats on four other occasions (early summer, mid-summer, late summer, and early fall). Upon each site visit, when a site had an area that was less than 3-m^2 of blooming forbs present, or no blooming forbs were present, the site would be noted as having no blooming forbs at that time.

II. Quadrat Plant Species Presence & Absence, Functional Type Percent Cover

We surveyed plant species, including each species' functional type, to identify the community composition of the three habitat types. Using the same ten fixed quadrats, we surveyed plant species composition by identifying all present plants by species, functional group, and ranked functional cover rates from 1 to 5 (1: 1-15%, 2: 16-25%, 3: 26-50%, 4: 51-75%, 5: 76-100%). We surveyed each quadrat's plant species composition in 2023 from mid-May to early June. We identified plant species using the iNaturalist app. We collected unknown species from outside the sites' perimeters for herbarium specialist identification to genus or species. Within the same quadrats, we surveyed plant functional group cover adding together total forb, legume, graminoid, wood, and other ground covers, such as bare ground and litter, adding up to approximately 100%.

III. Plant Production:

a) Plant Leaf Area Index

Leaf area index (LAI) was used to determine canopy density in the late spring (mid-May to early June) of 2023. LAI is a non-destructive method for determining plant canopies, which can serve as a proxy for biomass when plant removal is not desired due to conservation concerns, or other purposes. We used LAI as an early season biomass proxy before the peak growing season when biomass, described below, was collected in July. We sampled LAI at the 1-m^2 quadrat level (LP-

80 AccuPAR Ceptometer) taking two LAI measurements per each quadrat during the late spring season and averaged this value as the quadrat's total LAI.

b) Above- and Belowground Biomass

We collected 172 samples (six samples less due to one site's conservation concern and two missing samples from two different sites) of biomass in July during the peak of the 2023 growing season. We clipped plant biomass samples in a 20 cm x 100 cm strip within the same ten fixed quadrats, leaving a remainder of 4 cm plant height. We placed each quadrats' plant clippings into brown paper bags, oven-dried them at 70°C for 48 hours, and afterwards measured the dry weights. To account for the paper bag weights, we oven-dried (70°C for 48 hours) five empty paper bags to derive an average weight per sample to subtract the average paper bag's weight from the plant biomass weight. To determine an estimate of the full 1-m^2 quadrats' total plant biomass, we divided it by 0.2-m^2 to estimate biomass per m^2 for g/m2.

For all root traits, we used the roots from our soil core samples. In 2023, we extracted roots from our soil core samples (n = 172) during the soil sieving process and stored them in sealed glass containers submerged in 30% ethanol to 70% DI water solution. We derived root biomass using paper bags for each sample of roots and placed them in the oven at 70 C for 48 hours. We used the following equation to scale from 5 cm^2 to the quadrat area of 1 m^2 to calculate root biomass:

$$\text{root dry mass} * \frac{10000}{12.88249339} = root\ biomass \frac{g}{m^2}$$

For root trait analysis, we spread out each set of root samples in a clear, shallow dish filled with DI water to digitally scan them. We ran batch analysis for all samples using RhizoVision Explorer (Seethepalli and York, 2019). These analyses output the following root traits: root length (m), surface area (mm^2), average diameter (mm), and volume (cm^3). For specific root length (SRL, m/g), we divided root length by dry mass.

Invertebrates

I. Pollinator Observations

We performed pollinator observations to examine how pollinator taxonomic groups are associated with habitat type. We conducted four total visits per site for pollinator observations during the months of May through October of 2023 (two research observers) temporally spaced three to four weeks apart and during ideal weather conditions. We conducted pollinator observations on clear or mostly sunny days with wind speeds below 9 mph and temperatures ranging between 54°F to 96°F to ensure pollinator activity. When blooming forbs were present within the site perimeter, we randomly identified a minimum of four to a maximum of ten blooming quadrats, recording the approximate location as a blooming 1-m^2 floater quadrat and noting the identification of the present blooming forbs (i.e., quadrats not linked to plant and soil surveys and collections) (Appendices Figure S3).

We observed flying insects at each blooming floater quadrat for 3 minutes. We treated flying insects as pollinators when they contacted the forbs' (including legumes) reproductive organs (stigma and/or anthers) recording the total number of individual pollinators. We categorized

pollinators into broad taxonomic groupings by order, family, and size (Appendices Figure S4). If there were no forbs blooming within the site perimeter upon our visit, we recorded the visit as "no blooms, no observations" and the pollinator count was recorded as zero.

II. Foliar Invertebrate Surveys

In early June of 2023, we collected invertebrate samples by sweeping canvas nets along four transects that ran along the north, east, south, and west edges of each site's perimeter (approximately 20 m in length; Appendices Figure S5). Pollinator garden site collections were taken further outside of the site's perimeter to avoid breaking blooming forb and legume species stalks intentionally cultivated by gardeners. Sweep netting took place one meter to a maximum of twenty meters away from each site's perimeter in grassy areas. One PG site requested no invertebrate collections due to the site's monarch butterfly (*Danaus plexippus*) conservation efforts. After capture, we transferred the invertebrates from the nets into clear plastic bags and placed them under ice in coolers in the field. We stored invertebrate samples in the laboratory freezer. We organized the invertebrates from each transect by laying them out on white paper plates according to size and morphospecies and photographed them with a ruler for later categorization. Invertebrate functional groups were identified to determine the ability of the habitat to support multiple trophic levels and functional groups of invertebrates.

III. Invertebrate Functional Trophic Groupings

We used North American insect identification guides (Eaton, E. R., & Kaufman, K., 2007; Abbott, J. C., & Abbott, K., 2023) to identify collected invertebrate specimens to the finest taxonomic level possible. We counted the abundance of each group and categorized them by functional trophic groups (predator, parasitoid, floral herbivore, chewing herbivore, piercing herbivore, omnivore, non-feeding adults, and unknown). To assure accurate identification at each trophic level, we only used predator, chewing herbivore, and piercing herbivore abundance in our analysis of invertebrate functional trophic groupings (i.e., spiders are predators, caterpillars are chewing herbivores, and tree hoppers are piercing herbivores, etc.).

IV. Proxy of Invertebrate Biomass

To estimate invertebrate biomass, we processed the images of each site's transect samples using ImageJ to determine the total area of invertebrates on each plate. This afforded our study a two-dimensional proxy for invertebrate biomass. To further our investigation of invertebrate biomass, we oven-dried one sample from each site that was the average two-dimensional area of the transect samples. We assessed the dry mass by the total area of invertebrates to ensure that the two-dimensional results could be translated into biomass.

Soils

We collected soil cores from the surface to a depth of 10 cm, with a diameter of 5 cm, from ten randomly generated quadrats (the same quadrats used for plant collection and surveys) at each site (AMS, American Falls, ID) totaling 172 samples (less six samples due to one site's conservation practice and two were missing samples from 2 different sites).We collected soil cores from the

western edge of each quadrat (Appendices Figure S6). We placed the soil samples in individual plastic zip bags and stored them in an iced cooler in the field then in the refrigerator (5.6°C) in our laboratory. We sieved the soil samples, removing materials (roots, invertebrates, rocks, and other non-soil materials), and took pre- and post-sieve weights of the soil samples before further processing.

I. Soil Moisture and pH

We measured the gravimetric water content (GWC) for each quadrat sample by oven drying approximately 10 g of soil at 105°C for approximately 48 hours. We measured pH on approximately 10 g of dry soil with 0.01 mol L−1 CaCl2 (Robertson et al. 1999).

II. Soil Total Carbon and Nitrogen

To determine total soil carbon and nitrogen, we used a soil organic carbon protocol. We air-dried 10 g of soil per sample in coin envelopes for 24 hours, which was then sieved at 2 mm before being ground with a ceramic mortar and pestle and passed through a 0.25 mm mesh sieve. We removed soil carbonates by adding drops of 1 N HCL until soils were saturated and left for 24 h (Zhang and Wang, 2014). After the carbonates were removed, we rinsed and filtered the soil for carbon and nitrogen analyses ([Oklahoma State University, Soil, Water and Forage Analytical Laboratory, Stillwater, OK, USA] Zhang and Wang, 2014). To determine C:N ratio we divided the organic carbon by the total nitrogen.

Statistical Analyses

Univariate Analyses

We analyzed SLA, LAI, plant Simpson evenness, plant functional cover and Simpson evenness, and all root traits using a linear mixed model (LMM). We analyzed soil moisture, soil carbon, soil nitrogen, bare ground, plant litter, plant biomass, and plant Shannon-Weiner diversity with log transformation LMM. We analyzed total plant species using Poisson log GLMM. All LMMs and GLMMs have habit type as the fixed and sites as the random factor to account for the repeated measures from individual quadrats within each site. We analyzed soil pH, abundance of invertebrate trophic groups, and the proportion of site native plant species using analysis of variance (ANOVA). We used Tukey HSD tests post hoc comparisons across habitat types. We used the GLMM Add-Ins tool in JMP ® Pro 18.0.0 for our analysis.

Multivariate Analyses

We compared plant species and pollinator communities using permutational multivariate analysis of variance (PERMANOVA). We used the Jaccard index for plant (presence/absence) and Bray-Curtis index for pollinator (relative abundance) compositional similarity analyses across habitat types. This process included the analysis of resemblance matrices that transformed the pollinator abundance data by the fourth root for clarity of the analysis (Clarke et al., 2006). We used principal component analysis (PCA) of all three habitat plant communities combined for the visual analysis and multidimensional scaling (MDS) for the visual analysis of pollinator communities. To determine whether habitat types differed in their plant and pollinator beta diversity, we assessed

compositional dispersion using permutational multivariate analysis of dispersion (PERMDISP). These data were analyzed in Primer-e software (version 6) (PRIMER-e, Albany, Auckland, New Zealand).

EMF Analyses

I. Categorizing Ecosystem Functions

To assess ecosystem multifunctionality we categorized each variable into six ecosystem functions (EF[s]), including biodiversity, culture, nutrient cycling, pest regulation, production (encompassing food and fiber production), and water cycling (Millennium Ecosystem Assessment, 2005). In this study, we examine how varied plant communities (PG, BG, and RP) and management regimes influence EMF through the analysis of multiple variables both above- and below-ground. We assessed correlation relationships among the following variables using principal component analyses (PCA): total root length, average root diameter, root volume, root surface area, root biomass, specific root length (SRL), soil pH, soil total carbon, soil moisture, soil total nitrogen, soil carbon to nitrogen, plant leaf area index (LAI), total plant species, plant Shannon-Weiner diversity, plant Simpson diversity, total plant functions, plant functional cover, plant function Shannon-Weiner diversity, plant height, plant biomass, specific leaf area (SLA), bare ground cover, litter cover, graminoid total cover, forb total cover, legume total cover, forb to graminoid ratio, forb to legume ratio, dominant native plant species, pollinator total species, pollinator abundance (N), pollinator Pielous evenness, pollinator Shannon-Weiner diversity, chewing herbivore N, piercing herbivore N, and predator N. We used JMP ® Pro 18.0.0 to conduct these analyses.

We used all the variables in our dataset to compared each habitat's ability to contribute to EMF using multifunctionality scores (Asbjornsen et al., 2014; Meissen et al., 2020). The results from the PCA and cluster analysis provided the most representative variables that we then categorized into EFs. In addition, we derived like variables that related to each EF, that we refer to as "sub"-variables, that were used in the final EMF analysis using multifunctionality scores. By using PCA and cluster analysis, we performed a robust and data-driven approach in working with a large dataset with multi-level and -trophic data. Further, the variables in this study often represent more than one function. However, we chose the function that is associated with each variable based on the primary function for that variable. For example, total pollinator species was associated with culture (described further below) as opposed to biodiversity, which this data also represents functionally.

II. Principal Component Analysis and Clustering Analysis

There were seven most representative variables derived from the PCA and cluster analysis, including total pollinator species, soil total nitrogen, LAI, proportion native plant species, root surface area, SRL, and total plant species. We condensed these variables into six EFs, including: biodiversity, culture, nutrient cycling, pest regulation, production, and water cycling. To make sure that each of the six EFs were contributing equally to the multifunctionality score, we added four "sub"-variables (described above) and weighted each variable according to how many others were sharing the same EF. These sub-variables were added because they are often included in EMF

analyses, including soil total carbon (O'Riordan et al., 2021; Richter et al., 2024), chewing herbivore abundance (N), pollinator N, and predator N (Isbell et al., 2017; Jha et al., 2023). In total, we derived eleven variables from a dataset of thirty-one variables and categorized them by EFs as follows: total plant species, chewing herbivore N categorized as biodiversity; total pollinator species, pollinator N categorized as culture; soil total nitrogen, soil total carbon categorized as nutrient cycling; predator N categorized as pest regulation; LAI, proportion native plant species categorized as production; and root surface area and SRL were categorized as water cycling.

EFs are categories within the main ecosystem processes that contribute to humans (also known as ecosystem services). For this study, each ecosystem function makes up the following ecosystem process: biodiversity, nutrient cycling, and water cycling make up supportive processes; pest regulation makes up regulatory processes; production makes up provisioning processes; and pollinator taxon richness and abundance make up cultural processes (Acheampong, 2020; Millennium Ecosystem Assessment, 2005). It could be argued that pollinator taxon richness and abundance should be placed within the biodiversity section. However, due to the critical role pollinators provide to society through multiple EFs (Winfree et al. 2011) and efforts made to accommodate seeing them in gardens by enhancing floral abundance, we found it appropriate to categorize them under the cultural category, which encompasses educational, ethical, and aesthetic values, sense of place, cultural heritage values, and recreation (Millennium Ecosystem Assessment, 2005). Furthermore, we categorized native plants under (plant) production, which is defined under provisioning processes as food and fiber (Millennium Ecosystem Assessment, 2005). We found it appropriate to categorize native plants under this category due to growing support for using wild and native plants in global food production to diversify local crop production and conserve biological resources through fostering more sustainable agroecosystems (Shelef et al., 2017).

III. Multifunctionality Scores

We used the variables that were output using the cluster analysis and averaged the variable means that shared ecosystem function. We used multifunctionality flowers (visual representation) and scoring (percent value) methods (Asbjornsen et al., 2014; Meissen et al., 2020) to depict the relative abilities of each habitat type to provide EMF. The habitat type with the highest mean value for each ecosystem function was scored as a 1.0 and other habitat types were scored as a relative proportion of that average (i.e., highest possible multifunctionality score = 6.0). Each habitat type's multifunctionality score is the average of its six components.

Further, we estimated multifunctionality scores for each site. We converted all site-level averages from each ecosystem function into relative scores where the site with the highest mean value for the respective ecosystem function was scored as 1.0, and all other sites were scored as a relative proportion of that average. We used ANOVA to assess each function separately between habitat types. Finally, we used ANOVA to assess the sum of all multifunctionality scores to assess how multifunctionality is compared between habitat types.

RESULTS

Due to the high number of variables (n=31) in this study, we only show the figures for the univariate and multivariate results that make up the final EMF results from the PCA (Appendices Figure S7) and cluster analysis (Appendices Table S3), whether they are significant or not. We include the results for all other variables, including those from the EMF results, within Table 1 of the Tables and Figures section.

Plants

Composition and Diversity

Overall, plant species composition differed across all habitats ($p = 0.0001$) during the month of May 2023 (Figure 3, Table 1). The proportion of native plant species differed between habitats (Figure 4, Table 1). Ninety percent of plant species in RP were native, followed by 60% in PG and 35% in BG. Species richness differed between habitats ($p = 0.0019$, Figure 5a, Table 1). RP significantly differed from PG and BG which both shared similar values. Shannon-Wiener diversity index differed between habitats ($p = 0.0023$, Table 1). RP had the greatest plant diversity at 26% greater than BG and 41% greater than PG. Plant evenness did not differ between habitats ($p = 0.3299$, Table S3). RP and BG both had higher functional richness that were 27% and 29%, respectively, greater than PG. Plant functional evenness marginally differed between habitats ($p = 0.0510$, Table 1) while plant functional cover (graminoid, forb, legume, and woody) did not differ across habitats ($p = 0.1512$, Table 1). RP had the highest and PG had the lowest values of Simpson evenness where BG shared values with both RP and PG.

Traits and Biomass: Above- and Belowground

Bare ground cover differed between habitats (log transformed, $p = 0.0034$, Table 1). PG were the only habitats with wood mulch as ground cover. Mulch was initially categorized as bare ground cover, however, due to mulch cover's positive effects on carbon retention (Jha et al., 2023) we tested the habitats with mulch against TC. The three PG sites that had wood mulch as bare ground cover were CUF, PRPRK, and WRP with 54% higher soil total carbon than the other three PG sites (ARF, NCL, and STP). PG had a higher bare ground cover which was 73% higher than RP and BG. It should be noted that three PG sites (CUF, PRPRK, and WRP) had wood mulch cover that were initially categorized as bare ground. Plant litter differed between habitats ($p = 0.0311$, Table 1). RP had higher plant litter which was 46% higher than BG which was 15% higher than PG.

Specific leaf area (SLA) differed between habitats ($p < 0.0001$, Table 1). BG had 46% higher SLA than PG and 72% higher SLA than RP. Leaf area index (LAI) differed between habitats ($p = 0.0003$, Figure 5b, Table 1). PG had the highest LAI compared to RP and BG. PG had 48% higher LAI than RP and 92% higher LAI than BG, RP and BG did not differ from one another. Root biomass differed between habitats ($p = 0.0013$, Table 1). BG had 45% higher root biomass than RP and 81% higher root biomass than PG, RP and PG did not differ from one another. Root surface area (Figure 5c), specific root length (SRL, Figure 5d), total root length, average diameter, volume, did not differ by habitat type (Table 1). Biomass did not differ between habitats during the month of July (Table 1).

Invertebrates

Pollinators

Overall, pollinator community composition differed between habitats ($p = 0.0004$, Figure 6, Table 1). When analyzing by site visits, referred from now on as rounds, we found that early and mid-summer (rounds 1 and 2) pollinator community composition differed between all three habitats ($p = 0.0002$ and $p = 0.0335$, respectively). During early summer, differences in abundance were detected between habitats for the orders of beetles ($p = 0.0297$, Appendices Figure S8a), bees ($p = 0.0101$, Appendices Figure S8a), and wasps ($p = 0.0279$, Appendices Figure S8a). During mid-summer, no differences were detected between habitats for any pollinator orders. Late summer and early fall (rounds 3 and 4) pollinator community composition did not differ between habitats ($p = 0.3172$ and $p = 0.2176$, respectively). BG sites had no pollinators and were thus excluded from the analysis, while PG and RP did not differ from each other.

Pollinator taxonomic richness differed between habitats ($p = 0.0068$, Figure 7a, Table 1). PG and RP shared similar pollinator taxonomic richness (PG had 19% higher than RP), and BG had the lowest (73% lower than PG and 67% lower than RP). Pollinator abundance differed between habitats ($p = 0.0018$, Figure 7b, Table 1). PG and RP shared similar pollinator abundance (PG had 19% higher than RP), and BG had the lowest (55% lower than RP and 63% lower than PG). Pollinator Shannon-Wiener diversity differed between habitats ($p = 0.0111$, Table S3). Pollinator Pielous evenness did not differ between habitats ($p = 0.1398$, Table S3).

Foliar Invertebrates and Proxy for Biomass

Chewing herbivore abundance differed between habitats ($p = 0.0043$, Figure 8, Table 1). RP had 44% greater chewing herbivores abundance than PG and 58% greater than BG. Predator abundance differed between habitats ($p = 0.0043$, Figure 8, Table 1). RP had 46% greater predator abundance than PG and 62% greater than BG. Piercing herbivore abundance did not differ between habitats ($p = 0.1633$, Figure 8, Table 1). The total two-dimensional area values used as a proxy for biomass showed a significant difference between habitats ($p = 0.0027$, Table 1). RP had 88% and 90% greater invertebrate biomass (2D area) than BG and PG, respectively.

Soils

Soil total carbon differed between habitat types ($p = 0.0085$). PG had 64% greater total carbon than RP and BG both of which had similar total carbon (Figure 9a, Table 1). Soil total nitrogen (Figure 9b, Table 1), soil moisture, and pH did not differ between habitats (Table 1).

Multifunctionality Scores and Forb Total Cover

Multifunctionality scores differed between habitat types ($p = 0.0004$; Figure 10a). RP and PG had the highest multifunctionality scores of 70% and 66%, respectively, but did not differ from each other ($p = 0.8546$). BG had the lowest multifunctionality score of 36%, which differed from the other two habitats in multifunctionality. We determined multifunctionality scores between sites by

habitat type for each EF (Figure 10b), using the site multifunctionality scores for analysis as follows. The results of each individual EF include biodiversity ($p = 0.0010$, Table 2), culture ($p = 0.0031$, Table 2), nutrient cycling ($p = 0.0044$, Table 2), pest regulation ($p = 0.0239$, Table 2), and production ($p < 0.0001$, Table 2) differed between habitat types. Water cycling did not differ between habitats ($p = 0.2408$, Table 2). Furthermore, biodiversity was high in RP, but similarly low in BG and PG. Culture was similar between high values in PG and RP, but RP shared similarly low values with BG. Next, nutrient cycling was highest in PG, but BG and RP shared similarly low values. Pest regulation was similarly high in RP and PG, but PG also shared similarly low values with BG. Further, production was highest in PG and RP, and BG had significantly lower values. Lastly, our results indicate a 0.544 R^2 when multifunctionality scores for all sites were plotted against site median forb total cover (Figure 11).

DISCUSSION

We provide evidence that plant composition and management effect multiple EFs in PG (culture, nutrient cycling, production, and pest regulation) and RP (biodiversity, pest regulation, production, and culture), and show that BG provide significantly lower values for the majority of EFs, apart from water cycling which is not a significantly different EF from PG and RP. Our study suggests management approaches that allow for more productive plant communities (i.e., reduced disturbance regimes to once or twice a year) and have native plants in high proportion benefit invertebrate diversity at multi-trophic levels, specifically chewing herbivores, pollinators, and predators as well as providing food and fiber through agroecosystems, in which biodiversity performs multiple functions from pest control to nutrient cycling (Altieri, 1999). Further, belowground chemical properties, specifically soil total carbon, were different between habitats due to management practices. However, belowground biotic traits were similar between habitat types, apart from root biomass, at the top 10 cm soil layer, regardless of management practices (i.e., high or low frequency mowing regimes as well as plant selection choices). These findings allude to recommendations for holistic land management that would increase EMF in urban areas.

Three Grassland Habitats

The multifunctionality results of our study indicate that RP and PG habitats have the greatest multifunctionality but by differing functions, and BG have the lowest multifunctionality. This supports our hypothesis that plant communities, and their maintained approach to management, influence EMF, as supported by other study's findings (Allan et al., 2015; Hoekstra et al., 2005; Meissen et al., 2020). The plant communities in our study represent three varied types of functionally heterogeneous (RP), and functionally homogeneous (BG, PG) plant communities with differing mixes of native and non-native plant communities. Native plants were most dominant in RP, then PG, and least dominant in BG. The findings in our study agree that RP, the native habitat, are high in EMF (Meissen et al., 2020) and that the addition of floral resources promotes pollinators (Winfree et al., 2011; Meissen et al., 2020).

I. Remnant Prairies

Historically, the prairies of North America have been managed and sustained by the Indigenous peoples of North America for thousands of years through pyro-management (Johnston, 2022), the use of fire as a controlled disturbance regime. Regimes of regular pyro-management reduce the degree of plant litter cover which promotes new plant growth and seed germination. This process promotes native seed germination, multiple trophic levels of biodiversity, and directly benefits humans through the production of culturally important medicine, food, and fiber, as well as enhances soil multifunctionality through nutrient and water cycling (Johnston, 2022). Thus, there is a legacy of biodiversity, especially within plant communities, in RP from pyro-management which are still practiced today, along with annual mowing regimes by brush hogging, as took place in our study's RP sites.

II. Pollinator Gardens

Urban PG are like RP having high EMF scores, however PG and RP function differently in nutrient cycling and biodiversity. These results are likely due to differences in management practices that affect soil input and plant species diversity. Plant diversity is much higher in RP, promoting multi-trophic levels of invertebrate taxa. The addition of plant species to PG could promote biodiversity. Further, our results show that PG had high nutrient cycling compared to RP and BG. These results are due to the use of mulch and compost by management increasing soil total carbon in the top 10 cm of soil. This addition of carbon may benefit plants with additional nutrients to uptake as well as potentially hinder the effects of PG serving as biodiverse habitats in urban areas. Added carbon from using compost or interim mulch for ground cover, likely benefits nutrient cycling through the stabilization and/or mineralization of the carbon that is added to the system which could benefit further soil carbon sequestration as climate changes (Amorim et al., 2022) and precipitation patterns continue to change in the south-central region of the U.S. (Hajek & Knapp, 2022). However, studies have shown negative effects of added carbon and mulch to plant species diversity as added nutrients could decrease the niche dimensionality of plant diversity and evenness in PG (Harpole et al., 2016).

III. Bermudagrass Turfs

BG are singular functioning habitats that are used to provide soil stability through plant communities made up of fast-growing plants with shallow fibrous root systems. In addition, BG, or more generally turf grasses, are meant to promote carbon sequestration and cooling effects in developed areas (Milesi et al., 2005). Our results show that BG provides effective ground cover in developed areas and is likely to provide carbon sequestration and cooling effects, as PG and RP would also be expected to provide, however, due to the inability of BG to promote biodiversity, pest regulation, and provision for pollinators we advise that land managers consider reducing the spread of BG to promote biodiversity with the addition of PG in BG areas. Our analyses indicate that by using BG as a default plant community will likely accelerate ecosystem degradation from reduced biodiversity and ecological functions as humans continue to develop and expand.

Ecosystem Functions

I. Biodiversity

Grasslands are among the most highly converted and vulnerable world biomes (Hoekstra et al., 2005) and are a hotspot for biodiversity reduction (Newbold et al., 2016), meaning there is more biodiversity lost in grasslands relative to other biomes. In our study, biodiversity - made up of total plant species and chewing herbivore N - was a significant result of our EMF analysis and was greatest in RP, and lowest in PG and BG. These results indicate that RP promote biodiversity, and that PG and BG are lacking biodiversity which is a likely effect of land use and management approaches. Our study aims to allude to the negative effects of biodiversity loss in grassland ecosystems (Hoekstra et al., 2005; Allan et al., 2015; Newbold et al., 2016; Li et al., 2017; Giling et al., 2019) and these results indicate that plant communities and management approach are determining factors that have the capability to either degrade or enhance biodiversity.

II. Culture

Our study supports previous findings that pollinator communities are promoted by plant community composition, namely the abundance of blooming forbs that have a variety of seasonal blooms providing resources for much of the growing season (Winfree et al., 2011; Wratten et al., 2012). We show that PG and RP promote high abundance and diversity of pollinator communities through high blooming forb cover. Blooming cover was present in BG only during early to mid-summer, most often including forbs such as clovers, dandelions, and *Oxalis* species, along with other small and fast-growing plants, however, through the late summer to fall, BG no longer provided floral resources for pollinators (Appendices Figure S8b). Furthermore, PG and RP had seasonal blooms throughout the duration of our study (May to October) which further contributed to greater support for differing pollinator communities (Appendices Figure S8b).

III. Nutrient Cycling

Our analyses found total soil nitrogen and carbon to be the most representative variables in their correlated cluster. Nitrogen and carbon cycles are closely linked with plant production and soil organic matter (Amorim et al., 2022). Further, grasslands are significant ecosystems that play a major, and underrecognized, role in the global carbon cycle storing tons of carbon stocks belowground in extensive root systems (Scurlock & Hall, 1998). There were no differences between habitat type in total soil nitrogen and this is likely due to the general scarcity of this mineral element in ecosystems (Amorim et al., 2022). However, our results did indicate significant differences in total soil carbon as PG values were greater than BG and RP. RP and BG had similar values in soil total carbon which indicate soil properties were likely unchanged since prairie land conversion to turfs.

The high levels of total carbon in PG soils are indicative of high rates of carbon sequestration taking place in these habitats. However, our results indicate that the high rates of carbon in PG are due in part to soil amendments input by management (occurring within most PG sites; Appendix Table S2) with a portion of carbon input caused by nutrient allocation from increased plant production (Conant et al., 2001). PG management should be advised of likely tradeoffs that occur with nutrient addition, especially in the form of mulch. These tradeoffs include reduced nesting habitat for native ground-nesting bees (McFrederick & LeBuhn, 2006; Threlfall et al., 2015; Jha et al., 2023), decrease native seed germination (O'Connell et al., 2021; Jha et al., 2023), and altered invertebrate predator diversity (Arnold et al., 2019; Dudás et al., 2016; Jha et al., 2023). Nevertheless, the high rates of soil total carbon in PG indicate the potential for synergies of multifunctionality through the growth of food along with pollinator support, such as those in urban agroecosystems, where positive food and biodiversity relationships are evident and serve as critical habitats (Jha et al., 2023).

IV. Pest Regulation

The presence of predator invertebrates in any ecosystem reduces herbivory and as a result prevents overgrazing of plant resources, a species interaction that ecosystem functioning and services depend on (Isbell et al., 2017). We included predator abundance in our EMF analysis to account for biological control (Asbjornsen et al., 2014), also referred to as pest regulation (Millennium Ecosystem Assessment, 2005). RP and PG had high predator abundance; however, lower values were also similar between PG and BG. The variation of PG high and low pest regulation could be attributed to habitat patch size, which is positively correlated to predator abundance (Fenoglio et al., 2013; Asbjornsen et al., 2014; Jha et al., 2023) as well as plant diversity where high plant diversity leads to high herbivore and predator diversity (Haddad et al., 2009). The low abundance of predators in BG is likely due to a lack of plant heterogeneity and structure (Frey et al., 2018).

This study's approach to collecting invertebrates did differ between PG and the other two habitats. We collected samples directly from BG and RP plant communities. Our approach to collecting invertebrates from grassy areas surrounding PG was a mediated effort to predict the effects blooming plant communities have on nearby habitats. Our results indicate that predators are supported in nearby areas potentially due to PG plant communities. This presents a similar effect to biodiversity strips, long areas of land dedicated to wildflower communities that provide habitat for beneficial insects increasing their presence and biological pest control, most often used in agricultural areas (Nichols et al., 2022). Therefore, it is likely that PG could help promote pest regulation outside of habitat perimeters causing top-down cascade effects which benefit several other ecosystem functions from biodiversity to soil (Estes et al., 2011). Further, these results suggest that PG can benefit adjacent food gardens, enriching urban agroecosystems and their efforts towards community resilience (Jha et al., 2023).

V. Production

Production as a provisioning ecosystem process refers to plant food and fiber production (Millennium Ecosystem Assessment, 2005). Plant production influences multiple ecosystem functions beyond provision processes from soil erosion prevention, increased carbon sequestration (Scurlock & Hall, 1998) and taxonomic diversity (Allan et al., 2015). In addition, plant production can be directly altered by land use intensification which can negatively affect ecological functions and services due to reduced habitat for, and diversity of, many taxa (Allan et al., 2015). Our study found that leaf canopy density, or LAI, was greatest in PG, followed by RP, and lowest in BG in the early summer of the year 2023. These results promote our study's findings that RP and PG support greater biodiversity due to a diverse habitat structure as opposed to BG which experience high and regular frequencies of disturbance through mowing, therefore, reducing plant production and capacity for enhanced habitat structure.

Furthermore, our analysis found that native plant dominance was a most representative variable for our EMF analyses. Management of native plant species in urban and natural areas for production in agroecology has many benefits from higher plant survival due to native plant adaptation to their native ranges and high yields of phytochemically rich foods that require low inputs from fertilizers, water, to pest control (Provenza et al., 2015; Shelef et al., 2017). In addition,

studies show value in native plant communities over nonnatives and monocultures (Shelef et al., 2017) as they not only provide opportunities for agroecology production, but also enhanced water quality and supply, pest control, nutrient cycling, soil formation, and pollination, as well as cultural values from education to medicine, all of which are currently at stake of diminishment as land intensification enhances through development (Power, 2010; Asbjornsen et al., 2014). Our study indicates that plants that are native, in our study region to prairies, should be highly considered over nonnative plants as urban areas expand. This is due to the need to help sustain and enhance multiple ecological functions through protecting threatened ecosystems, such as those in the Great Plains, and to reduce further ecological degradation in the face of a world biodiversity crisis and climate change (Hoekstra et al., 2005).

VI. Water Cycling

After biodiversity and nutrient cycling, supportive ecosystem processes that contribute to the function of localized water cycling are important processes that maintain soil fertility and water availability (Acheampong, 2020), influencing EMF. As urban areas become locations of increased human populations, 60% of the population is expected to reside in these areas by 2030, it is important to maintain replenished water cycles (Jha et al., 2023). Through this study, we were able to assess the likely cycle of water that occurs between plant communities and soils. Our results indicate a trend of slightly higher values of root surface area and average diameter in BG, although these were not significant, showing that all three habitats have similar functional values for water cycling.

Urban warming caused by increased impervious surfaces and reduced natural areas, including pervious grasslands, favors warm season graminoids, C4 species, (Duffy & Chown, 2016), which could indicate BG are ideal habitats due to urban heat effects. However, when considering multifunctionality, we do not recommend BG as main habitats to mitigate warming with continued human expansion and a changing climate. This is due to indications that unirrigated BG can act as impervious surfaces, granted absorbing more heat than concrete, that result in considerable amounts of water leaving the soil layer as outflow (Milesi et al., 2005) often overwhelming urban creeks and streams with rushing water leading to increased risks of flooding. The alternative to unirrigated BG are irrigated turfs that result in enhanced water holding capacity and carbon sequestration (Milesi et al., 2005). However, regular irrigation of urban habitats is ultimately dependent on region and the levels of capacity for usage of water and energy resources which is far less reasonable for water-limited regions such as the southern Great Plains where seasonal rainfall has and is predicted to further shift to increased summer droughts along with climate change (Hajek & Knapp, 2022).

CONCLUSION

Land management's focus on maximizing a subset of ecosystem functions has altered native plant communities making functional trade-offs commonplace (Allan et al., 2015). Our study across three grassland habitats, native (RP) and installed (BG, PG), agrees that management approaches do alter multiple ecosystem functions, both by maintaining, enhancing, and reducing them. Understanding how human relationships with urban and natural, but still managed, habitats affect overall EMF is essential to fostering effective and sustainable land management practices that can help mitigate the biodiversity crisis and associated ecosystem function declines by recognizing competing goals of intensive land management versus conservation stewardship. PG promote multiple ecosystem functions that benefit humans ranging from cultural, provisionary, regulatory, and supportive processes. However, PG could better serve to contribute to biodiversity, beyond pollinators, through increasing plant species diversity, especially native species over nonnative and cultivated varieties. BG are constrained habitats serving reduced ecosystem functions and are an example of the functional trade-offs that occur from maximizing turf grass aesthetic and function over the promotion of biodiversity and system-level functioning. This is important to reconcile as multifunctional habitats are most likely to provide more sustainable habitats in urban areas extending to the broader ecosystems onto society.

Holistic and sustainable approaches to land stewardship have been practiced in the biomes of North America for thousands of years to the present day by Indigenous peoples (Johnston, 2022). Future studies in EMF, therefore, should work to include more cultural values, along with more abiotic and biotic mechanisms, of society beyond economically based services, including recognition and respect for Indigenous land practices through ethical collaborations. This is important as research in EMF provides space for interdisciplinary investigation, beyond western science's worldviews, to determine what human relationships can be made with nature through management as opposed to what contributions we receive from nature. Indigenous lifeways teach us to practice land stewardship through the act of reciprocity which is reciprocal in receiving from the natural world through the act of giving to it (Kimmerer, 2012), ultimately this is done through our land management approaches, or, in other words, our relationship with nature. We therefore recommend integrating biodiversity that compliments, or emulates, surrounding native habitats, such as introducing more native (prairie) forb and graminoid species, into urban areas and taking careful consideration of management approaches that will work to enhance, and maintain, multiple ecosystem functions for the generations to come.

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TABLES & FIGURES

Table 1. Summary table of generalized linear mixed model results of all levels of variables and how each variable is categorized into ecosystem functions. Significant p-values are italicized, and insignificant p-values are normal script. Shared letters by habitat type show no significance, and differing letters show significance between habitat types.

Level	Ecosystem Function	F Ratio	Prob > F	BG	PG	RP
Plant						
Species composition	Biodiversity	.	*0.0001*	.	.	.
Proportion of native sp.	Production	7.4817	*0.0056*	B	AB	A
SLA	Production	32.0741	*< 0.0001*	A	B	C
LAI	Production	14.5784	*0.0003*	C	A	B
Species richness	Biodiversity	10.3146	*0.0019*	B	B	A
Shannon-Weiner diversity	Biodiversity	9.3558	*0.0023*	B	B	A
Simpson evenness	Biodiversity	1.195	0.3299	A	A	A
Functional cover	Biodiversity	2.1499	0.1512	A	A	A
Funct. Simpson evenness	Biodiversity	3.6513	*0.0510*	AB	B	A
Biomass	Production	2.5932	0.1079	A	A	A
Root length	Water cycling	1.958	0.175	A	A	A
Root average diameter	Water cycling	1.4406	0.2683	A	A	A
Root volume	Water cycling	0.1787	0.8381	A	A	A
Root surface area	Water cycling	1.5214	0.2495	A	A	A
SRL	Water cycling	3.3016	*0.0647*	A	A	A
Root Biomass	Water cycling	10.527	*0.0013*	A	B	B
Litter	Water regulation	4.4209	*0.0311*	AB	B	A
Aboveground Cover						
Bare ground cover	Water regulation	5.0055	*0.0216*	B	A	B
Soil						
Moisture	Water regulation	2.0738	0.1604	A	A	A
Total C	Nutrient cycling	6.6692	*0.0085*	B	A	B
Total N	Nutrient cycling	2.7806	0.0939	A	A	A
pH	Nutrient cycling	1.3737	0.2833	A	A	A
Pollinator						
Taxonomic composition	Biodiversity	.	*0.0004*	.	.	.
Total taxa	Cultural	7.0842	*0.0068*	B	A	A
Abundance (N)	Cultural	8.3626	*0.0018*	B	A	A
Shannon-Weiner diversity	Biodiversity	4.819	*0.0111*	A	B	B
Pielous evenness	Biodiversity	2.2973	0.1398	A	A	A
Invertebrate						
Chewing herbivore N	Biodiversity	7.7783	*0.0043*	B	B	A
Piercing herbivore N	Biodiversity	2.0996	0.1633	A	A	A
Predator N	Pest regulation	7.1031	*0.0043*	B	B	A
Biomass Proxy	Biodiversity	9.1372	*0.0027*	B	B	A

Table 2. Assessing the influence of habitat type on ecosystem functions. Summary table from ANOVA results using cluster variable from our principal component analysis (PCA) for each ecosystem function including the most representative variables that make up each function. Significant p-values are italicized, and insignificant p-values are normal script. Shared letters by habitat type show no significance, and differing letters show significance between habitat types.

Ecosystem Functions	F Ratio	Prob > F	Cluster Number	Most Representative Variables	BG	PG	RP
Biodiversity	11.2573	*0.001*	4	Total plant species, chewing herbivore abundance	B	B	A
Cultural	8.6831	*0.0031*	1	Pollinator total taxa and abundance	B	A	AB
Nutrient cycling	7.97	*0.0044*	6	Soil total nitrogen and total carbon	B	A	B
Pest regulation	4.838	*0.0239*	4	Predator abundance	B	AB	A
Production	19.2697	*< 0.0001*	5, 7	LAI, proportion of native plant species	B	A	A
Water cycling	1.5679	0.2408	2, 3	SRL, root surface area	A	A	A
Sum of all functions	16.8461	*0.0001*	1 - 7	All variables shown above	B	A	A

Figure 1. Study sites from 2023 by habitat type in Central Oklahoma, USA. Habitat types are shown as follows: bermudagrass turfs (BG) are light green triangles, pollinator gardens (PG) are green squares, and remnant prairies (RP) are dark green diamonds. The red toned areas within the

map represent development, or urban areas. The sites names are shorthand as follows: for BG Cherry Creek Park (CCP), Dane Park (DAN), Hathaway Park (HTP), Meadow Park (MEAD), Purcell Lake bermudagrass area (PCL-BG), Songbird Park (SON); for PG Aquatic Research Facility (ARF), Common Wealth Urban Farms (CUF), Norman Central Library (NCL), Prairie Creek Park (PR-PRK), Scissortail Park (STP), Will Rogers Park (WRP); and for RP Kessler Atmospheric and Ecological Field Station (KAEFS), Lake Stanley Draper (LSD), Purcell Lake remnant prairie area (PCL-RP), Saxon Park (SAX), Sutton Park (SUT), and Trail's End Boy Scout Campgrounds (TREND).

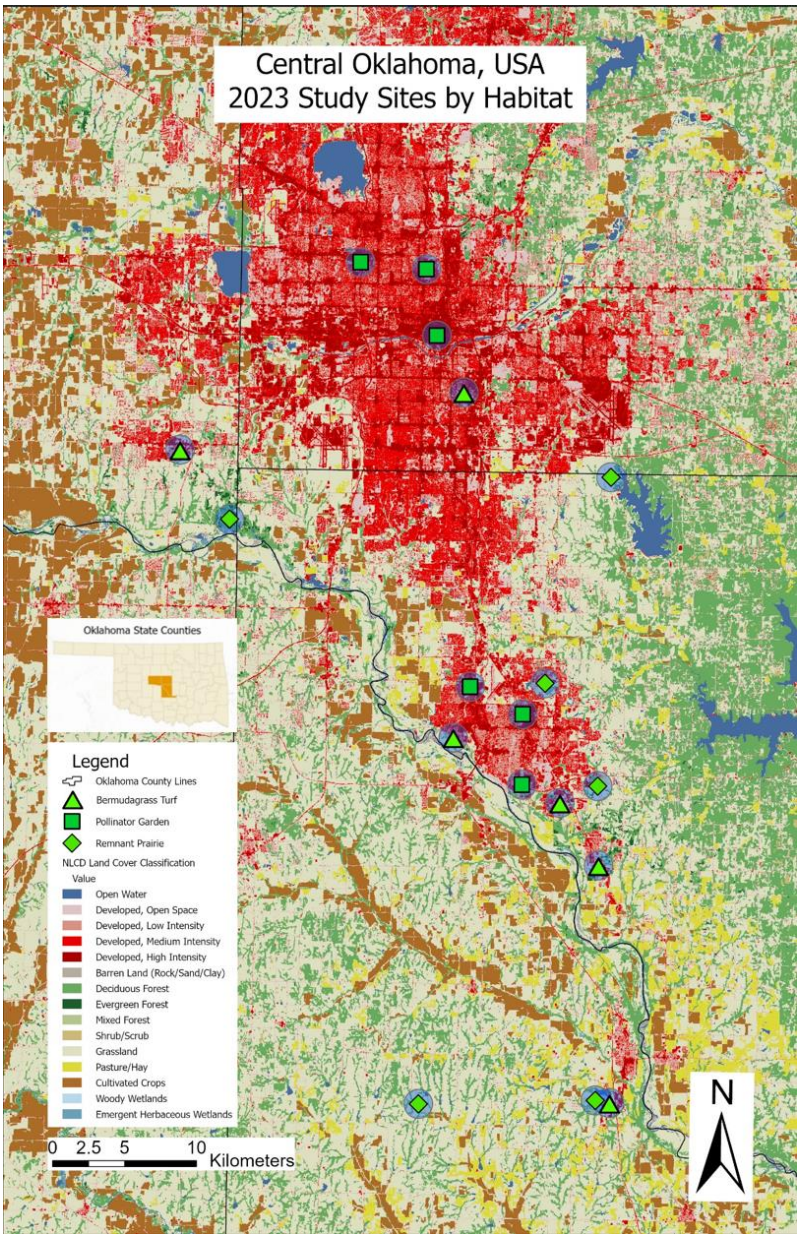


Figure 2. Study sites were scaled between 30-m^2 and 400-m^2, determined by layout of the vegetation. The sites were generally set up as a) 400-m^2 (20m x 20m) but varied due to the layout

of forb-dominant pollinator gardens, b) CUF was the smallest layout. Each site was sectioned into a grid with 1-m^2 quadrats which were identified by the north edge representing letter, a through t, and the west edge representing numbers, 1 through 20. Therefore, the northwest quadrat always started at A1.

a) 400-m^2

A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	O1	P1	Q1	R1	S1	**T1**
A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	M2	N2	O2	P2	Q2	R2	S2	T2
A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3	M3	N3	O3	P3	Q3	R3	S3	T3
A4	B4	C4	D4	E4	F4	G4	H4	I4	J4	K4	L4	M4	N4	O4	P4	Q4	R4	S4	T4
A5	B5	C5	D5	E5	F5	G5	H5	I5	J5	K5	L5	M5	N5	O5	P5	Q5	R5	S5	T5
A6	B6	C6	D6	E6	F6	G6	H6	I6	J6	K6	L6	M6	N6	O6	P6	Q6	R6	S6	T6
A7	B7	C7	D7	E7	F7	G7	H7	I7	J7	K7	L7	M7	N7	O7	P7	Q7	R7	S7	T7
A8	B8	C8	D8	E8	F8	G8	H8	I8	J8	K8	L8	M8	N8	O8	P8	Q8	R8	S8	T8
A9	B9	C9	D9	E9	F9	G9	H9	I9	J9	K9	L9	M9	N9	O9	P9	Q9	R9	S9	T9
A10	B10	C10	D10	E10	F10	G10	H10	I10	J10	K10	L10	M10	N10	O10	P10	Q10	R10	S10	T10
A11	B11	C11	D11	E11	F11	G11	H11	I11	J11	K11	L11	M11	N11	O11	P11	Q11	R11	S11	T11
A12	B12	C12	D12	E12	F12	G12	H12	I12	J12	K12	L12	M12	N12	O12	P12	Q12	R12	S12	T12
A13	B13	C13	D13	E13	F13	G13	H13	I13	J13	K13	L13	M13	N13	O13	P13	Q13	R13	S13	T13
A14	B14	C14	D14	E14	F14	G14	H14	I14	J14	K14	L14	M14	N14	O14	P14	Q14	R14	S14	T14
A15	B15	C15	D15	E15	F15	G15	H15	I15	J15	K15	L15	M15	N15	O15	P15	Q1	N	S15	T15
A16	B16	C16	D16	E16	F16	G16	H16	I16	J16	K16	L16	M16	N16	O16	P16	Q1	↑	S16	T16
A17	B17	C17	D17	E17	F17	G17	H17	I17	J17	K17	L17	M17	N17	O17	P17	Q1		S17	T17
A18	B18	C18	D18	E18	F18	G18	H18	I18	J18	K18	L18	M18	N18	O18	P18	Q1		S18	T18
A19	B19	C19	D19	E19	F19	G19	H19	I19	J19	K19	L19	M19	N19	O19	P19	Q1		S19	T19
A20	B20	C20	D20	E20	F20	G20	H20	I20	J20	K20	L20	M20	N20	O20	P20	Q20	R20	S20	**T20**

b) 30-m^2

A1	B1	C1
A2	B2	C2
A3	B3	C3
A4	B4	C4
A5	B5	C5
A6	B6	C6
A7	B7	C7
A8	B8	C8
A9	B9	C9
A10	B10	C10

Figure 3. Principal Coordinate Analysis (PCO) indicates the similarities of plant composition across study sites of the same habitat types. Permutation analysis indicates that the three habitat types had significantly different plant composition based on quadrat species presence and absence data across habitat types ($p = 0.0004$) and dispersion within habitat types ($p = 0.0703$). Habitat types are shown as follows: bermudagrass turfs (BG) are light green triangles, pollinator gardens (PG) are green squares, and remnant prairies (RP) are dark green diamonds. BG plant communities are more variable than RP and PG habitats.

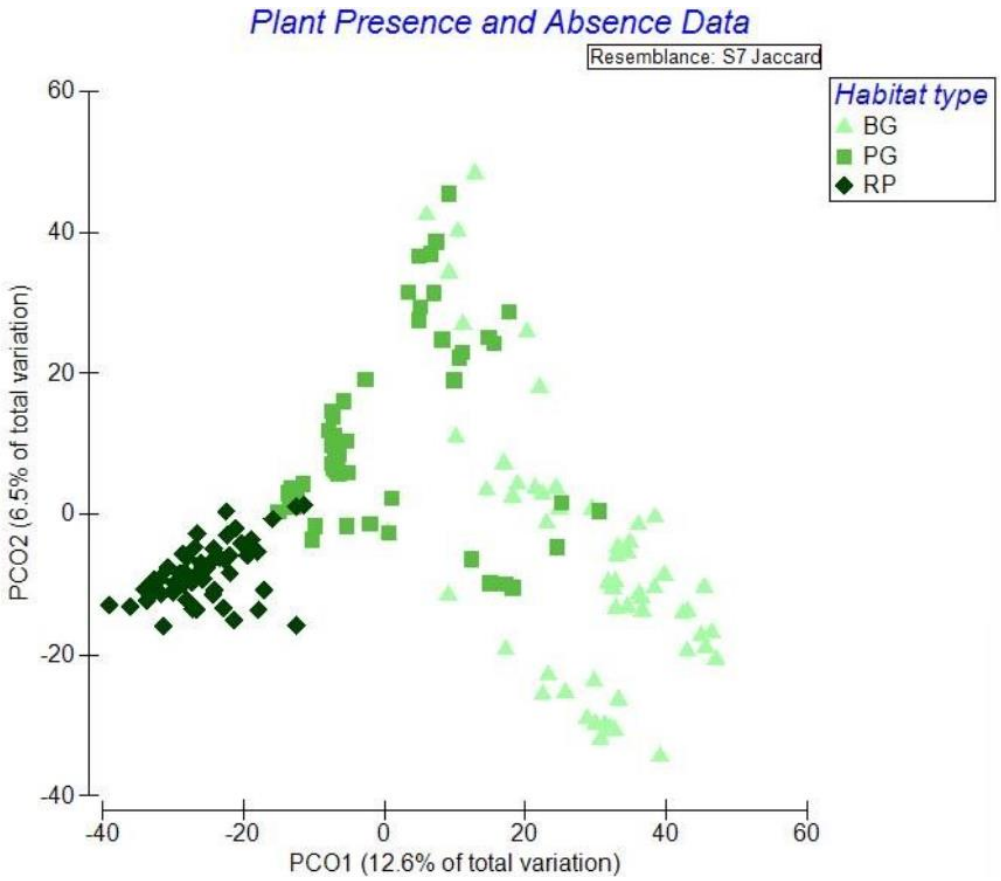


Figure 4. A bar graph of proportion of native plant species by habitat type. Remnant prairie (RP) are shown in dark green; pollinator garden (PG) are shown in green; and bermudagrass turf (BG) are shown in light green. Each error bar is constructed using 1 standard error from the mean. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

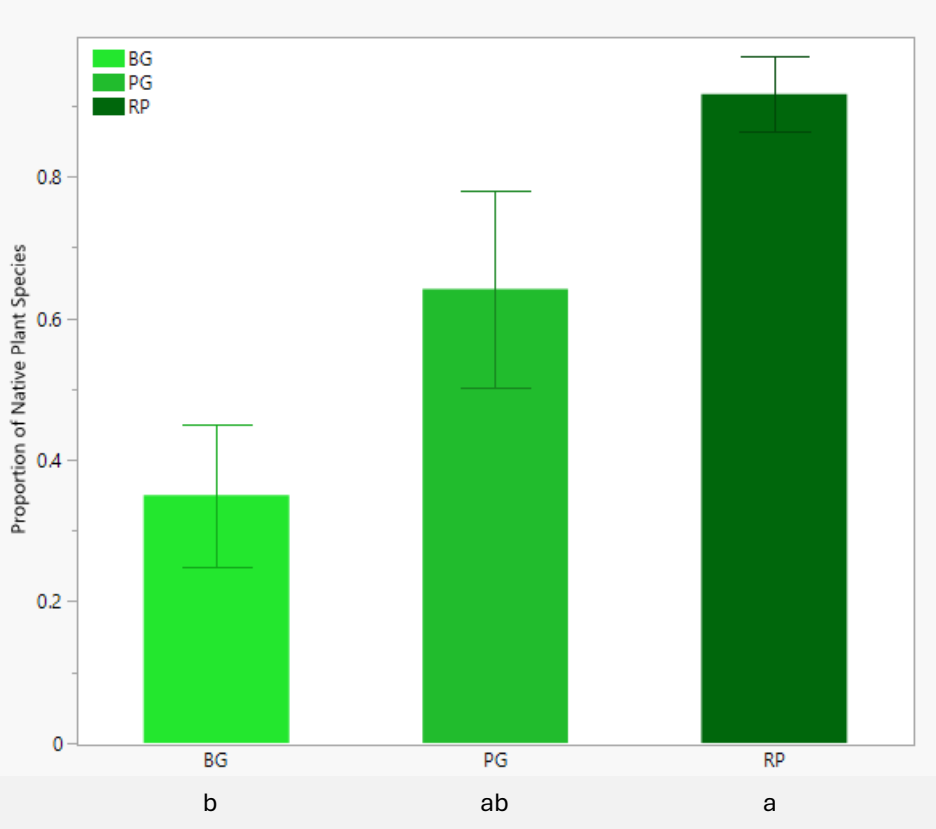


Figure 5. Box plots of a) plant species richness, b) leaf area index (LAI), c) root surface area, and d) specific root length by habitat type. Remnant prairie (RP) are shown in dark green; pollinator garden (PG) are shown in green; and bermudagrass turf (BG) are shown in light green. The mean value for each habitat is indicated by a black point. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

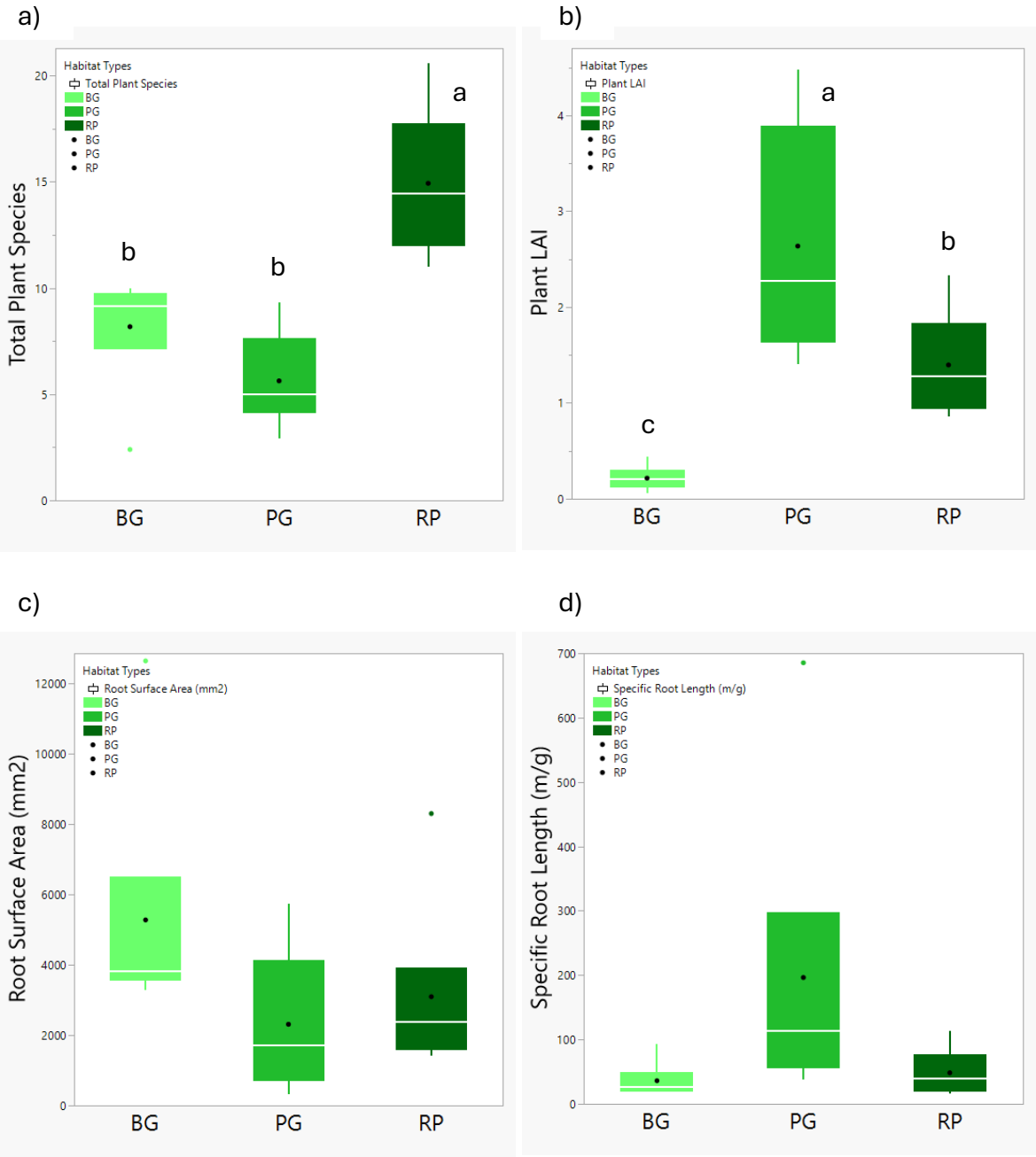


Figure 6. Principal Coordinate Analysis (PCO) indicates the similarities of pollinator composition across study sites of the same habitat types. Permutation analysis indicates that the three habitat types had significantly different pollinator composition based on quadrat pollinator taxonomic abundance data across habitat types (p = 0.0004) and dispersion within habitat types (p = 0.0703). Habitat types are shown as follows: bermudagrass turfs (BG) are light green triangles, pollinator gardens (PG) are green squares, and remnant prairies (RP) are dark green diamonds.

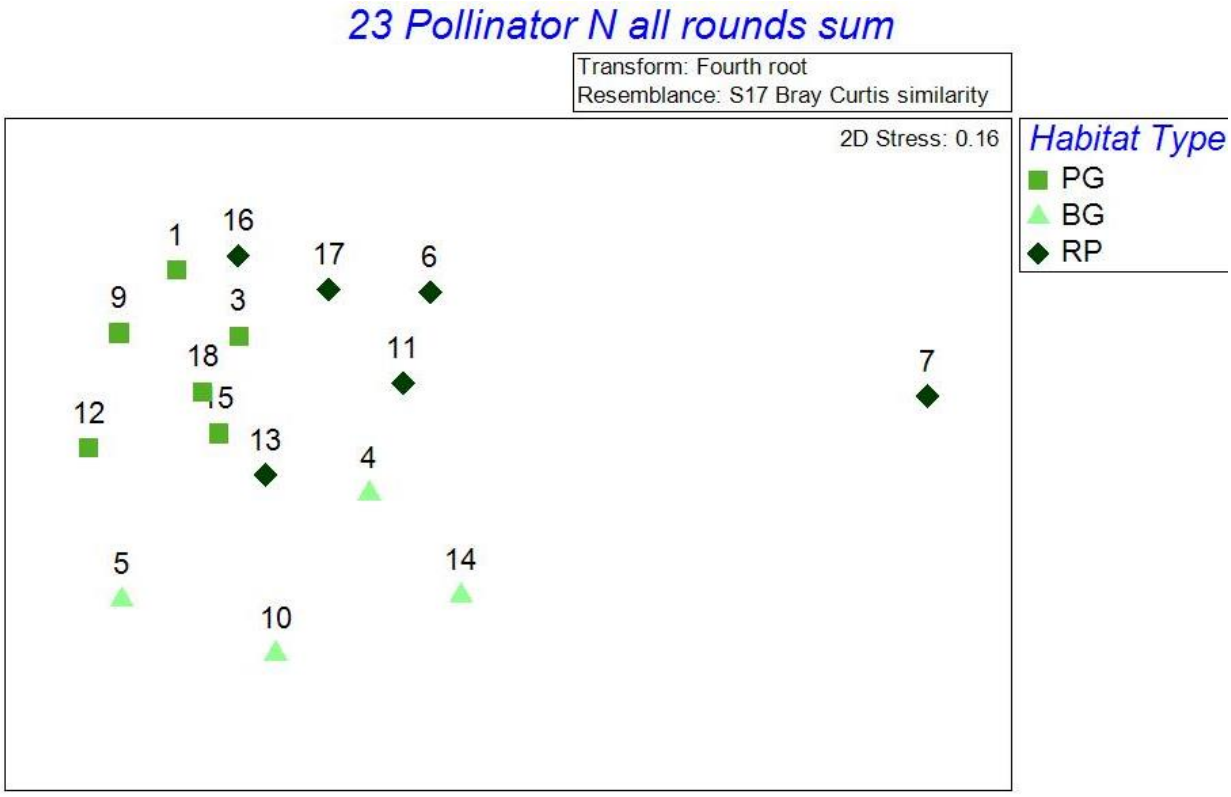


Figure 7. Box plots of a) pollinator richness and b) abundance. Remnant prairie (RP) are shown in dark green; pollinator garden (PG) are shown in green; and bermudagrass turf (BG) are shown in light green. The mean value for each habitat is indicated by a black point. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

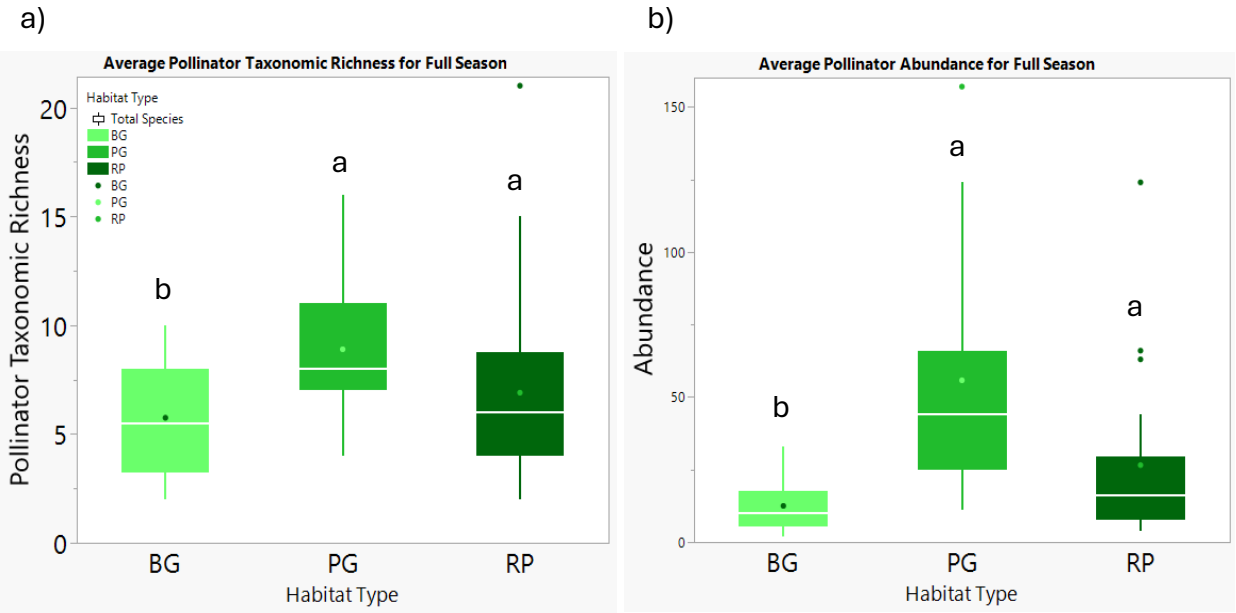


Figure 8. A bar graph of mean abundance of chewing herbivores (blue), piercing herbivores (orange), and predators (green) by habitat type, bermudagrass turf (BG), pollinator garden (PG), and remnant prairie (RP). Each error bar is constructed using 1 standard error from the mean. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

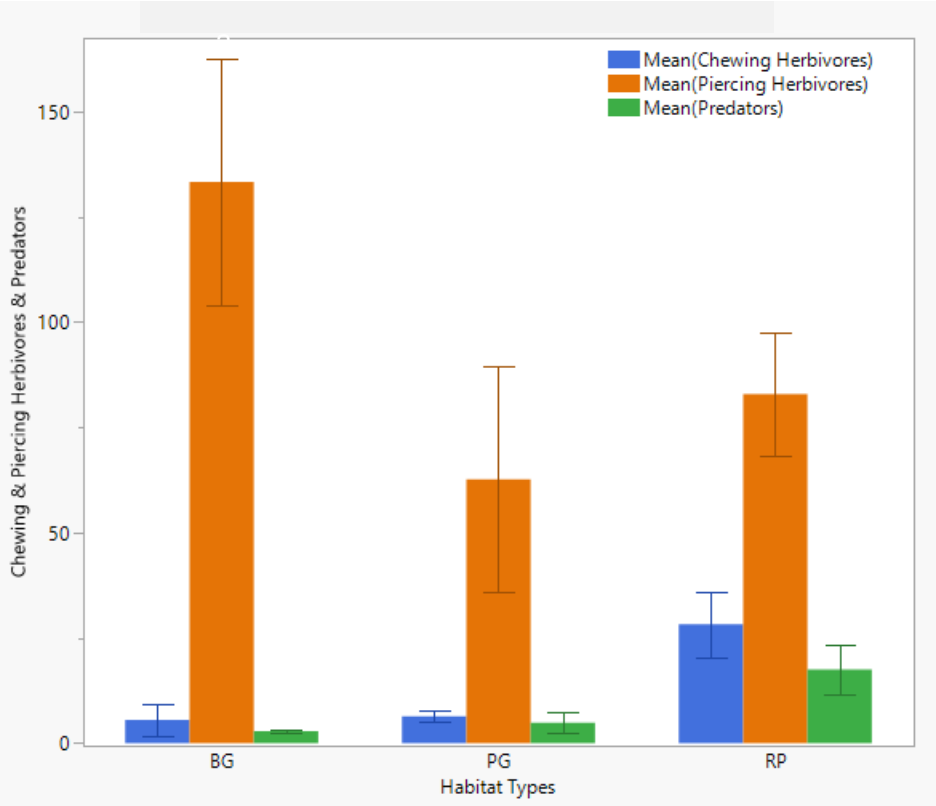
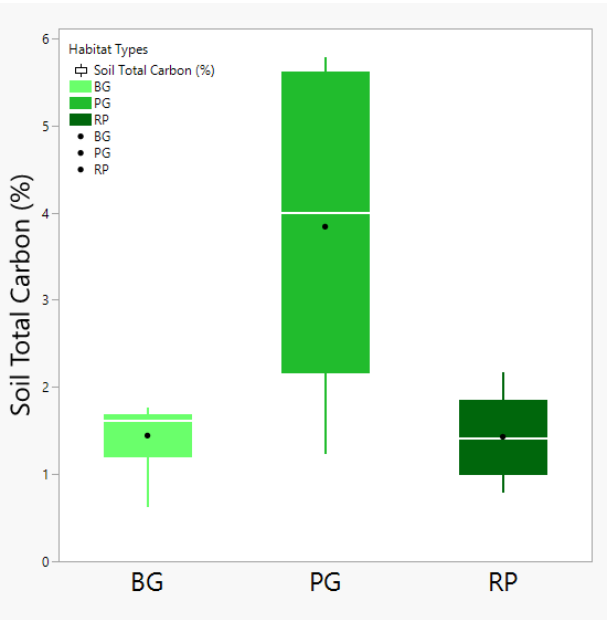


Figure 9. A box plot of a) soil total carbon (%) and b) soil total nitrogen (%) by habitat type. Remnant prairie (RP) are shown in dark green; pollinator garden (PG) are shown in green; and bermudagrass turf (BG) are shown in light green. The mean value for each habitat is indicated by a black point. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

a)



b)

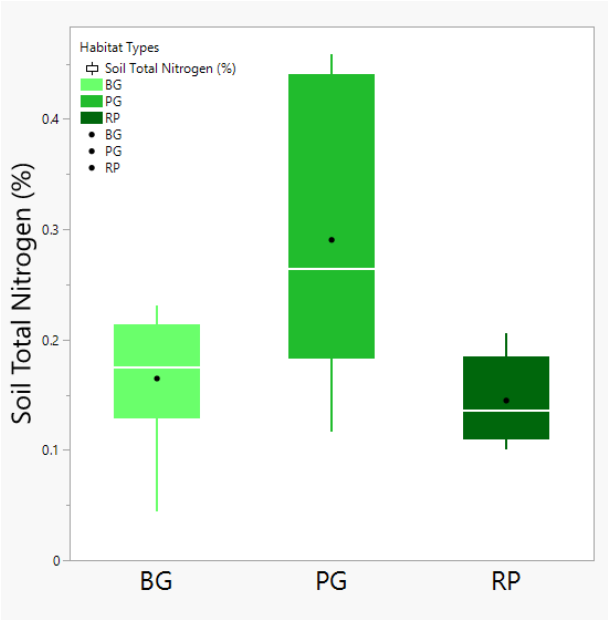
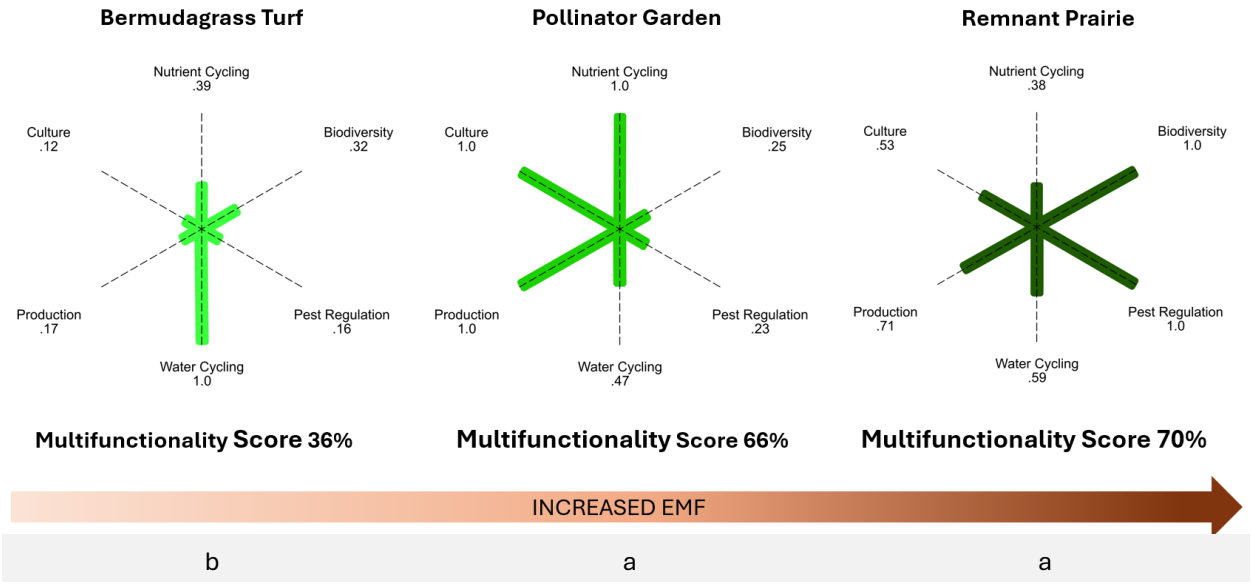
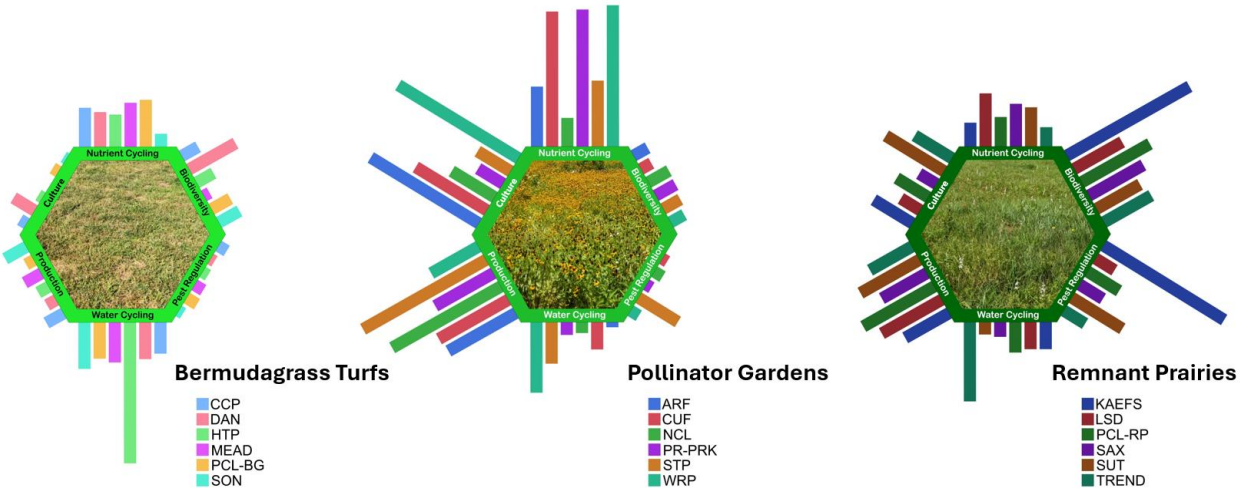


Figure 10. Multifunctionality flowers and scores by a) habitat and b) site. The habitat, or site, type with the highest mean value for each ecosystem function and service was scored as a 1.0 and other habitat types were scored as a relative proportion of that total sum (i.e., highest possible multifunctionality score = 6.0 = 100%). Multifunctionality scores were made up of ecosystem functions that were representative of this dataset's most representative variables, including: soil total nitrogen and carbon categorized as nutrient cycling; plant total species and chewing herbivore abundance categorized as biodiversity; root surface area and SRL categorized as water cycling; native plant species and LAI categorized as production; predator abundance categorized as pest regulation; and pollinator total taxa and abundance categorized as cultural. Each habitat type's multifunctionality score is the average of its six components. Remnant prairies, shown in dark green, had a multifunctionality score of 70%, PG, shown in green, had a multifunctionality score of 69%, and BG, shown in light green, had the lowest multifunctionality score of 41%. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types. Modified from Meissen et al. (2020).

a)



b)



Multifunctionality Scores

CCP	16%
DAN	21%
HTP	**27%**
MEAD	14%
PCL-BG	17%
SON	14%

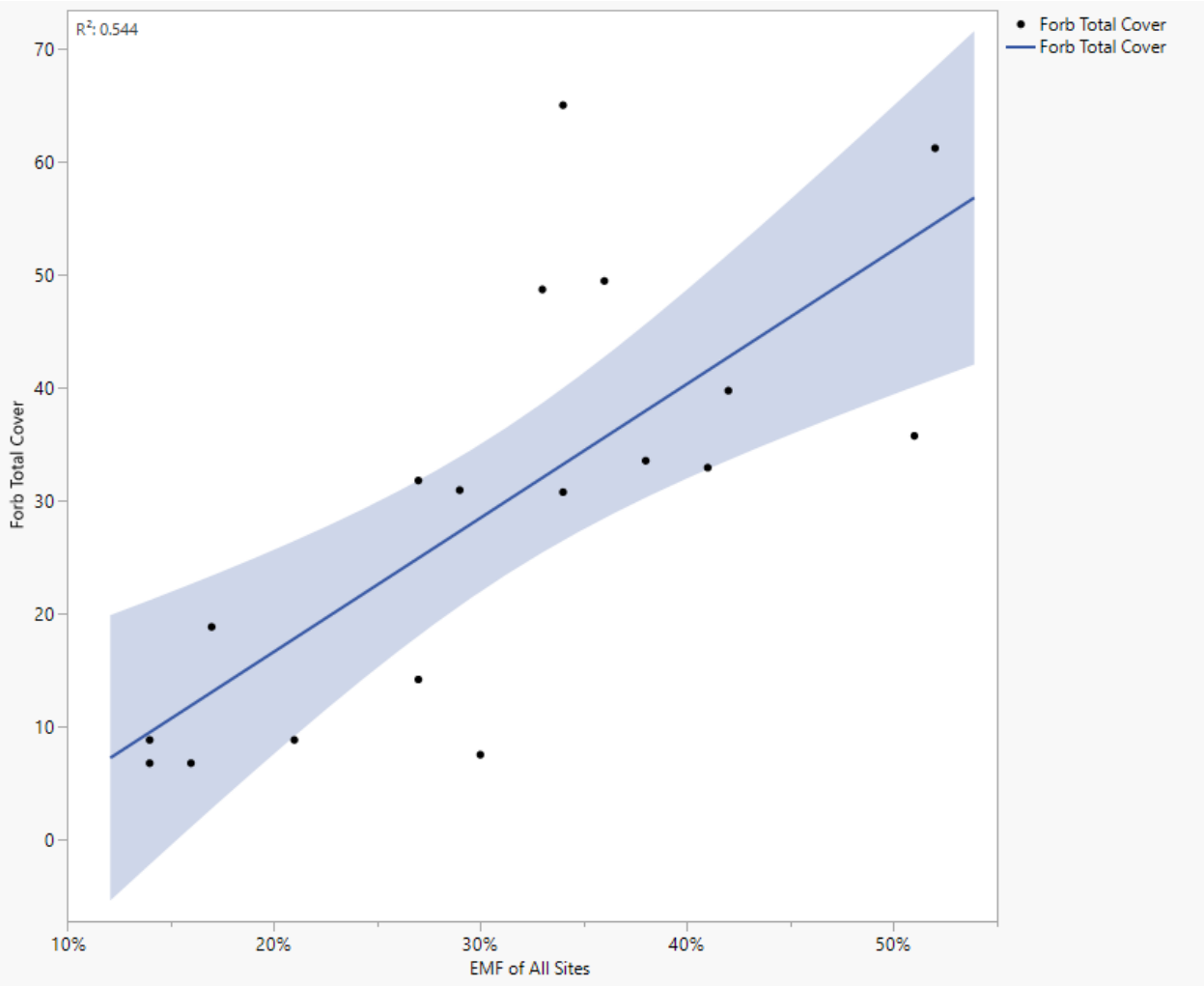
Multifunctionality Scores

ARF	34%
CUF	41%
NCL	29%
PR-PRK	33%
STP	42%
WRP	**52%**

Multifunctionality Scores

KAEFS	**51%**
LSD	30%
PCL-RP	38%
SAX	27%
SUT	36%
TREND	34%

Figure 11. Scatter plot with line to fit of forb total cover against EMF scores from all sites showing R^2 of 0.544.



APPENDIX

Table S1. Total percent developed and natural land cover surrounding a 1-km2 buffer around research sites from 2022 and 2023. Mean percentage and standard deviation are shown for each habitat type, bermudagrass turfs, pollinator gardens, and remnant prairies, for both developed and natural cover percentages.

Habitat Type	Site	*Developed (%)*	*Natural (%)*	*Mean Developed*	*Mean Natural*	*SD*
BG				69	31	20.80
	CCP	51	49			
	DAN	51	49			
	HTP	100	0			
	MEAD	76	24			
	PCL_BG	56	44			
	SON	66	34			
PG				94	6	8.30
	ARF	82	18			
	CUF	100	0			
	NCL	100	0			
	PR_PRK	93	7			
	STP	99	1			
	WRP	99	1			
RP				17	83	19.67
	KAEFS	3	97			
	LSD	3	97			
	PCL_PR	21	79			
	SAX	21	79			
	SUT	53	47			
	TREND	3	97			

Table S2. Site characteristics: **Habitat type** (BG=bermudagrass turf, PG=pollinator garden, RP=remnant prairie), **Site Name** (CCP=Cherry Creek Park, DAN for Dane Park, HTP for Hathaway Park, MEAD for Meadow Park, PCL-BG for Purcell Lake bermudagrass habitat, SON for Songbird Park, ARF for Aquatic Research Facility, CUF for Commonwealth Urban Farms, NCL for Norman Central Library, PR-PRK for Prairie Creek Park, STP for Scissortail Park, WRP for Will Roger Park, KAEFS for Kessler Atmospheric and Ecological Field Station, LSD for Lake Stanley Draper, PRL-RP for Purcell Lake prairie habitat, SAX for Saxon Park, SUT for Sutton Park, and TREND for Trails End), **Latitude/Longitude**, **Land cover history** (B.T. = bermudagrass turf lawn, O.F. = old fields that were used for agricultural, Other1 = mixture of forest and prairie, and Other2 = industrial buildings), **Use of mower** (N = No, Y* = once a week, Y** = twice a week, Y*** = once a month, Y**** = twice a month, 2y = twice a year, 1y = once a year), **Use of irrigation** (Y = yes, SU = summer, TR = after transplant), **Seed added** (M.P. = seeds are dispersed by mature plants), **Soil addition** (C = compost, CT = compost tea used throughout the growing season), and **Chemical usage** (H = herbicides are used, P = pesticides are used).

* Land cover history ranges from 1 to 15+ years, apart from WRP which is the only site established as a garden 90+ years ago.

Habitat Type	Site Name	Latitude	Longitude	Land cover history	Use of mower	Use of brush hog mower	Use of clipping	Use of irrigation	Seeds added	Potted plants added	Use of wood or plant mulch	Soil additives	Chemical usage
BG	CCP	35.212045	-97.501858	Other1	Y****	N	N	N	1y	N	N	N	2y, H
BG	DAN	35.133897	-97.388555	O.F.	Y*	N	Y	N	N	N	Y	N	1y, H
BG	HTP	35.4266194	-97.4978944	O.F.	Y****	N	N	N	N	N	N	N	N
BG	MEAD	35.388073	-97.716241	O.F.	Y****	N	N	N	N	N	N	N	2y, H
BG	PCL-BG	34.986352	-97.377493	B.T.	Y*	N	N	N	M.P.	N	N	N	N
BG	SON	35.1724681	-97.4189706	Other1	Y****	N	Y	N	1y	N	N	N	2y, H
PG	ARF	35.18344	-97.448496	B.T.	N	N	Y	Y*	1y	1y	Y	N	N
PG	CUF	35.502909	-97.528332	B.T.	N	N	Y	Y***	1y	2y	Y	N	N
PG	NCL	35.22725	-97.448675	O.F.	2y	N	Y	N	M.P.	N	N	N	N
PG	PR-PRK	35.243845	-97.489504	B.T.	N	N	Y	Y* TR	1y	2y	Y	1y, C	N
PG	STP	35.4617611	-97.5193528	Other2	2y	N	Y	Y* SU	M.P.	N	N	Y***, C	N
PG	WRP*	35.506559	-97.579286	O.F.	N	N	Y	Y**	1y	2y	Y	1y, C, CT	2y, H, P
RP	KAEFS	34.9839889	-97.5242194	O.F.	1y	1y	Y	N	N	N	Y	N	N
RP	LSD	35.375299	-97.383271	--	--	--	--	--	--	--	--	--	--
RP	PCL-RP	34.987799	-97.388428	B.T.	N	1y	N	N	M.P.	N	N	N	N
RP	SAX	35.1831694	-97.3900694	Other1	1y	N	Y	N	1y	N	N	N	2y, H
RP	SUT	35.246656	-97.431804	Other1	1y	N	Y	N	1y	N	N	N	2y, H
RP	TREND	35.345497	-97.677087	--	--	--	--	--	--	--	--	--	--

Table S3. Assessing the influence of habitat type on ecosystem functions. Summary tables from principal component analysis (PCA) cluster results of all variables and correlations by cluster.

Cluster	Members	RSquare with Own Cluster	RSquare with Next Closest	1-RSquare Ratio
1	Pollinator Total Species	0.896	0.213	0.132
1	Pollinator Shannon	0.833	0.15	0.197
1	Graminoid Total Cover	0.838	0.222	0.208
1	Forb Total Cover	0.8	0.242	0.263
1	Root Biomass	0.767	0.3	0.333
1	Pollinator Abundance	0.73	0.433	0.477
1	Root.Average.Diameter.mm	0.226	0.156	0.917
2	Specific Root Length mg	0.857	0.318	0.21
2	C to N	0.755	0.23	0.318
2	Soil Moisture	0.764	0.356	0.366
3	Root Surface Area mm^2	0.968	0.293	0.046
3	Root Volume cm3	0.811	0.111	0.212
3	Total Root Length m	0.764	0.288	0.331
3	pH	0.493	0.108	0.568
4	Total Plant Species	0.803	0.261	0.267
4	Chewing Herbivore	0.722	0.215	0.354
4	Plant Shannon Diversity	0.739	0.358	0.407
4	Predator	0.608	0.154	0.463
4	Plant Simpson Diversity	0.415	0.108	0.656
5	Plant LAI AVERAGE	0.861	0.23	0.181
5	Plant Biomass Area 100x20	0.576	0.118	0.481
5	Piercing Herbivores	0.554	0.09	0.49
5	Pollinator Pielous evenness	0.489	0.154	0.603
5	Average Plant Height	0.72	0.543	0.612
6	Total Nitrogen	0.867	0.261	0.18
6	Soil Total Carbon	0.902	0.564	0.225
6	Bare Ground Cover	0.756	0.355	0.378
6	Legume Total Cover	0.35	0.133	0.75
6	Litter Cover	0.346	0.142	0.762
7	Proportion Native Plant Sp.	0.834	0.162	0.198
7	Plant SLA (mm^2/mg)	0.834	0.291	0.234

Figure S1. In correspondence with soil and biomass sampling, each site had ten total 1-m^2 randomly placed, fixed quadrats for plant surveys and collection.

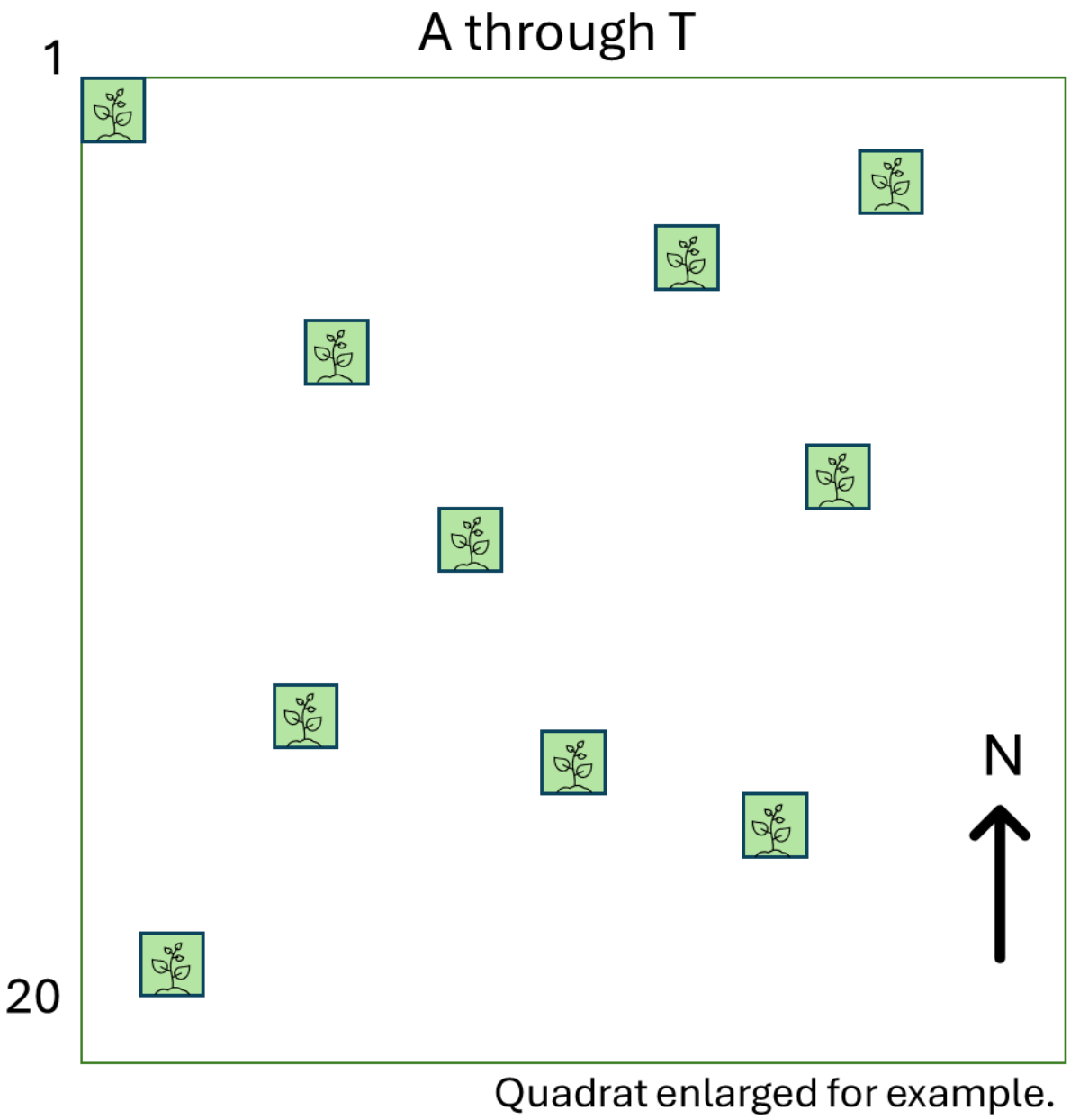


Figure S2. An example, RP habitat and KAEFS site, shows areas that had blooming plants by shading in the areas on the grided map that corresponded to our location within the site with a pencil.

KAEFS Blooming Date: 5/3/2023

A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	O1	P1	Q1	R1	S1	T1
A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	M2	N2	O2	P2	Q2	R2	S2	T2
A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3	M3	N3	O3	P3	Q3	R3	S3	T3
A4	B4	C4	D4	E4	F4	G4	H4	I4	J4	K4	L4	M4	N4	O4	P4	Q4	R4	S4	T4
A5	B5	C5	D5	E5	F5	G5	H5	I5	J5	K5	L5	M5	N5	O5	P5	Q5	R5	S5	T5
A6	B6	C6	D6	E6	F6	G6	H6	I6	J6	K6	L6	M6	N6	O6	P6	Q6	R6	S6	T6
A7	B7	C7	D7	E7	F7	G7	H7	I7	J7	K7	L7	M7	N7	O7	P7	Q7	R7	S7	T7
A8	B8	C8	D8	E8	F8	G8	H8	I8	J8	K8	L8	M8	N8	O8	P8	Q8	R8	S8	T8
A9	B9	C9	D9	E9	F9	G9	H9	I9	J9	K9	L9	M9	N9	O9	P9	Q9	R9	S9	T9
A10	B10	C10	D10	E10	F10	G10	H10	I10	J10	K10	L10	M10	N10	O10	P10	Q10	R10	S10	T10
A11	B11	C11	D11	E11	F11	G11	H11	I11	J11	K11	L11	M11	N11	O11	P11	Q11	R11	S11	T11
A12	B12	C12	D12	E12	F12	G12	H12	I12	J12	K12	L12	M12	N12	O12	P12	Q12	R12	S12	T12
A13	B13	C13	D13	E13	F13	G13	H13	I13	J13	K13	L13	M13	N13	O13	P13	Q13	R13	S13	T13
A14	B14	C14	D14	E14	F14	G14	H14	I14	J14	K14	L14	M14	N14	O14	P14	Q14	R14	S14	T14
A15	B15	C15	D15	E15	F15	G15	H15	I15	J15	K15	L15	M15	N15	O15	P15	Q15	R15	S15	T15
A16	B16	C16	D16	E16	F16	G16	H16	I16	J16	K16	L16	M16	N16	O16	P16	Q16	R16	S16	T16
A17	B17	C17	D17	E17	F17	G17	H17	I17	J17	K17	L17	M17	N17	O17	P17	Q17	R17	S17	T17
A18	B18	C18	D18	E18	F18	G18	H18	I18	J18	K18	L18	M18	N18	O18	P18	Q18	R18	S18	T18
A19	B19	C19	D19	E19	F19	G19	H19	I19	J19	K19	L19	M19	N19	O19	P19	Q19	R19	S19	T19
A20	B20	C20	D20	E20	F20	G20	H20	I20	J20	K20	L20	M20	N20	O20	P20	Q20	R20	S20	T20

Figure S3. During the months of May through October 2023, we visited each site four times. When blooming forbs were present within the site perimeter, we identified a minimum of four to maximum of ten blooming patches, recording the approximate location, based on each site's gridded layout, as a blooming 1-m2 floater quadrat (quadrats not linked to plant and soil surveys and collections).

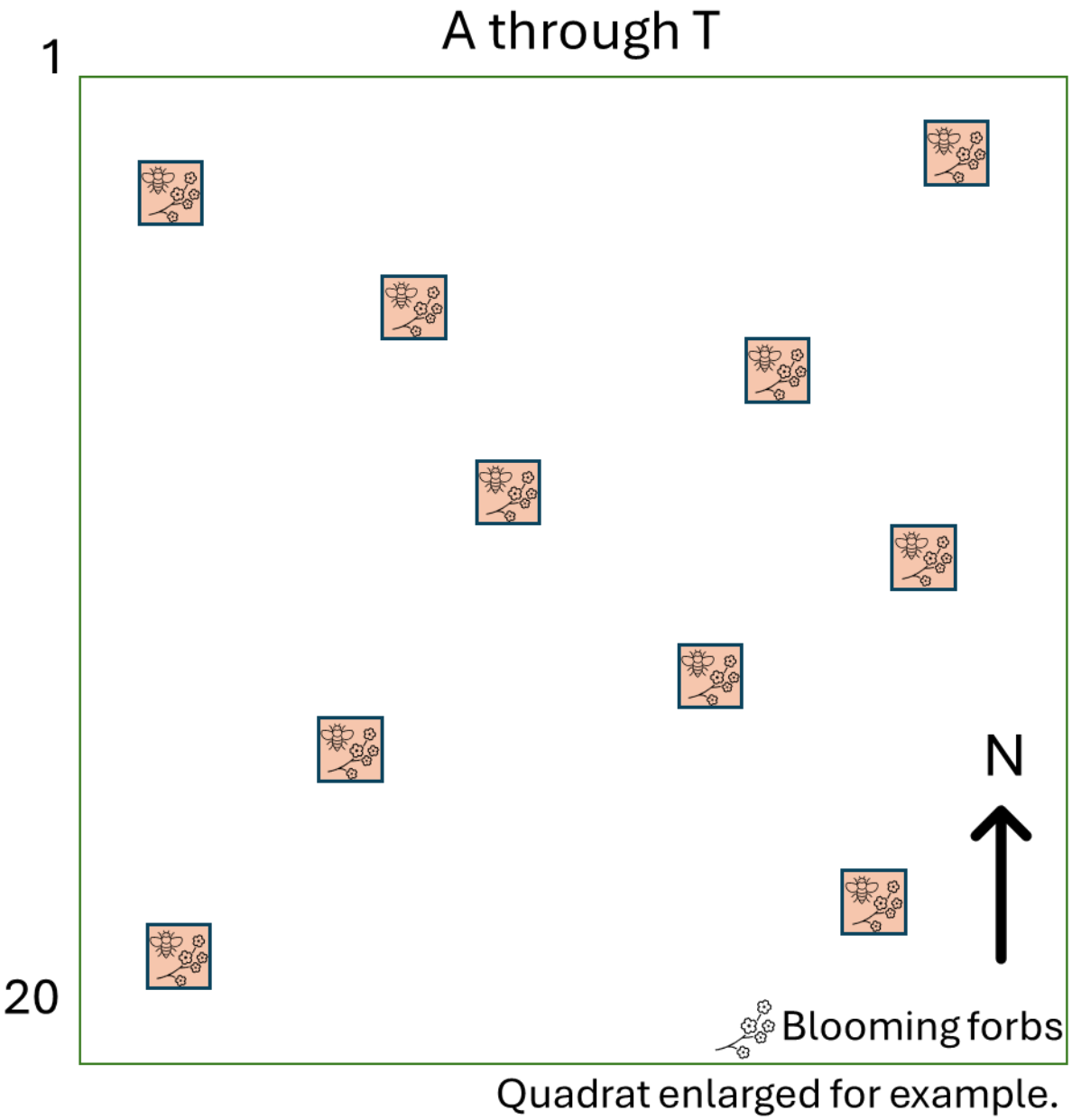


Figure S4. Pollinator taxonomic group categorization: *Hymenoptera* (bees, wasps), *Lepidoptera* (butterflies, moths), *Coleoptera* (scarabs, soldier beetles, weevils), *Diptera* (bee flies, hover flies), suborder *Heteroptera*, and other. Size was also accounted for scaled against *Apis* (honeybee) abdomen: less than or equal to **Apis** abdomen was categorized as small, equal to or same size as *Apis* as medium, and larger than *Apis* as large. Photo credits come from various iNaturalist photographers.

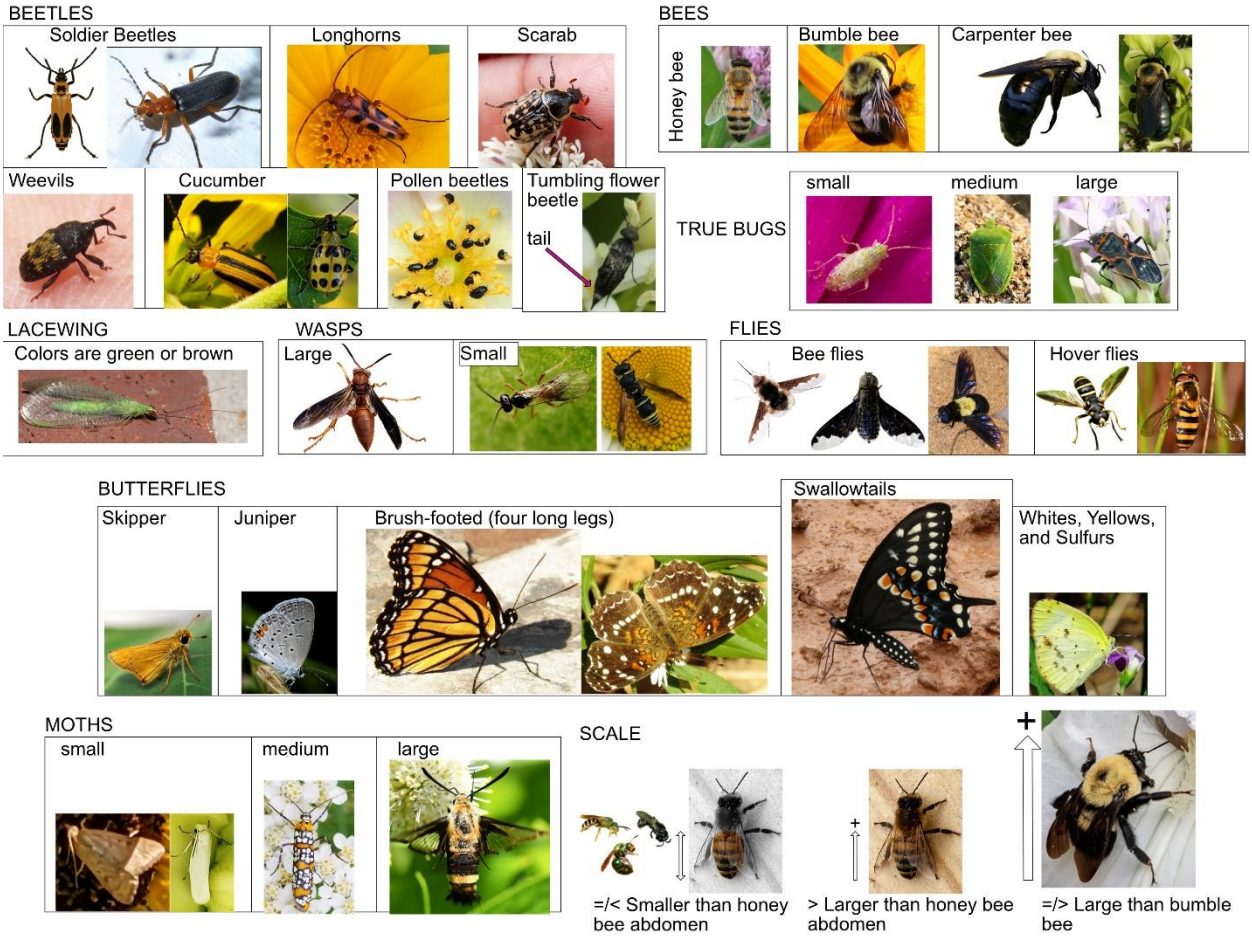
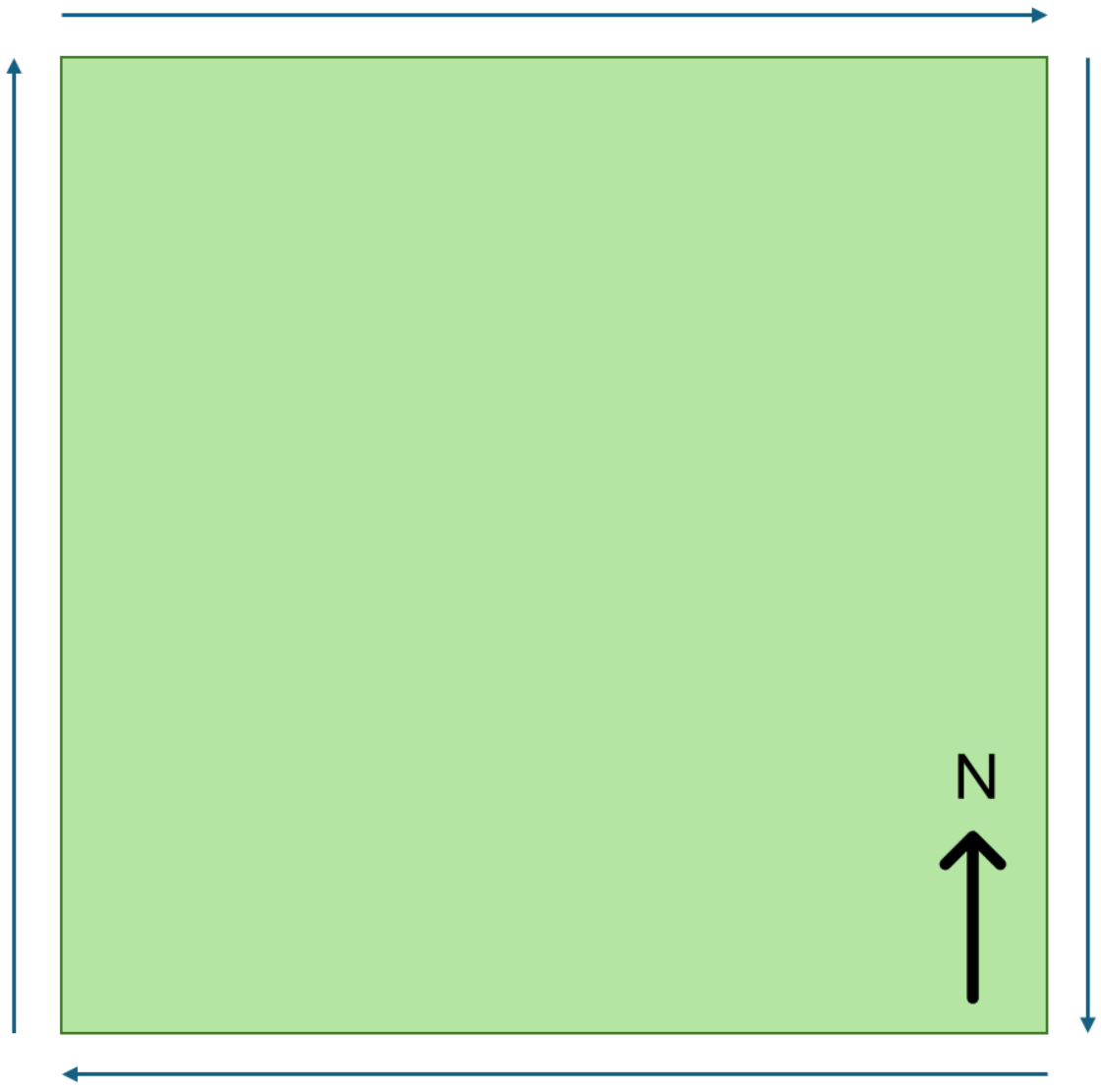


Figure S5. Invertebrate sweep-net sampling of site area, shown in green, and transect sampling area, shown with blue and black arrows. Most RP and BG, including STP a PG, sites shared the same a) 20x20 m^2 layout; whereas, b) PG sites, NCL shown, are the exception where sites ARF, CUF, NCL, PR-PRK, and WRP all had varied layouts due to gardening space allotted to land management.

a)



b)

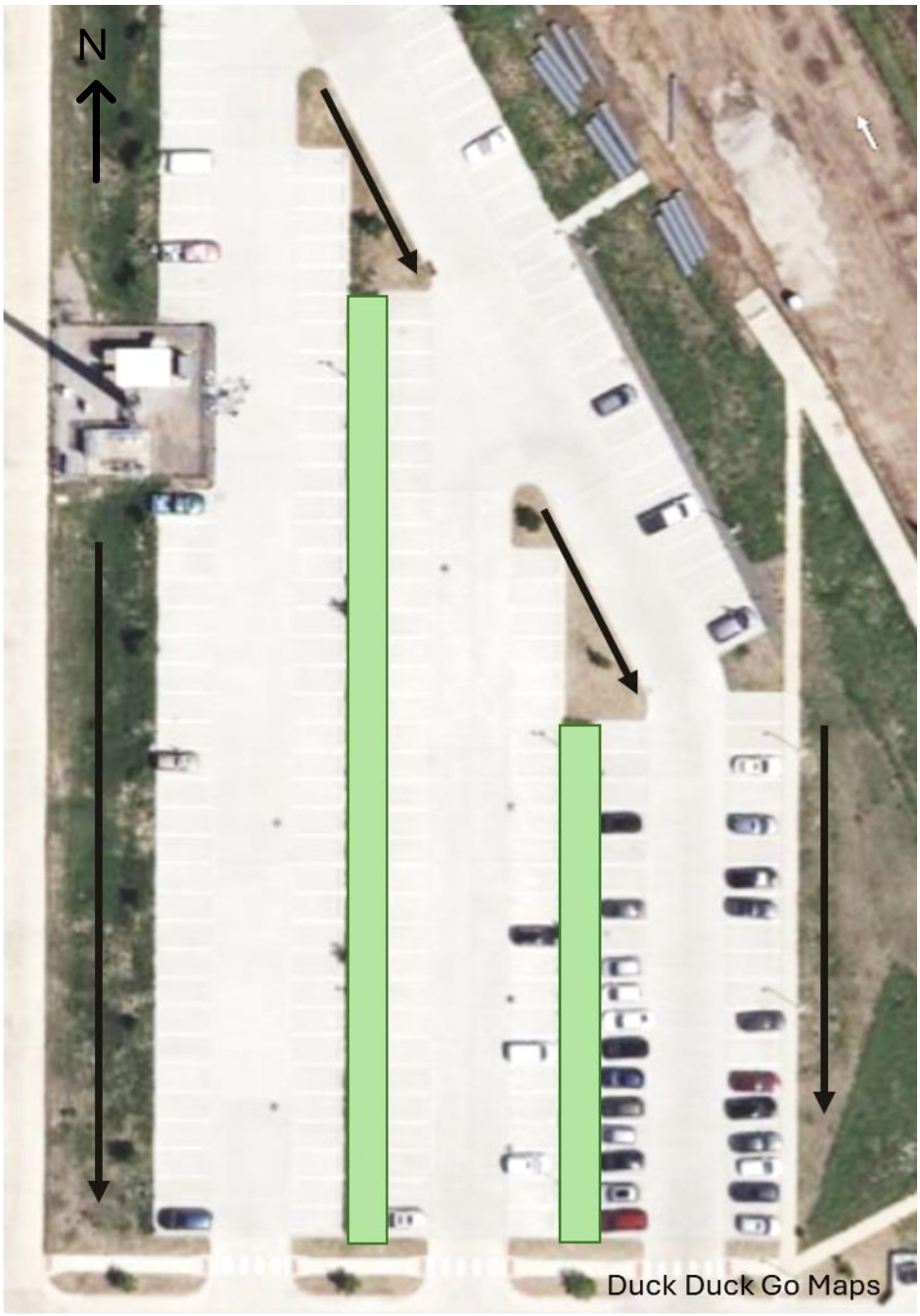


Figure S6. Soil and plant biomass were collected from the western edge of each randomly selected quadrat in July of 2023 from every site. Quadrat area are represented by light green squares, soil cores are represented by blue circles, and biomass collection area are represented by dark green rectangles.

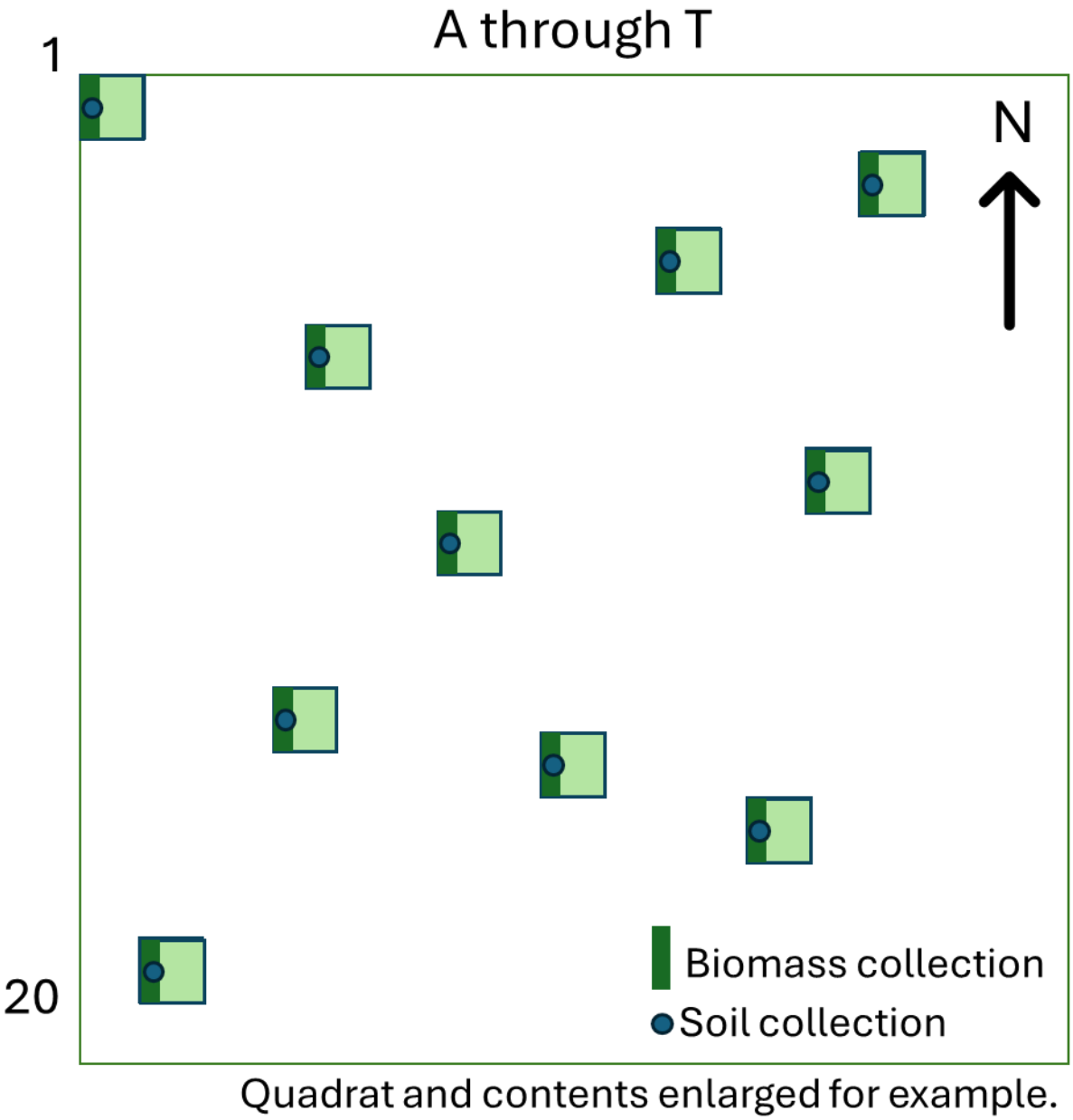


Figure S7. Principal component analysis (PCA) of the means of all variable (site and quadrat). Biodiversity is represented by purple, cultural is represented by pink, nutrient cycling is represented by teal, water cycling is represented by blue, and production is represented by green. Dotted lines represent the cluster analysis most represented variables and sub-variables used in the multifunctionality scores and EMF analysis and solid lines represent those that were not included.

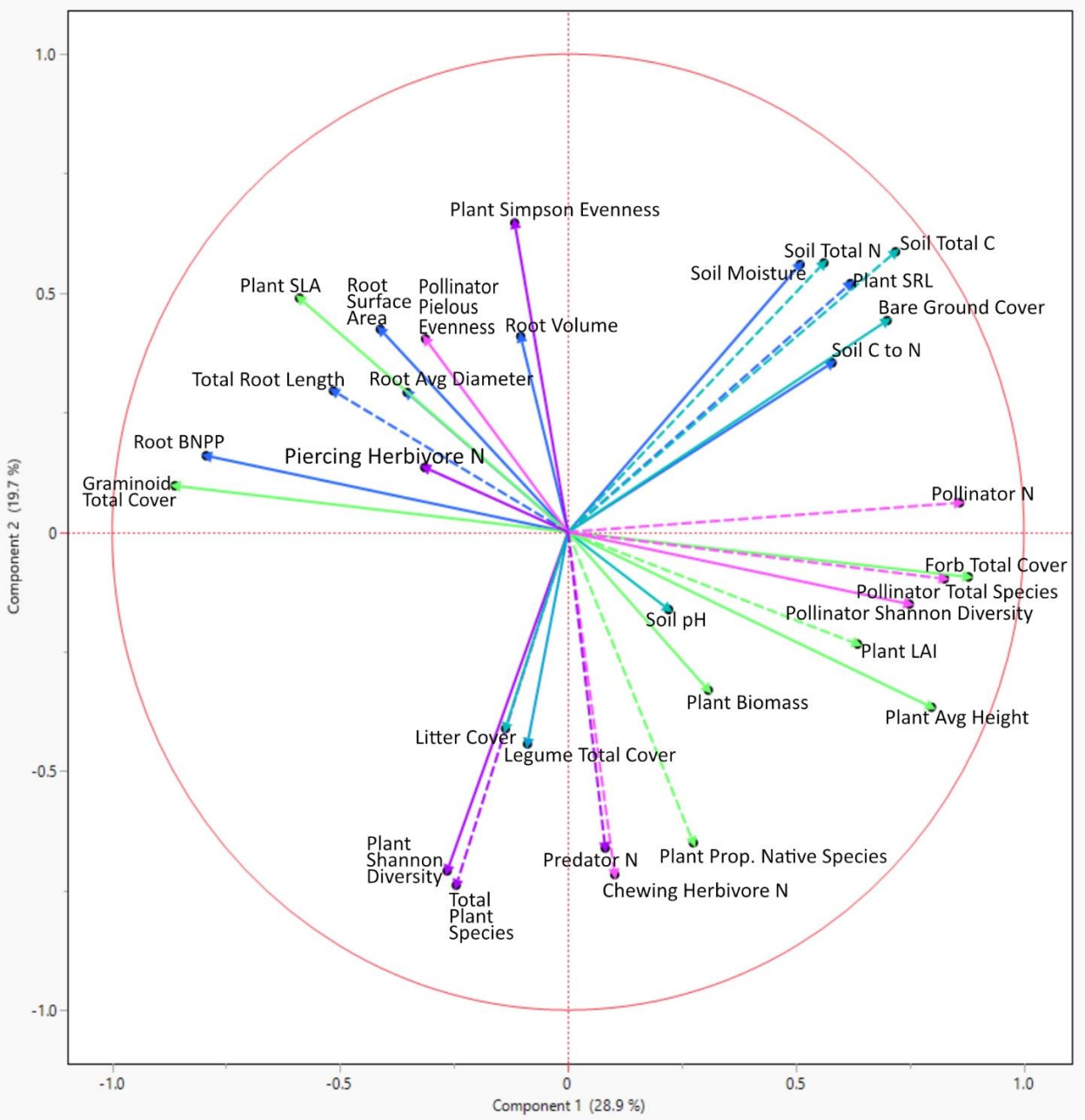
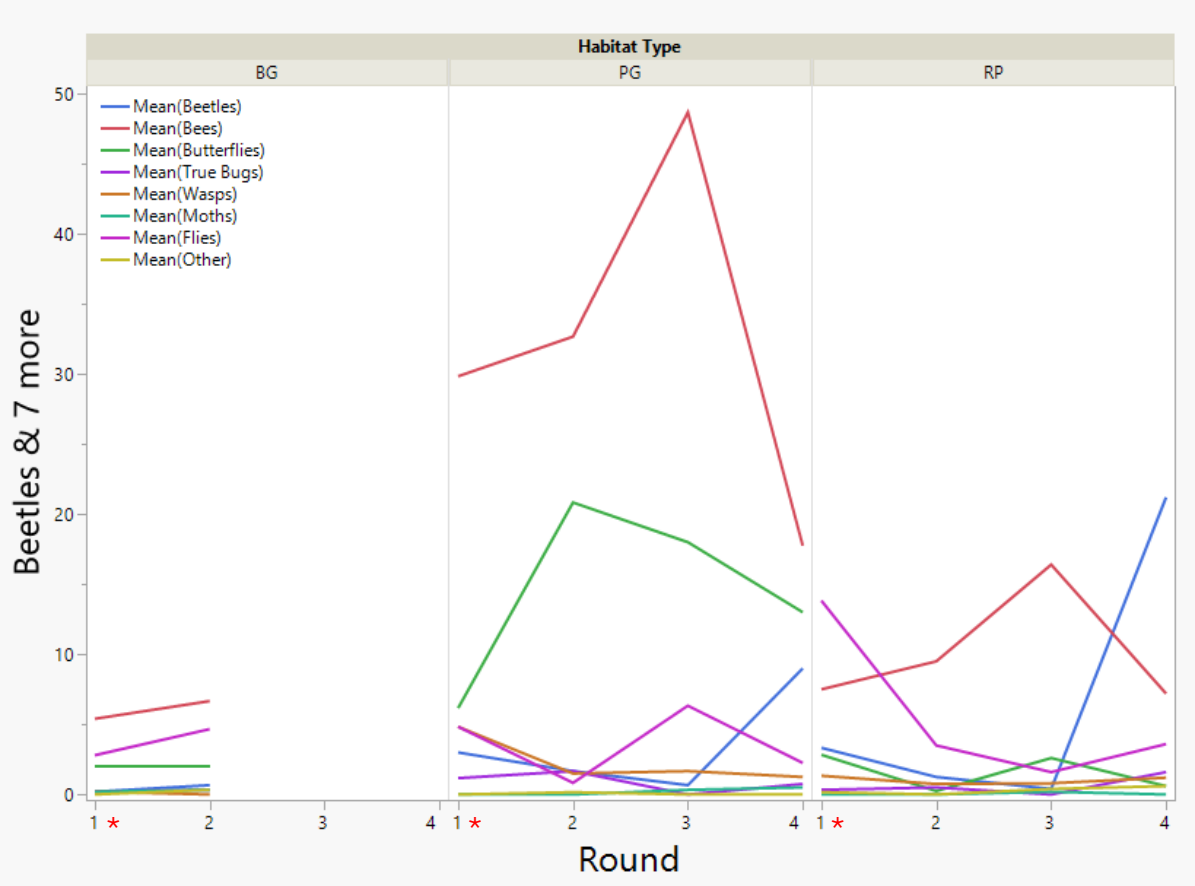
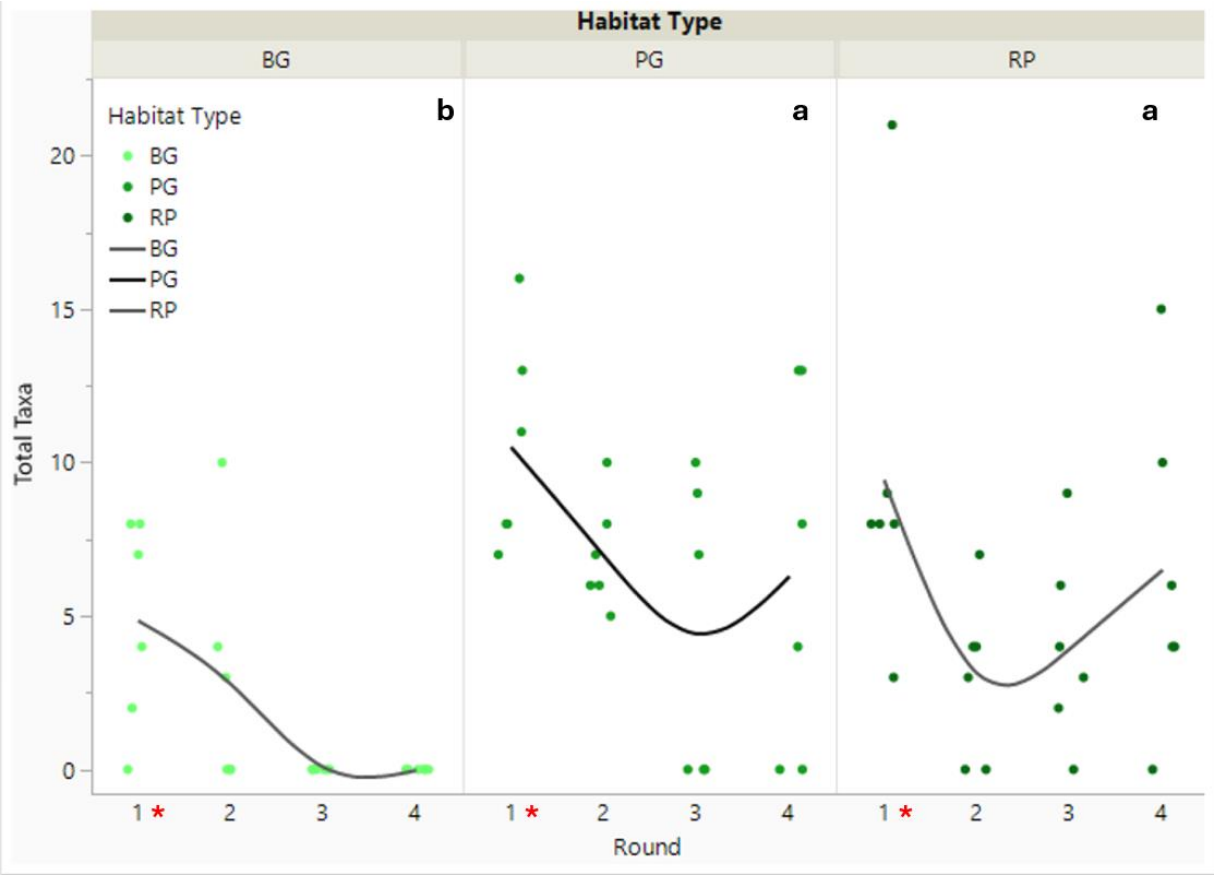


Figure S8. Pollinators by a) abundance by taxonomic order and b) taxonomic richness against round (bottom x-axis) and habitat type (top x-axis). Round numbers represent the time of year visits that took place, 1 = early summer, 2 = mid-summer, 3 = late summer, and 4 = early fall. Line to fit represents average total taxon over the seasons. For a) abundance by taxonomic order, during early summer differences in abundance were detected between habitats for the orders of beetles ($p = 0.0297$), bees ($p = 0.0101$), and wasps ($p = 0.0279$). For b) taxonomic richness, habitats significantly differed over time, shown in b), ($p = 0.0068$) and during the first round ($p = 0.0010$) represented by a red asterisk. Significant differences are indicated by letters. Shared letters show no significance, and differing letters show significance between habitat types.

a)



b)


Habitat Type
BG
PG
RP
Habitat Type
BG
PG
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BG
PG
RP
b
a
a
Total Taxa
20
15
10
5
0
1 *
2
3
4
Round