Evaluating the effects of vegetation structure and composition, grassland size, and surrounding land cover on bird communities in grasslands undergoing restoration in Ann Arbor, Michigan

by

Samuel Heilman

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Thesis Committee:

Sara Adlerstein-Gonzalez, Chair

Michael Kost

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Abstract

Native grasslands (prairies and savannas) have undergone a catastrophic decline in North America as well as in the state of Michigan, with less than 1% of Michigan's native grassland present at the time of European colonization remaining. Grassland birds have declined along with them and are the most threatened group of birds in North America. Urbanization has fragmented the landscape, causing many new conservation challenges for grassland birds, and made it crucial to understand how grassland bird communities are affected by both patch-level characteristics and the surrounding landscape. I used Generalized Additive Models (GAMs) to investigate how abundance of grassland birds is affected by 1) local vegetation structure, 2) vegetation composition, 3) landscape-level habitat structure, 4) degree of urbanization in the surrounding landscape, and 5) area of the grassland. Overall vegetation richness and tree species richness appeared to be positively correlated with grassland bird species richness, indicating that removing invasive species that tend to homogenize the plant community, and that ensuring a high species richness of native plants is crucial to maintaining grassland bird populations in restoration areas embedded within urban landscapes. Landscape-level variables related to urbanization (bridges and urban land cover within 500 m of the area center) and patch-level variables (vegetation richnesses and grassland size) were found to be important predictors of the total grassland bird abundance, highlighting the importance of considering both patch-level and landscape-level factors in locating and managing grassland restoration areas.

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Introduction

The disappearance of grassland (prairie and savanna) habitats since European colonization has heavily impacted bird species, with grassland birds exhibiting the largest decline in abundance of any of the North American bird groups (Rosenberg et al. 2019). Habitat fragmentation has also contributed to this phenomenon, mostly by reducing nesting success of grassland birds through increased nest predation and parasitism near edge habitat (Herkert 1993). This underscores the importance of protecting grasslands in the face of ongoing anthropogenic landscape changes, as well as restoring land to native prairie and savanna habitats, in order to conserve North American grassland bird populations.

Native grasslands (grass-dominated ecosystems with less than 60% canopy cover) are a crucial ecosystem in North America that support one third of all endangered species on the continent as of 1994 (Sampson & Knopf 1994). Grasslands, which include prairies (grass-dominated ecosystems with less than 1 tree per acre) and savannas (grass-dominated ecosystems with more than 1 tree per acre and less than 60% tree cover) are, however, highly threatened. Estimates of prairie loss from 1830-1994 by state range from 20 to 99.9 % of the original area covered by prairies (Samson and Knopf 1994), and total grassland area destroyed for human uses is estimated at 80% (Samson and Knopf 1994, Rahmig et al. 2009).

In Michigan, grasslands are rare and declining habitats, with over 99% of prairies and savanna cover lost since European colonization (USDA 2006). Savannas were historically more abundant than prairies in the state, making up 80% of the grassland area in Michigan according to an 1816-1856 survey, and often had a much larger patch size (O'Connor et al. 2009). Fires started by Native Americans, who burned to maintain the landscape structure for hunting, promoting berry growth, escaping enemies, and other reasons, played a major role in maintaining the health of grasslands. They did so in a variety of ways, including preventing woody encroachment (especially in areas with mesic soil conditions), stimulating wildflower growth, and assisting with germination of native species (O'Connor et al. 2009). Post-

European settlement, lack of fire on the landscape caused an increase in encroachment of woody vegetation, which closed the overstory and caused the conversion of many grasslands into forests. Grassland birds are defined as “Those species that use the grassland habitats during the breeding season for courtship, nesting, foraging, rearing young, roosting or resting” (Sample and Mossman 1997). Birds historically found in Michigan grasslands include songbirds such as grasshopper sparrows (*Ammodramus savannarum*), Eastern and Western Meadowlarks (*Sturnella magna* and *S. neglecta*), dickcissel (*Spiza americana*), bobolink (*Dolichonyx orizyvorous*), Savannah Sparrow (*Passerculus sandwichensis*), and Henslow’s Sparrow (*Ammodramus henslowii*), as well as game birds like Northern bobwhite (*Colinus virginianus*), Greater Prairie Chicken (*Tympanuchus cupido*) (Ross et al. 2006) and wild turkey (*Melleagris gallopavo*) (O’Connor et al. 2009).

There has been much discussion with regards to bird conservation in large versus small patches of grassland habitat (Davis 2004, Hamer and Flather 2006, With et al. 2008). “High-sensitivity”, or “area-sensitive”, grassland bird species are much more likely to be found in large grassland patches (Herkert 1993, Davis 2004). However, due to agricultural practices, it is not clear whether a strategy focusing on large tracts of grassland alone will be sufficient to mitigate the drop in grassland bird abundance (With et al. 2008), and the importance of small tracts of grassland in bird conservation has been acknowledged by multiple studies (Davis 2004, Walk et al. 2010, Mundahl & Borsari 2016). In addition, many of the remaining protected prairies exist as small, isolated fragments, and are embedded within urban landscapes (McLaughlin et al. 2014, Steinauer & Collins 1996).

Urbanization presents unique challenges to grassland bird conservation. Many protected grassland fragments were established as part of city park systems or have been swallowed up by expanding urban and suburban environments (Schwartz and Van Mantgem 1997, Bock and Bock 1998, Mclaughlin et al. 2014). Grasslands can become fragmented by urban landscapes (Hamer and Flather 2006, McLaughlin et al. 2014), and urban matrices are thought to be less permeable to birds than agricultural surroundings.

Bird species richness tends to decrease as an area becomes more fragmented due to loss of habitat specialist species (Schneiberg et al. 2020). Additionally, urban environments provide less foraging habitat, and landscape changes caused by urban expansion are potentially irreversible (McLaughlin et al. 2014).

Urban park systems have been shown to play a major role in maintaining biological diversity in cityscapes (Nielsen et al 2013), and parks surrounding a potential nesting territory have been found to be important drivers of occupancy in bird species (Melles et al. 2003). Restoration of urban grasslands has the potential to provide substantial social, recreational, and economic benefits to surrounding human communities (Klaus 2013, Standish et al. 2013), as well as provide ecosystem functions that surpass a traditionally managed turfgrass landscape (Bennett and Lovell 2014, Norton et al 2019).

Another challenge for bird communities in urban grasslands is invasive plant species. For 96% of terrestrial bird species, an abundance of insects (particularly Lepidoptera caterpillars) is critical to serve as food for nestlings during the breeding season (Tallamy and Shriver 2021). For these birds, reduced insect abundance results in decreased nesting success. To support a healthy bird community, healthy native plant communities are required, since many native insects have associations with native plants. Because of these associations, invasive species have the potential to impact bird species composition by reducing availability of insect prey, thereby reducing nesting success of insectivorous species. In addition, invasive species can alter habitat structure, reducing foraging opportunities for birds (Baiser et al. 2008). Therefore, it is important to determine how plant species composition of urban grasslands, and surrounding forests, affects bird communities in grasslands.

Trees and shrubs in particular play an important role in driving the bird community composition. Tree and shrub height, cover, and species richness have been cited as a driver of bird presence/absence or abundance in numerous studies (MacGregor-Fors 2008, Ortega-Álvarez and MacGregor-Fors 2009, Dondina et al. 2015, Melles et al. 2003, Nilon et al. 2011). In addition, tree Diameter at Breast Height (dbh), basal area, and composition significantly affect bird presence or absence depending on habitat preferences of the species (Dondina et al. 2015).

For the above reasons, it is important to develop knowledge of how grassland bird communities in smaller grassland patches respond to patch-level characteristics and surrounding land cover in urban and suburban landscape contexts. Numerous studies have examined the effect of site-level variables such as patch size, vegetation structure, and degree of urbanization surrounding the site, on grassland bird communities (Davis 2004, Au et al. 2008, Tack et al. 2017), but seldom in urban park systems.

Two conservation organizations, The City of Ann Arbor Natural Area Preservation (NAP) and Matthaei Botanical Gardens and Nichols Arboretum (MBGNA), have been conducting restoration work at eight grassland areas in Ann Arbor, Michigan, since the 1990s (City of Ann Arbor Parks and Recreation Department 2023a, MBGNA 2024) (Figure 1). These grasslands are being restored to dry-mesic prairies and savannas. Restoration work at NAP-managed grasslands is carried out by staff and volunteer crews and involves prescribed burns and invasive species removal, both manually and with herbicide treatments (City of Ann Arbor Parks and Recreation Department 2023c, b). The same type of restoration work has been ongoing at Dow Field, which is managed by the University of Michigan MBGNA (MBGNA 2024).

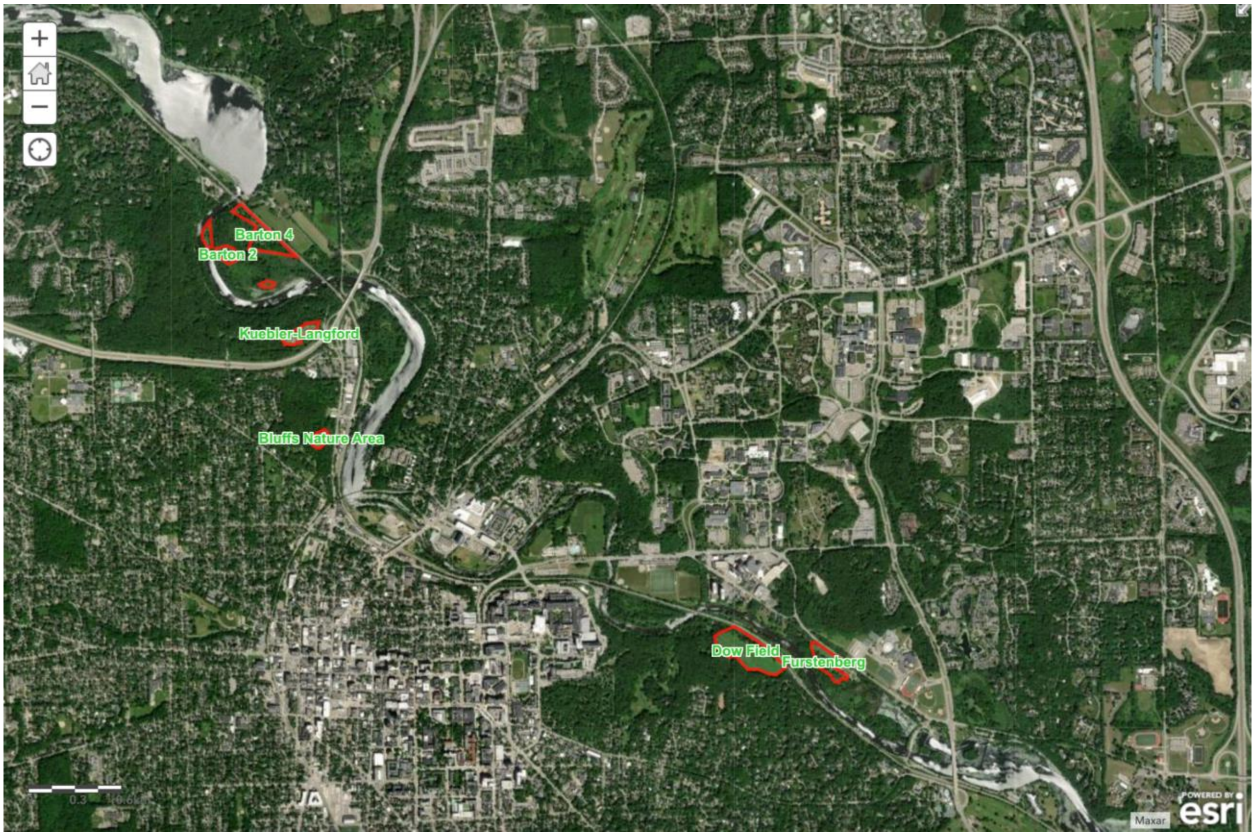

Figure 1. Satellite imagery of restoration study sites (outlined in red). The sites are embedded within urban/suburban Ann Arbor. Note the Huron River running through the landscape. The Imagery basemap on ArcGIS Online was used to create this map.

In order to investigate the relationship between the grassland bird community, at grassland restoration areas in an urban/suburban setting, and patch-level characteristics and surrounding land cover, I collected bird and plant data at several prairie and savanna areas that have been subjected to restoration within Ann Arbor, Michigan. I also characterized the landscape in a 500-m radius surrounding the restoration areas using publicly available online imagery. I explored the relationships between the grassland bird community and relevant patch-level and landscape-level factors including: 1) local vegetation structure within each of the study grassland areas; 2) vegetation composition; 3) land cover types surrounding the area; 4) distance to urban features; and 5) size of the grassland. I expect that areas with a relatively large percentage of surrounding urban and suburban land use will harbor fewer grassland species with lower relative abundances than those surrounded by forest or grassland, due to urbanization-related factors such as disturbance from traffic, movement barriers, and displacement of native vegetation (based on results from Rottenborn 1999). The results from McLaughlin et al. (2014) also postulate that reduced grassland bird densities in urban areas could be the result of increased nest parasites and predators. I predict that grassland areas with higher richness and relative abundances of native tree species will harbor higher richness and relative abundance of insectivorous bird species due to the importance of native trees in supporting an abundance of caterpillars as a food source for nestlings (Tallamy and Shriver 2021).

Methods

Study Areas

The study was conducted in eight grassland areas in Ann Arbor, Michigan. The study areas were selected due to their location within the Ann Arbor urban-suburban landscape and the grassland restoration activities that take place there. Seven grassland areas are contained within city parks, including Furstenberg, Bluffs, Kuebler-Langford, and Barton. Dow Field at the Nichols Arboretum was also included in the study. Furstenberg, Kuebler-Langford, and Bluffs contain one grassland area, whereas Barton contains four. Except for Dow Field, which is managed by MBGNA (MBGNA 2024), the selected areas are managed by the City of Ann Arbor NAP (Ann Arbor Parks and Recreation Department 2023a). The NAP managed areas were purchased by the city of Ann Arbor from the 1950s to 1970s to restore them as natural areas. Management practices at NAP restoration areas and at Dow Field are similar, and include controlled burns and invasive shrub removal, both manually and using herbicide treatments (MBGNA 2020, Ann Arbor Parks and Recreation Department 2023b, 2023c). The areas are all in proximity (less than 200 m) to the bank of the Huron River at their closest points (Figure 1).

Alex Dow Field at Nichols Arboretum

The Dow Field is approximately 8-ha in size (MBGNA 2024b). It was acquired by the University of Michigan from Detroit Edison in 1943. From the 1940s-1970s, it was managed as a recreational lawn and mowed several times each year (Heslinga and Grese 2010). This resulted in a lower native species diversity than surrounding unmowed areas and a dominance of non-native Kentucky bluegrass (*Poa pratensis*) and spotted knapweed (*Centaurea stoebe*). Starting in 1991, it was divided into seven management units, burned every 1-3 years (3 years since 1999), and invasive shrubs were removed periodically by volunteers (Heslinga 2010). Walters et al (2018) listed 165 plant species in the prairie and 121 in the savanna from 2011-2012 surveys. The majority of plants are native (66.5% in the prairie and 74.4% in the savanna) (Appendices 2 and 3). Restoration goals at Dow field include restoring native prairie and oak savanna habitats.

Figure 2: Furstenberg Nature Area (right) and Dow Field at Nichols Arboretum (left), with grassland areas bordered in red. Both study areas have open areas of prairie and savanna. Binocular icons indicate bird point count locations. This map was created using ArcGIS Online with the “imagery” basemap.

Furstenberg Nature Area

Furstenberg Nature Area, a 15.38-ha park (Figure 2), was purchased by the city of Ann Arbor in 1971, and used for clean fill dumping in 1986 (Ann Arbor Parks and Recreation Department 2023a). Since the mid-1990s, restoration activities including burning, invasive shrub removal, and revegetation have been used to restore sections of the park to native grassland habitats. Invasive plant removal began in 1992, and revegetation in 1995 (Becky Hand, Ann

Arbor NAP, Personal Communication). No information was available about grassland restoration goals for Furstenberg, plant species present or what invasive species are being managed.

Bluffs Nature Area

Bluffs Nature Area is a 16.18-ha park (Figure 3), half of which was purchased by NAP in 1952, and the second half in 2001 (City of Ann Arbor Parks and Recreation Department 2001). The grassland area at Bluffs was previously mined for road-building materials. When mining activity ceased, it was colonized by native plant species such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), mountain mint (*Pycnanthemum virginianum*), Indian grass (*Sorghastrum nutans*), stiff goldenrod (*Solidago rigida*), showy goldenrod (*S. speciosa*), spiked lobelia (*Lobelia spicata*), butterfly milkweed (*Asclepias tuberosa*), and lance-leaf coreopsis (*Coreopsis lanceolata*). A canopy layer of scattered trees developed including Eastern cottonwood (*Populus deltoides*), quaking aspen (*P. tremuloides*) and Eastern redcedar (*Juniperus virginiana*).

Restoration activities conducted at Bluffs have included removal of nonnative plants, prescribed fires, sowing native seeds, trash cleanups, and installation of birdhouses (Unpublished Management Plan, NAP Staff, 2001). Invasive plant removal and native revegetation started in 1997 (Becky Hand, Ann Arbor NAP, Personal Communication). Invasive species being managed include common buckthorn (*Rhamnus cathartica*), honeysuckle (*Lonicera maackii),* garlic mustard (*Alliaria petiolata*), purple loosestrife (*Lythrum salicaria*), Dame's rocket (*Hesperis matronalis*), lily-of-the-valley (*Convollaria majalis*), and spotted knapweed (*Centaurea stoebe*). Grassland restoration goals include restoring a native prairie on the previously strip-mined area

(Unpublished management plan, NAP Staff, 2001). A plant list for the grassland was not available for Bluffs.

Figure 3: Bluffs Nature Area, showing grassland area borders in red and locations of bird point count binocular icons. This map was created using ArcGIS Online with the "imagery" basemap.

Kuebler-Langford Nature Area

Kuebler-Langford Nature Area is a 12.54-ha park adjacent to M-14 and Huron River Drive (Ann Arbor Parks and Recreation Department 2023a) (Figure 4). It was purchased by the city in 1975. Native dry prairie species such as brown-headed bush clover (*Lespedeza capitata*) and stiff goldenrod (*Solidago rigida*) have been found here. Similarly to Bluffs Nature Area, the grassland area was previously mined for gravel for road building. The mining caused problems with erosion which are still being managed. Invasive species removal at Kuebler-Langford started in 2000, and native revegetation in 2002 (Becky Hand, Ann Arbor NAP, Personal Communication). No information was available about restoration goals for Kuebler-Langford, plant species present or what invasive species are being managed.

Figure 4: Kuebler-Langford Nature Area, showing grassland area borders (in red) and locations of bird point count sites (black-and-white binocular icons). This map was created using ArcGIS Online with the “imagery” basemap.

Barton Nature Area

Barton Nature Area is a 39.66-ha park that sits on historically farmed land (Ann Arbor Parks and Recreation Department 2023a) and contains four distinct grasslands separated by wooded areas that are apparent from satellite imagery, which I designated Barton 1-4 for this study (Figure 5). It was purchased by the city in the 1960’s. Grassland restoration goals at Barton include preservation of dry-mesic prairie remnants, also with an emphasis on reducing abundance of yellow sweetclover (*Melilotus alba*) and white sweet clover (*M. officinalis*) (Unpublished Management Plan, NAP Staff, January 2020). Prescribed burns have been conducted at Barton annually since 1996 (except 2000, 2012, 2017 and 2018), with burns occurring every 2-4 years in each grassland. Invasive species removal has been carried out since 1997, and seed collection and distribution have been carried out by volunteer crews since 1996 (Becky Hand, Ann Arbor NAP, Personal Communication). No information on plant species present was available for Barton grasslands.

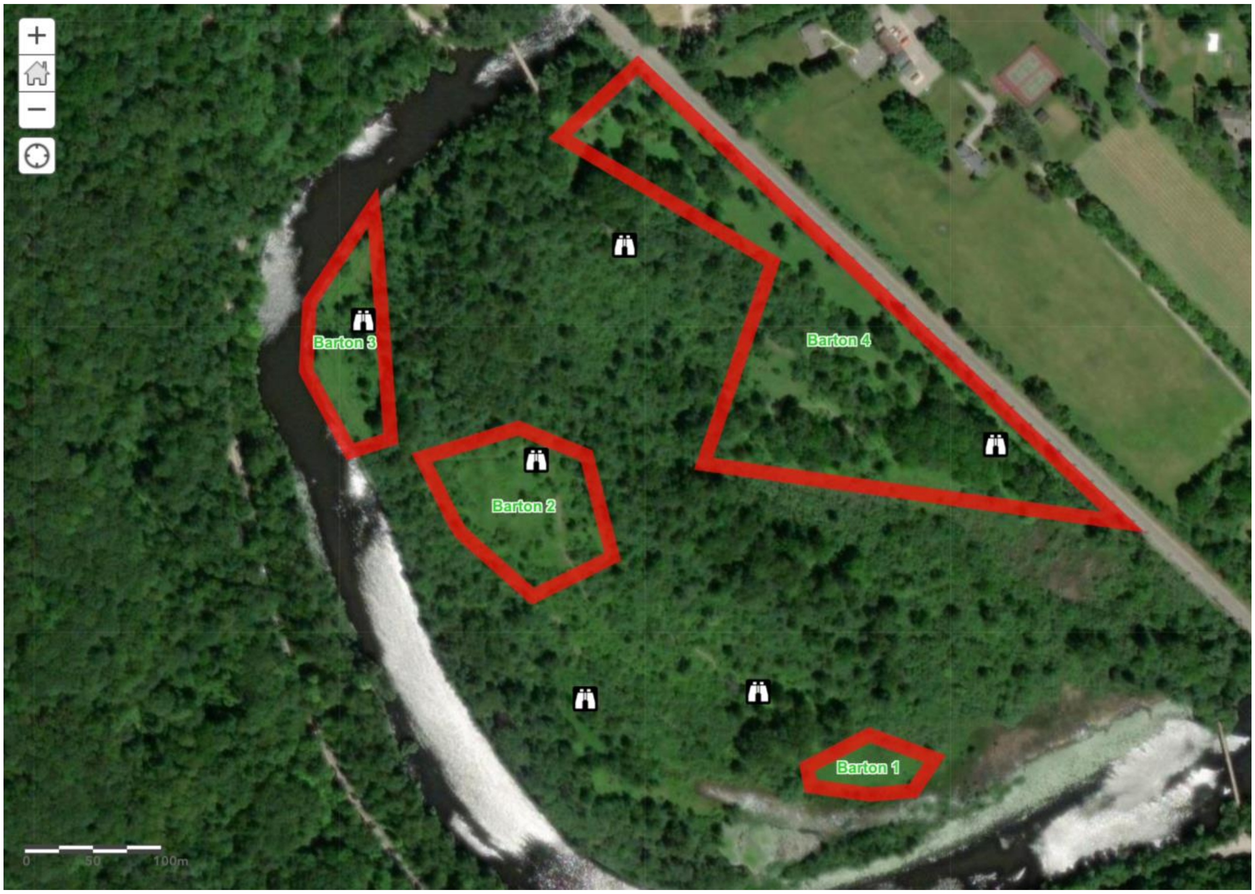

Figure 5: Barton Nature Area, showing grassland area borders in red and locations of bird point count sites binocular icons. Four distinct grassland areas were delineated within Barton Nature Area. This map was created using ArcGIS Online with the "imagery" basemap.

1. Local Habitat Structure Within Selected Grassland Areas

I classified the habitat structure within each grassland area via inspection of satellite imagery with ArcGIS Online followed by ground-truthing in the spring of 2022. Within each grassland area, the area occupied by savanna and prairie habitats was estimated based on the Michigan Natural Features Inventory (MNFI) classification system (Kost et al. 2007). Based on Curtis

(1959), savanna was classified as a tree density of more than one mature tree per acre, but less than 60% tree cover while less than one tree per acre was considered prairie (Figure 6).

Figure 6: Examples of prairie and savanna characteristics used to classify areas based on vegetation structure. Prairie (left) and savanna (right) are grass-dominated in the understory: prairies have an open canopy with less than one tree per acre, savannas contain scattered trees.

2. Vegetation Composition Within Study Areas

I conducted meander surveys (Cohen et al. 2023) to determine vegetation composition within the study areas from July 31 to August 18, 2022. I walked through the areas and recorded an abundance code for each plant species (trees, shrubs,and herbaceous plants) in each vegetative layer (Table 1). I used iNaturalist and Michigan Flora Online to assist with plant identification. Plant abundance was ranked as: Dominant (D); Abundant (A); Common (C); Uncommon (U); or Scarce (S). If a species occurred in one specific area within the grassland, an L for "Locally" was used for coding. For example, a species only abundant in the savanna section but absent elsewhere was coded (LA) for Locally Abundant. Tree and shrub species present along the edge of the grassland area were recorded as well. Height categories for trees and shrubs were assigned by visual inspection or using a clinometer or Diameter at Breast Height (dbh) tape, where needed.

Table 1: Vegetative layers used in assessing the vegetation composition of the study areas. Trees were assigned to a layer by visual inspection or using a Diameter at Breast Height (DBH) tape or clinometer, where needed.

Vegetative Layer	**Description**
Overstory	plants >20 m in height
Understory	plants 5-20 m in height
Tall Shrub	plants 1-5 m in height
Low Shrub	plants 0.2-1 m in height
Ground	All herbaceous plants (and woody plants <20 cm in height)

3. Landscape Surrounding Selected Grassland Areas

I characterized land cover surrounding the study areas by visual inspection of satellite imagery in a 500-m buffer around a centroid for each grassland area in ArcGIS Online. This buffer size was chosen because it falls within the range of scales (20-150 ha) at which small birds respond to land cover according to Hostetler and Holling (2000). Distinct patches were visually identified within the buffer. Patches with less than 11% impervious surface (buildings and paved roads) were classified based on percentage of trees and bush coverage (Table 2) as defined by MNFI (Kost et al. 2007). Open water was defined as any part of the Huron River or Barton Pond.

Patches with more than 11% impervious surface were classified as suburban or urban using the classification described in Kaminski et al. (2021) using percentage of impervious surface (Table 2). The grassland area itself was not included in the classification of surrounding land cover since it would be accounted for by grassland size. The area of land cover types was calculated within the buffer using the “summarize within” analysis tool in ArcGIS Online. In addition, the following landscape-related variables were estimated as described in Rottenborn (1999). Distance was measured from the area centroid to the nearest: 1) building (DISTBUIL); 2) paved road (DISTPAVE); and 3) bridge across the Huron River (DISTBRID). Number of bridges across the Huron River within 500 m of the grassland area centroids (BRIDGE) were also counted.

Table 2: Land cover categories measured within a 500-m buffer zone around a centroid of each study area determined by visual inspection using ArcGIS Online.

Category	**Description**
Forest	>60% tree cover
Savanna	> 10% and < 60% tree cover
Prairie	<10% tree cover (more than one mature tree per acre)
Open water	Any part of the Huron River or Barton Pond
Suburban	> 11% and <55% impervious surface
Urban	>55% impervious surface

4. Grassland Bird Community

I conducted unlimited-distance Bird Point Count surveys to assess the number and abundance of grassland bird species**.** I selected 13 point counts sites (Table 2) and conducted a total of 39 point counts. Three of the grassland areas (Bluffs, Barton 1 and Barton 3) had only one point count site, while the other five had two (Dow Field, Furstenberg, Kuebler Langford, Barton 2, and Barton 4) (Table 3). I conducted three 10-minute counts (maximum duration recommended by Smith et al. 1995) at each point count site. Surveys were spaced out by at least two weeks at each site. Surveys were conducted in 2022 from May 25 to July 15 from 8:02 to 10:19 AM.

Table 3: Coordinates of bird point count sites, selected from sites established by NAP as part of the Ann Arbor Breeding Bird Survey (City of Ann Arbor Parks and Recreation, 2023d).

Point Count Site	**Latitude**	**Longitude**	**Associated Grassland Area**
Dow Field Point 1	42.281	-83.7123	Dow Field
Dow Field Point 2	42.2819	-83.7171	Dow Field
Furstenberg Point 2	42.2815	-83.709	Furstenberg
Furstenberg Point 3	42.2803	-83.7496	Furstenberg
Bluffs Point 2	42.294	-83.7482	Bluffs
Kuebler Langford Point 3	42.2996	-83.7508	Kuebler -Langford
Kuebler Langford Point 4	42.3001	-83.7548	Kuebler -Langford
Barton Point 1	42.3063	-83.7545	Barton 4
Barton Point 2	42.3049	-83.7553	Barton 2
Barton Point 3	42.3033	-83.7548	Barton 2
Barton Point 4	42.3033	-83.7533	Barton 1
Barton Point 5	42.305	-83.7511	Barton 4
Barton Point 6	42.3058	-83.7568	Barton 3

I surveyed a subset of 11 of the 28 NAP count sites established for their annual breeding bird surveys at Bluffs, Furstenberg, Kuebler-Langford, and Barton. The subset was chosen based on location in or within earshot of the grassland areas. The NAP point count sites were placed non-randomly with three criteria in mind: 1) Areas where there was known to be high bird species richness; 2) at least 150 feet from other count sites to minimize count overlap; and 3) easy access from trails (Juliet Berger, Ann Arbor NAP, Personal Communication). Additionally, I set up two point count sites in Dow Field at Nichols Arboretum using the same three criteria.

During the counts, I stood stationary at the site for 10 minutes while observing birds with binoculars and by ear. Counts of each species were later entered into eBird (Sullivan et al. 2009). Counts were unlimited-distance (Blondel & Frochot 1981) (i.e. there was no fixed radius within which birds were surveyed; all that were detected were entered into eBird). This method estimates an index of abundance for each species. The Merlin sound ID feature (Cornell Lab of Ornithology 2024) was used to assist with identification, however, only birds that were heard both by the Merlin app sound ID feature and confirmed by ear were recorded. Audio recordings of surveys were made by phone to provide records for more accurate and complete identification. Species that I found in my point count surveys were considered as grassland species if listed as grassland birds in Table 2 of Herkert (1993).

I conducted counts when two conditions were met: 1) there was no precipitation or fog; and 2) winds were less than 7 mph. These criteria helped to ensure good bird detectability and avoid sampling bias (Wolf et al.1995**)**. Wind speed was assessed by observing vegetation movement. If there was no movement, wind =1 (< 1 mph);   leaves moving but not rustling (1-3 mph)=2; rustling (4-7 mph)=3; constantly moving (8-12 mph)=4 and the survey was called off. Cloud cover was categorized as 1=sunny, 2=scattered clouds; 3=overcast; 4=foggy; and 5=precipitation. The survey was called off under foggy or rainy conditions.

5. Data Analysis

Multivariate Regression to Explore Relationships Between Bird Community and Habitat

I used regression models to assess which patch-level and landscape-level variables were the best predictors of grassland bird abundance. I implemented models with the total grassland bird count (sum of all species counts for each point count survey) and of selected species as the response variable and to explore relationships with explanatory variables generated in the study (Table 4).

Table 4: Summary of all variables measured in the study.

Category	**Variable**
Local Habitat Structure	prairie vs savanna
Local Vegetation Composition	plant species richness tree species richness plant richness in the overstory and understory layers combined plant richness in the tall shrub layer plant richness in the low shrub layer plant richness in the ground layer plant richness around the edge of the area
Surrounding Land Cover	distance to nearest building (DISTBUIL) distance to nearest paved road (DISTPAVE) distance to nearest bridge (DISTBRID) number of bridges within 500m of the area centroid (BRIDGE) forest cover within 500m of the area centroid savanna cover within 500m of the area centroid prairie cover within 500m of the area centroid

	open water cover within 500m of the area centroid suburban cover within 500m of the area centroid urban cover within 500m of the area centroid
Grassland Size	area of the grassland

I used Generalized Additive Models (GAMs) (Zuur et al. 2009) with a Poisson distribution. To select variables to include in the models, I first explored the data by visual inspection of plots to determine correlations among explanatory variables and relationships between grassland bird data and explanatory variables. I ran models with selected variables and evaluated models. Significance of nonlinearity of explanatory variables was tested with an analysis of deviance.I considered a 90% confidence interval. I used the gam() function in R (Perperoglou et al. 2019). I then used the anova.Gam() function in the “mgcv” package in R to perform an analysis of the deviance.

Results

1. Local Habitat Structure Within Selected Grassland Areas

Six of the eight grassland areas were classified exclusively as savanna based on satellite imagery: Bluffs, Kuebler Langford, and Barton 1, 2, 3 and 4 (Table 5, Figures 3, 4, 5, 7 and 8). Dow Field and Furstenberg contained 78% and 37%of the areas classified as prairie, respectively.

Table 5. Area (ha) covered by prairie and savanna habitats measured using the “measure” tool in ArcGIS Online. Barton includes four grassland areas separated by woodlands.

Site	Total Area (ha)	Prairie Area (ha)	Savanna Area (ha)
Dow Field	6.80	5.34	1.46
Furstenberg Park	2.42	0.65	1.78
Bluffs	0.68	0	0.68
Kuebler-Langford	1.45	0	1.45
Barton 1	0.27	0	0.27
Barton 2	1.10	0	1.10
Barton 3	0.72	0	0.72
Barton 4	4.05	0	4.05

Figure 7: Vegetation structure at grassland areas containing both prairie and savanna habitats. Top: Dow Field, bottom: Furstenberg. Both contained a mixture of open grassy area (prairie) and areas with scattered trees (savanna). Pictures by Sam Heilman.

Figure 8: Vegetation structure at savanna grassland areas which only contained savanna habitat. Top left: Kuebler Langford, top right: Bluffs, middle left: Barton 4, Middle Right: Barton 3, bottom left: Barton 2, bottom right: Barton 1. Pictures by Sam Heilman.

2. Vegetation Composition Within Grassland Areas

In total, 152 plant species were observed during the meander surveys. Overall plant species richness (including trees, shrubs, and herbaceous plants) ranged from 73 in Dow Field to 23 in

Barton 1 (Table 6). Tree species richness was also highest in Dow Field with 19 species and lowest at Barton with six species. Combined plant richness in the overstory and understory layers varied from two at Bluffs to 13 at Barton 4. Plant richness in the tall shrub layer varied from 1 at Barton 1 to 6 at Bluffs. Plant richness in the low shrub layer varied from 0 at Barton 3 to 10 at Dow Field, and in the ground layer varied from 15 at Barton 1 to 65 at Furstenberg. Tree and shrub species richness around the area edges varied from 1 at Barton 1 to 16 at Dow Field.

Table 6: Plant species richness for trees, vegetation layers, and edges.

Grassland Area	Plant	Tree	Over/ Understory	Tall Shrub	Low Shrub	Ground Layer	Edge Tree/Shrub
Dow Field	73	19	5	3	10	46	16
Furstenberg	65	10	5	2	3	65	12
Bluffs	44	7	2	6	4	32	9
Kuebler-Langford	43	11	3	2	4	31	7
Barton 1	23	6	4	1	4	15	1
Barton 2	39	9	5	2	4	28	5
Barton 3	28	8	3	3	0	19	4
Barton 4	59	14	13	2	3	39	8

Overstory and Understory Layers

Three tree genera, all native to Michigan, were found to be dominant in the overstory and understory layers (Figure 9, Appendix 5). Oaks (primarily white oak (*Quercus alba*), black oak (*Q. velutina*) and northern red oak (*Q. rubra*), were prevalent at Dow Field, Furstenberg, Barton 1 and Barton 4 (Appendix 5). Eastern cottonwood (*Populus deltoides*) was dominant at Bluffs and Kuebler Langford, while boxelder (*Acer negundo*) was dominant at Barton 2 and Barton 3.

Shrub Layers

In the shrub layers (Low Shrub and Tall Shrub), invasive species, primarily autumn olive (*Eleagnus umbellata*) and glossy buckthorn (*Rhamnus frangula*) were dominant and/or abundant at Bluffs and Kuebler Langford (Figure 10, Appendix 5). However, native species, including gray dogwood (*Cornus racemosa*), prairie willow (*Salix humilis*), and Eastern cottonwood (*Populus deltoides*), were also abundant in these layers at these sites (Figure 10, Appendix 5). The rest of the areas either had shrub layers dominated by native species or had no abundant or dominant species in those layers.

Ground Layers

In the ground layer, grassland areas were dominated by native prairie grasses big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*), although at Furstenberg non-native Kentucky bluegrass (*Poa pratensis*) was also abundant (Figure 11, Appendix 5). Native goldenrods were abundant in the ground layer of all grassland areas except for Barton 4. Native Virginia mountain mint (*Pycnanthemum virginianum*) and non-native queen Anne's lace (*Daucus carota*) were abundant at most sites as well.

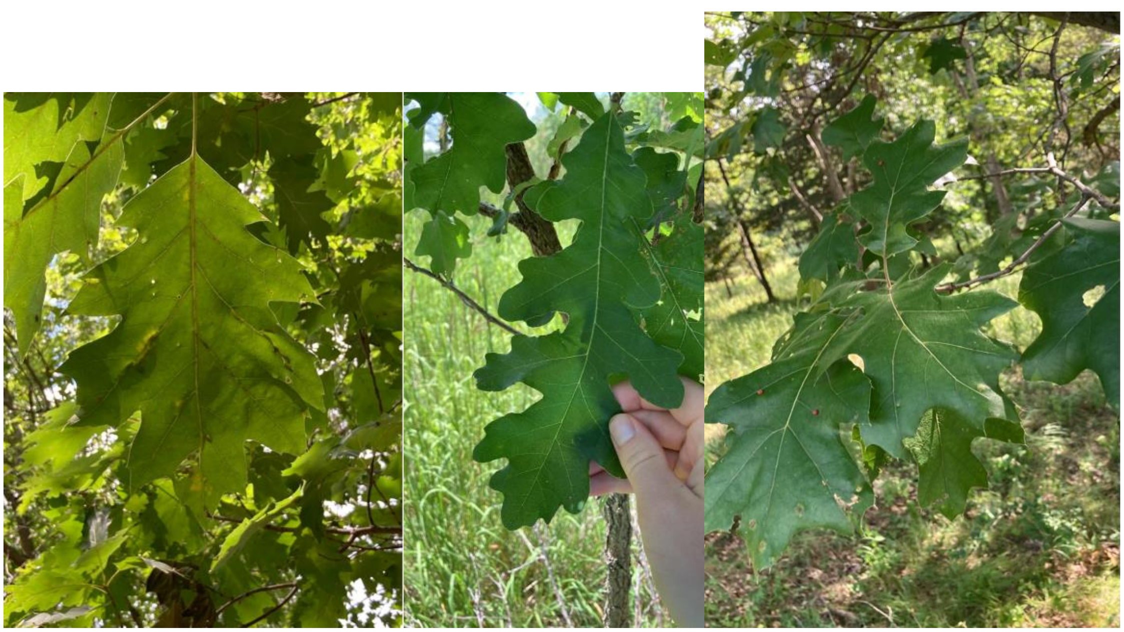

Figure 9: Tree species found to be Dominant or Abundant at the grassland areas. Top left: Northern Red Oak (*Quercus rubra*), top middle: white oak (*Q. alba*), top right: Black Oak (*Q. velutina*), bottom left: Boxelder (*Acer negundo*), Bottom right: Eastern Cottonwood (*Populus deltoides*). All of these tree species are native. Pictures by Sam Heilman.

Figure 10: Shrubs that were found to be Dominant or Abundant in the grassland areas. Top left: Gray Dogwood (*Cornus racemosa*), top right: Glossy Buckthorn (Rhamnus frangula), bottom left: Autumn Olive (*Eleagnus umbellata*), bottom right: Prairie Willow (*Salix humilis*). Gray Dogwood and Prairie Willow are native, while Autumn Olive and Glossy Buckthorn are invasive. Photos by Sam Heilman.

Figure 11: Herbaceous plants found to be Dominant or Abundant in the grassland areas. Upper left: Queen Anne's Lace (*Daucus carota*), Upper Middle: Virginia Mountain Mint (*Pycnanthemum virginianum*), Upper Right: Kentucky Bluegrass (*Poa pratensis*), Lower Left: Little Bluestem (*Schyzachyrium scoparium*), Lower Middle: Big Bluestem (*Andropogon gerardii*). All except for Kentucky Bluegrass are native plants. Photos by Sam Heilman.

3. Land Cover Surrounding Selected Grassland Areas

Forest cover varied from 31.42% at Bluffs to 69.24% at Barton 3 (Table 7). Savanna cover varied from 5.03% at Kuebler Langford to 12.90% at Barton 1. Prairie cover varied from 0% at

Bluffs to 15.43% at Barton 4. Open water cover varied from 3.56% to 16.47% at Barton 4. Suburban cover varied from 3.40% at Barton 1 to 27.22% at Dow Field. Urban cover varied from 1.36% at Barton 3 to 23.48% at Kuebler Langford.

Number of bridges within 500 m of the area centroid (BRIDGE) varied between 0 at Furstenberg and 4 at Kuebler Langford and Barton 4 (Table 8). Distance to the nearest building (DISTBUIL) varied from 53.9 m at Furstenberg to 390.4 m at Barton 2. Distance to the nearest paved road (DISTPAVE) varied from 74.5 m at Furstenberg to 291.5 m at Barton 4. Distance to the nearest bridge (DISTBRID) varied from 231.8 m at Barton 3 to 781.3 m at Furstenberg.

Table 7: Land cover types (%) within a 500-m radius circular buffer surrounding centroids of each grassland area (excluding the area itself). Patches>11% impervious surface cover were placed in urban or suburban categories. Patches<11% impervious surface cover were placed into forest, savanna, prairie, and open water categories based on tree and shrub cover (Table 2).

Grassland	Size (ha)	Forest	Savanna	Prairie	Open Water	Suburban	Urban
Dow Field	6.80	41.40	5.91	4.88	6.29	27.22	15.15
Furstenberg	2.42	38.94	5.79	14.37	3.56	22.47	16.19
Bluffs	0.68	31.42	9.55	0	13.13	25.26	20.87
Kuebler-Langford	1.45	56.18	5.03	0.62	6.54	8.54	23.48
Barton 1	0.27	61.91	12.90	9.22	8.62	3.40	4.27
Barton 2	1.1	63.95	12.59	6.31	10.27	5.75	1.42
Barton 3	0.72	69.24	12.02	2.51	10.07	5.10	1.36
Barton 4	4.05	44.80	11.32	15.43	16.47	10.21	1.87

Table 8: Number of bridges within a 500m buffer of the area centroid and distances to urban features. Urban features are buildings (DISTBUIL), paved roads (DISTPAVE) and bridges (DISTBRID). Distances are from area centroids to the closest point on the urban feature.

Grassland Area	BRIDGE (#)	DISTBUIL (m)	DISTPAVE (m)	DISTBRID (m)
Dow Field	2	182.4	248.3	382.3
Furstenberg	0	53.9	74.5	781.3
Bluffs	1	101.6	85.7	387.5
Kuebler-Langford	4	161.6	101.3	277.0
Barton 1	3	295.9	149.2	252.3
Barton 2	2	390.4	193.8	307.7
Barton 3	2	271.4	90.00	231.8
Barton 4	4	167.4	291.5	284.2

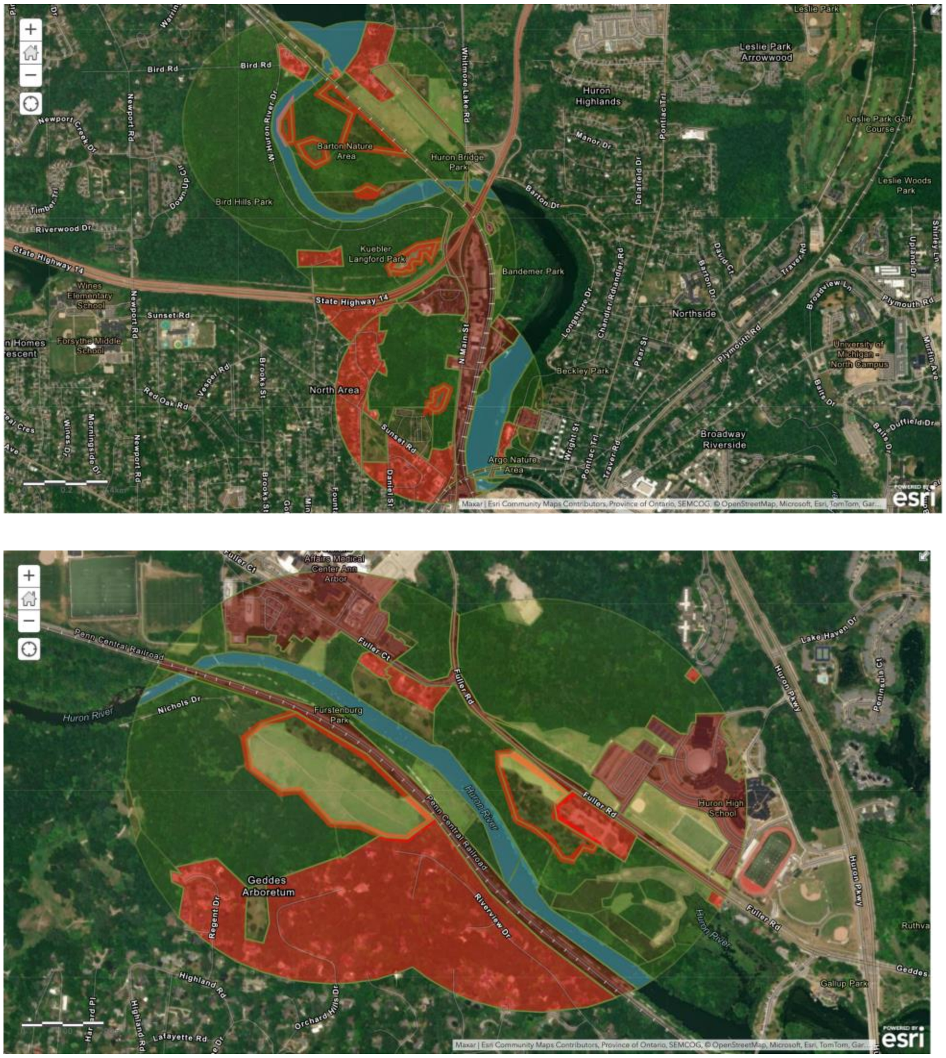

Figure 12: Land cover types surrounding the study areas in a 500-m radius from the area centroid. Top: Dow Field and Furstenberg; Bottom: Bluffs, Kuebler Langford, and areas contained within Barton Nature Area (Barton 1, 2, 3 and 4). Borders of study areas are outlined in red; green=forest. orange =savanna, yellow=prairie, blue=open water, bright red =suburban, and dark purple= urban cover.

4. Grassland Bird Community

Seven grassland bird species were present in the grasslands surveyed. American Goldfinch (*Spinus tristis*); Song Sparrow (*Melospiza melodia*); Field Sparrow (*Spizella pusilla*) and Common Yellowthroat (*Geothlypis trichas*) (Figure 13), were selected for analysis because of their inclusion in Table 2 of Herkert et al. (1993) . Additionally, Orchard Orioles (*Icterus spurius)* and Downy Woodpeckers (*Dryobates pubescens*) (Figure 14) were identified and included because of their associations with oak savanna ecosystems (Holoubeck and Jensen 2015), and Eastern Bluebirds (*Sialia sialis*) were identified and included due to their preference for nesting in savannas (Kruger 1985)**.**

Figure 13: Grassland bird species found in the study areas. Top left: Song Sparrow, top right: American Goldfinch, Bottom Left: Field Sparrow, Bottom Right: Common Yellowthroat. Pictures by Sam Heilman (except Field Sparrow). Source (Field Sparrow): https://www.allaboutbirds.org/guide/assets/photo/297663691-480px.jpg.

Figure 14: Grassland bird species found in the study areas. Top left: Downy Woodpecker, Top Right: Orchard Oriole, Bottom Left: Eastern Bluebird. Photos by Sam Heilman.

4.1 Grassland Bird Species Richness

Dow Field had the highest bird species richness (7) (Table 9). Dow Field was the only area at which all seven grassland bird species were present, while the lowest number of species (3) were found in Bluffs, Kuebler-Langford, and Barton 1. American Goldfinches were the only grassland species present in all eight areas (Table 9). Song Sparrows were absent only in Kuebler Langford and Common Yellowthroat in Bluffs and Kuebler Langford. Orchard Orioles were present only at Dow Field, Furstenberg, and Barton 2.

Dow Field was the only study area which contained mostly prairie habitat and where all seven grassland bird species were recorded. This suggests that prairie habitat may support a higher species richness of grassland birds than savanna, although this could also be attributed to Dow Field's larger size. Alternatively, since other areas (except Furstenberg) contained only one habitat structure (savanna), this could indicate that grasslands that contain multiple habitat structures (prairie and savanna vs. just savanna) supports more species of grassland birds than all-prairie or all-savanna grasslands. Further, grassland bird species richness was influenced by vegetation richness in the study area. Bird richness showed an increasing trend (Figure 15) with increasing plant richness (ranging from 23 to 73 species), tree richness (ranging from 6 to 19 species) (Table 6), edge tree and shrub richness (ranging from 1 to 16 species), and ground plant richness (ranging from 15 to 65 species).

Land cover variables that appeared to influence grassland bird species richness included prairie cover (ranging from 0% to 15.43%) and suburban cover (ranging from 3.40% to 27.22%), which both showed positive trends with grassland bird species richness.

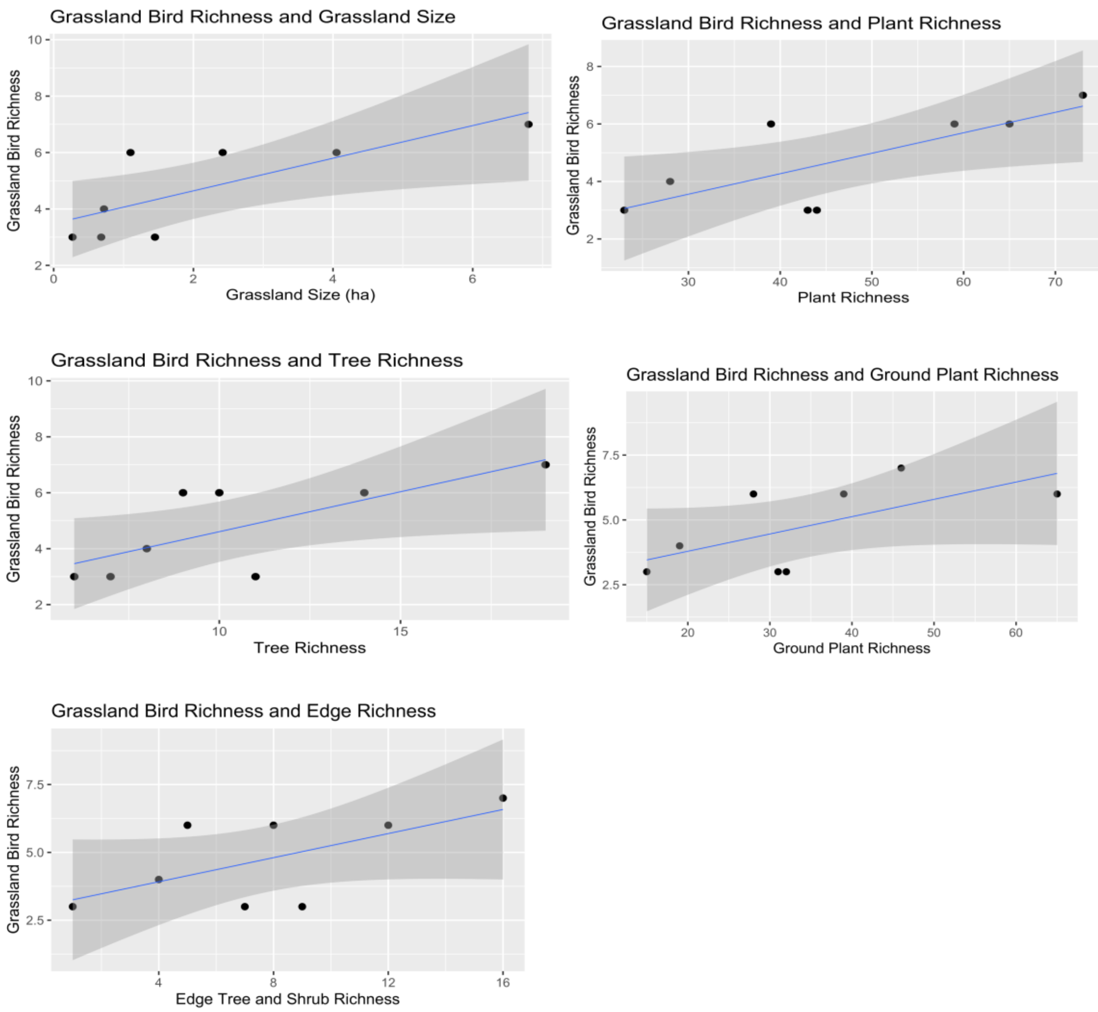

Figure 15: Grassland bird species richness and patch-level (vegetation and grassland size) variables.

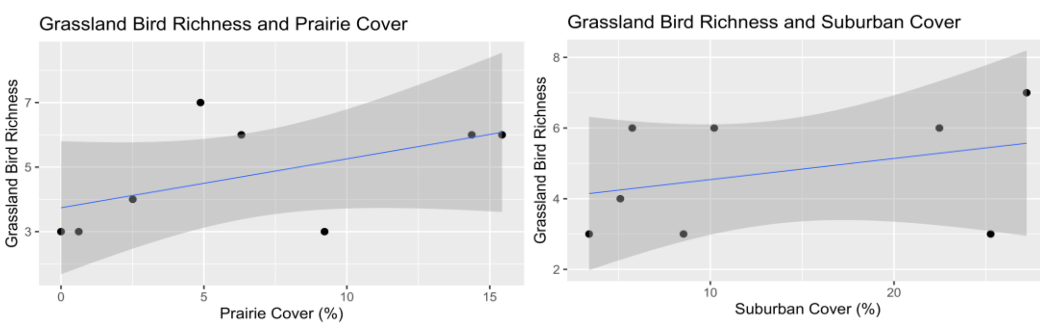

Figure 16: Grassland bird species richness and landscape-level variables.

Table 9: Mean counts (relative abundance) of grassland bird species found in the study and standard deviation. The mean is of the three counts conducted at each point count site, at grassland areas with two point count sites, they were averaged over the two sites.

Species	Dow Field	Furstenberg	Bluffs	Kuebler Langford	Barton 1	Barton 2	Barton 3	Barton 4
American Goldfinch	2.6 (3.77)	0.50 (0.71)	2.33 (3.21)	0.83 (0.24)	1.00 (1.00)	2.67 (0.94)	1.33 (1.53)	0.17 (0.24)
Eastern Bluebird	0.67 (0.94)	0.50 (0.71)	-	0.17 (0.24)	-	-	-	0.33 (0.47)
Field Sparrow	0.5 (0.24)	-	-	-	-	0.17 ± (0.24)	0.33 (0.58)	0.17 (0.24)
Song Sparrow	2.50 (2.59)	2.67 (0.47)	1.67 (1.15)	-	2.00 (1.00)	1.50 (0.71)	3.00 (1.00)	1.67 (1.41)
Common Yellowthroat	0.33 (0.47)	0.17 (0.24)	-	-	0.67 (0.58)	0.5 (0.24)	1.00 (1.00)	0.67 (0.94)
Orchard Oriole	0.17 (0.24)	0.17 (0.24)	-	-	-	0.17 (0.24)	-	-
Downy Woodpecker	0.17 (0.24)	0.83 (0.24)	1.33 (1.53)	0.50 (0.24)	-	0.17 (0.24)	-	0.33 (0.47)
Total Abundance	6.94	4.84	5.33	1.5	3.67	5.18	5.66	3.34
Bird Species Richness	7	6	3	3	3	6	4	6

4.2 Grassland Bird Abundance

Mean counts of American Goldfinch, only species found in all eight areas, varied between 0.17 in Barton 4 and 2.67 in Barton 2. Mean abundance of Eastern Bluebirds, found in four study areas, varied from 0.17 at Kuebler Langford to 0.67 at Dow Field (Table 9). Field Sparrow, found at four study areas, varied from 0.17 at Barton 2 and 4 to 0.5 at Dow Field, and Song Sparrow, found at all areas except Kuebler Langford, varied from 1.67 at Bluffs to 3 at

Furstenberg. Mean abundance of Common Yellowthroat, found at all areas except Bluffs and Kuebler Langford, varied from 0.17 at Furstenberg to 1 at Barton 3. Downy Woodpecker, found at all areas except Barton 1 and Barton 3, varied from 0.17 at Dow Field and Barton 2 to 0.83 at Bluffs, and abundance of Orchard Orioles, found at Dow Field, Furstenberg, and Barton 2, was 0.17 at each of these areas. Total grassland bird abundance varied from 1.5 at Kuebler Langford to 6.94 at Dow Field.

4.3. Relationships Between Grassland Bird Abundance and Explanatory Variables

1. Local Habitat Structure Within Study Areas

The only grassland areas in the study containing local habitat classified as mostly prairie were Dow Field (78%) and Furstenberg (37%), all others were classified as savanna (Table 5). Coincidentally, Dow Field was the area with the highest total grassland bird abundance (Table 9), but was also the largest. The correlation with area size, and lack of variation in the data (Table 5), precluded a statistical analysis of bird abundance as a function of the local habitat structure.

2. Vegetation Composition Within Grassland Areas

Exploratory analysis - correlation among explanatory variables for model selection

Exploratory analysis indicated that several explanatory variables to characterize the vegetation composition were correlated. Tree species richness and plant species richness seemed positively correlated, combined overstory and understory richness seemed negatively correlated with tall shrub richness, and edge tree and shrub richness seemed positively correlated with both ground richness and low shrub richness. Correlation precludes including these variables together in models for regression analysis.

3. Land Cover and Urban Features Surrounding Selected Grassland Areas

Exploratory analysis - correlation among explanatory variables for model selection

All land cover, distances to urban features variables and number of bridges in the landscape were correlated to each other, except for open water cover and forest cover, suburban cover and prairie cover, and number of bridges and urban cover.

4. **Grassland Size**

Exploratory analysis - correlation among explanatory variables for model selection

Grassland size was correlated with all measures of plant richness (overall plant richness, tree richness, overstory/understory plant richness, tall shrub richness, low shrub richness, ground richness, edge tree and shrub richness). Grassland size also appeared correlated with percentages of all land cover types except urban cover, and with distances to urban features, but not with the number of bridges.

4.4 Exploration of Potential Relationships Between Total Grassland Bird Abundance and Explanatory Variables

1. **Vegetation Composition**

Exploratory analysis for variable selection to include in models

The mean total abundance of grassland birds was highest at Dow Field (6.94) (Table 9); this area also harbored the highest number of plant species (73) and tree species (19) (Table 6). Exploratory analysis suggests that the total grassland bird abundance increases with low shrub richness (ranging from 0 to 10 species), edge tree and shrub richness (ranging from 1 to 16 species), overall plant richness (ranging from 23 to 73 species), and tree richness (ranging from 6 to 19 species) (Table 6) (Figure 17).

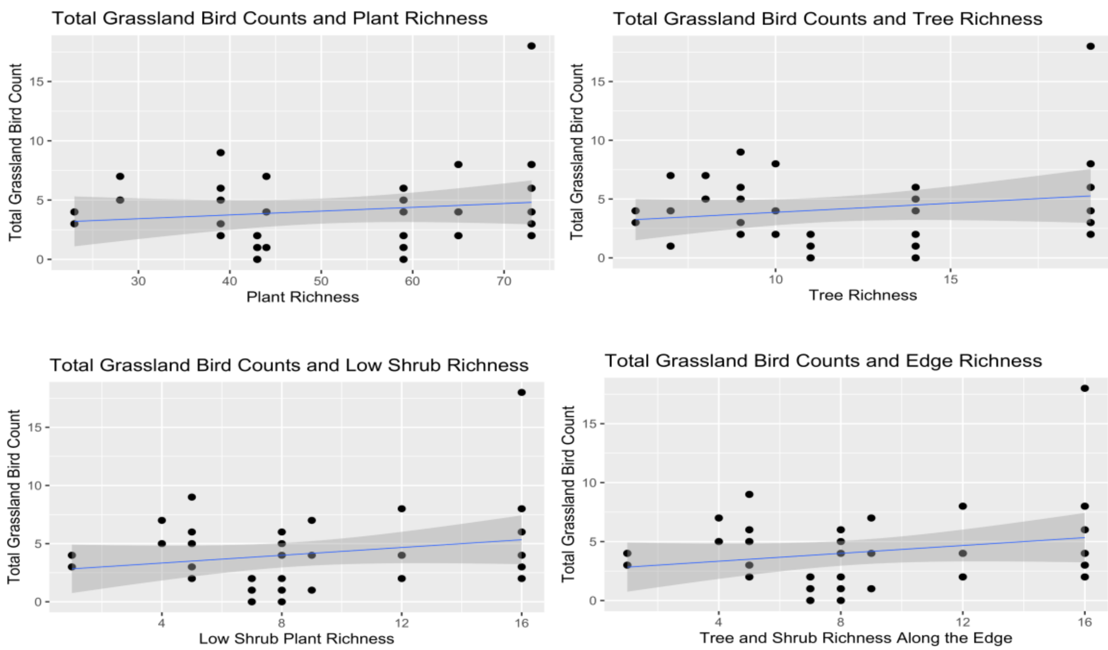

Figure 17: Total grassland bird count versus variables representing vegetation composition within study area. Variables are plant, tree, and low shrub richness, and combined richness of trees and shrubs along the edge.

2. Land Cover Surrounding Selected Areas

Exploratory analysis for variable selection to include in models

Dow Field, which had the highest total grassland bird mean abundance (6.94) (Table 9), also had the highest percentage of suburban cover in the surrounding landscape (27.22%) (Table 7). Total grassland bird counts show a decrease with increasing number of bridges (ranging from 0 to 4) and urban cover (ranging from 1.36% to 23.48%) in the surrounding landscape, and an increase with distance to nearest building (ranging from 53.9 m to 390.4 m), paved road (ranging from 74.5 m to 291.5 m), and suburban cover (ranging from 3.40% to 27.22%) (Tables 7 and 8, Figure 18). All other landscape-level variables did not display much variation or had no discernible patterns in relation to bird species abundance.

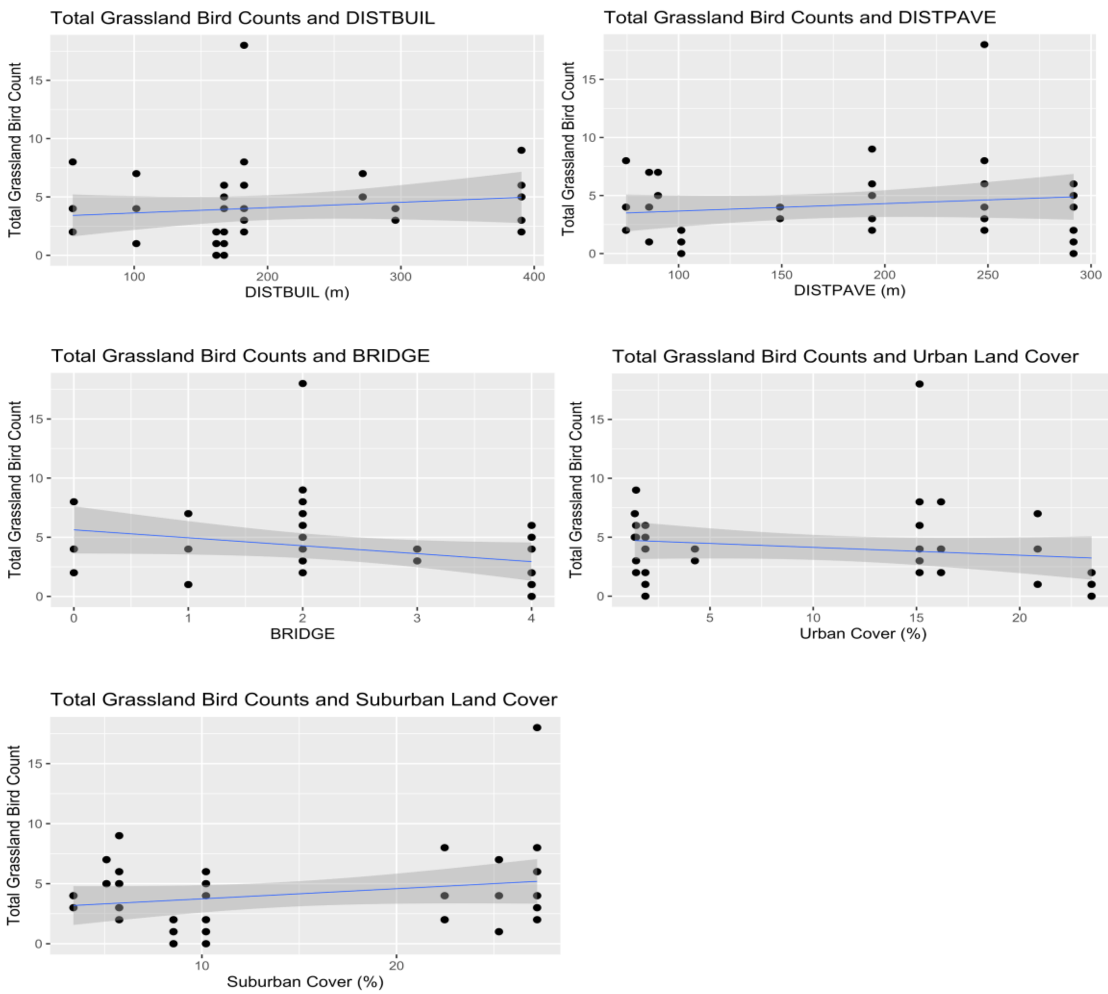

Figure 18: Total grassland bird counts vs. landscape variables surrounding study areas.

3. Grassland Size

Bird counts in the selected areas appeared to increase with the size of the grassland, from the smallest corresponding to Barton 1 (0.27 ha) to the largest corresponding to Dow Field (6.8 ha) (Figure 18).

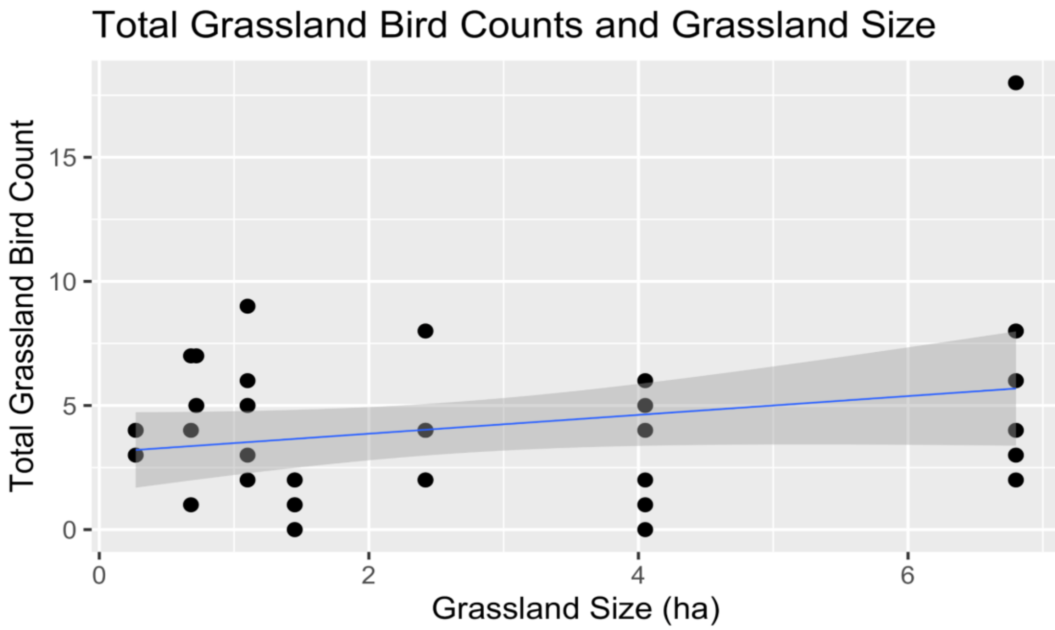

Figure 19: Total grassland bird count vs grassland size (in hectares).

5. Generalized Additive Models (GAMs): Relationships Between Grassland Bird Abundance and Explanatory Variables

The following six variables were included in the best models to evaluate the relationship between the total grassland bird abundance, local habitat structure and composition, and surrounding landscape: 1) edge tree and shrub richness; 2) total plant richness; 3) total tree richness; 4) grassland size; 5) number of bridges; and 6) urban land cover within 500m of the area centroid (Table 9). Four of these variables describe characteristics at the patch level (grassland size, plant richness, tree richness, and edge tree and shrub richness) and two at the landscape-level (number of bridges and urban cover). Except for percent urban cover, these variables were significant predictors of total grassland bird abundance.

All four selected models included a combination of patch-level and landscape-level variables (Table 10). Number of bridges and urban cover were included in all four of the best models. Total grassland bird abundance was found to have a significant nonlinear negative relationship with the number of bridges in all selected models (Table 10, Figures 19, 20, 21, 22). Urban cover was not a significant predictor of total grassland bird abundance in any selected model (Table 10). It showed a negative linear relationship with total grassland bird abundance. Total grassland bird abundances showed a significant positive linear relationship with edge tree and shrub richness, which was included in one model (Table 10, Figure 19). Total grassland bird abundances showed a significant positive linear relationship with tree richness, which was included in one model (Table 10, Figure 20).

Table 10: Generalized Additive Models (GAMs) of total grassland bird counts as a function of patch-level and landscape-level variables. A period (.) indicates statistical significance at the 90% confidence level, * at the 95% confidence level; ** at the 99% confidence level; and *** at the 99.9% confidence level. “Res. df” and “Res. Deviance” indicate the residual degrees of freedom and deviance for the model, respectively. “df” and “deviance” indicate the differences in degrees of freedom and deviance of the models, respectively. Full models are in bold. B = number of bridges, %U = percent urban cover in the surrounding landscape, E = combined tree and shrub richness, T = overall tree species richness, P = overall plant species richness, S = size of the grassland (in hectares). Null deviance for all models was 90.6133.

Model	Res. df	Res. Deviance	Test	df	Deviance	F	Pr(>F)
s(B,2) + %U + E	**34**	**57.7515**	-	-	-	**s(B,2): 2.6786 %U: 0.8757 E: 4.5638**	-
%U + E	36	73.7295	-s(B,2)	-2	-15.4328	%U: 0.9466 E: 6.6112	0.0004455 ***
s(B,2) + E	35	64.1798	-%U	1	9.5497	s(B,2): 2.692 E: 1.0803	0.0020001 **

s(B,2) + %U	35	65.3301	-E	0	-1.1503	s(B,2): 0.1098 %U: 0.931	4.112e-05 ***
s(B,2) + %U + T	**34**	**58.5703**	**-**	**-**	**-**	**s(B,2): 2.7624** **%U: 1.0124** **T: 4.8285**	**-**
%U + T	36	82.525	-s(B,2)	-2	-23.9547	%U: 1.24 T: 2.1026	6.285e-06 ***
s(B,2) +T	35	62.9762	-%U	1	19.5488	E: 0.07088 T: 0.14454	9.807e-06 ***
s(B,2) + %U	35	65.3301	-T	0	-2.3539	s(B,2): 2.692 %U: 0.931	1.218e-05 ***
s(B,2) + %U + P		**59.0328**	**-**	**-**	**-**	**s(B,2): 2.7610** **%U: 0.7111** **P: 3.4422**	**-**
%U + P	36	82.0379	-s(B,2)	-2	-23.0051	%U: 1.2298 P: 2.17722	1.010e-05 ***
s(B,2) + P	35	63.1562	-%U	1	18.8817	s(B,2): 3.4898 P: 0.22587	1.391e-05 ***
s(B,2) + %U	35	65.3301	-P	0	-2.1739	s(B,2): 2.692 %U: 0.931	1.535e-05 ***
s(B,2) + %U + S	**34**	**60.4835**	**-**	**-**	**-**	**s(B,2): 2.6364** **%U: 0.8775** **S: 5.1787**	**-**
%U + S	36	80.1136	-s(B,2)	-2	-22.2467	%U: 1.1966 S: 3.3478	1.476e-05 ***
s(B,2) + S	35	62.3067	-%U	1	17.8068	s(B,2): 3.4987 S: 2.6862	2.445e-05 ***
s(B,2) + %U	35	65.3301	-S	0	-3.0233	s(B,2): 2.692 %U: 0.931	7.516e-06 ***

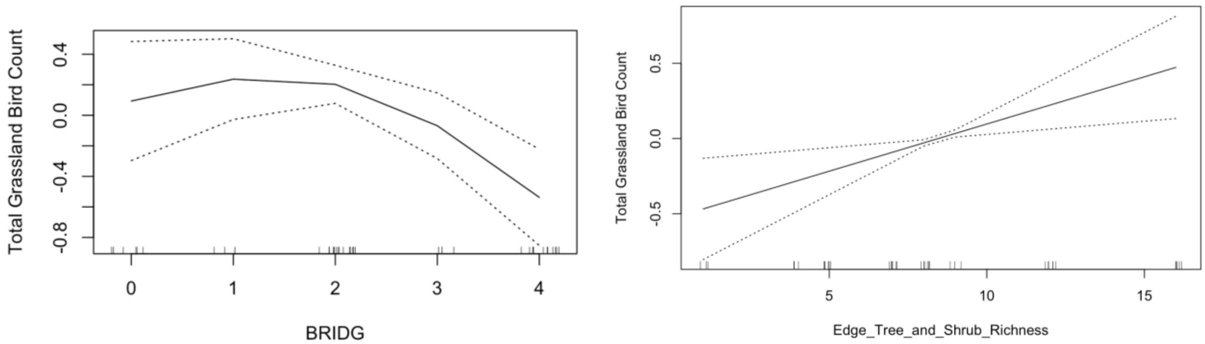

Figure 20: GAM output showing relationships between significant variables on total grassland
bird counts. The model includes: number of bridges (BRIDG) as a nonlinear variable, and % urban cover (Percent_Urban_Cover) and number of tree and shrub species at the area edges (Edge_Tree_and_Shrub_Richness) as linear. The dotted lines indicate the 95% confidence envelopes.

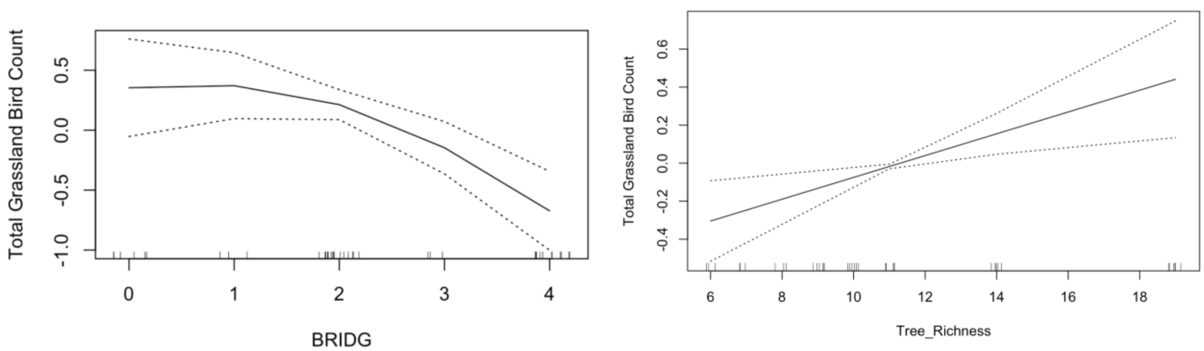

Figure 21: The total grassland bird count vs. variables that showed significant relationships. The model includes: number of bridges (BRIDGE) as a nonlinear variable, and % urban cover (Percent_Urban_Cover) and overall tree species richness (Tree_Richness) as linear. The dotted lines indicate the 95% confidence envelopes.

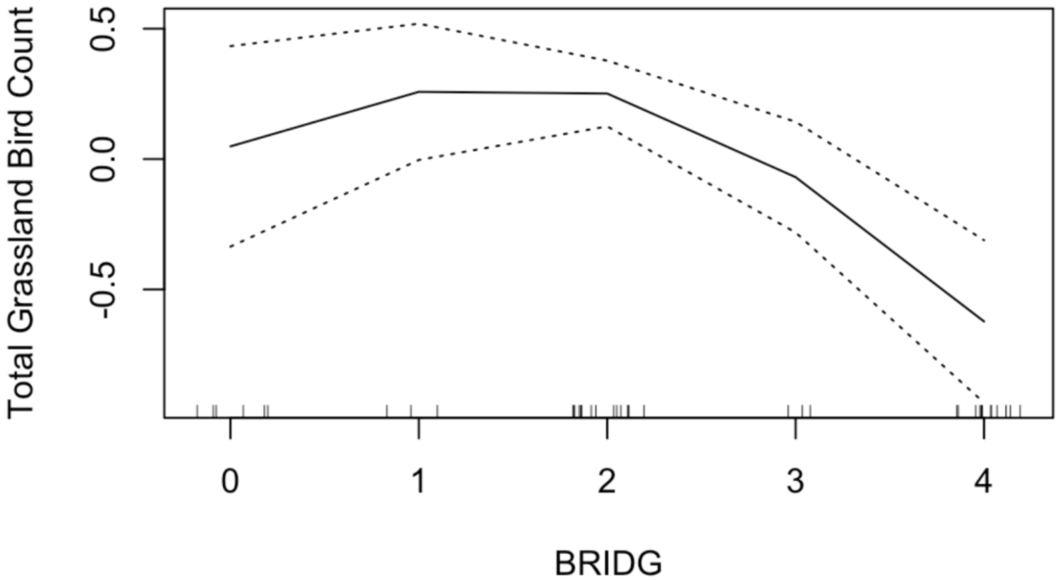

Figure 22: The total grassland bird count vs. variables that showed significant relationships. The model includes: number of bridges (BRIDGE) as a nonlinear variable, % urban cover in the surrounding landscape (Percent_Urban_Cover) and plant species richness (Plant_Richness) as linear. The dotted lines indicate the 95% confidence envelopes.

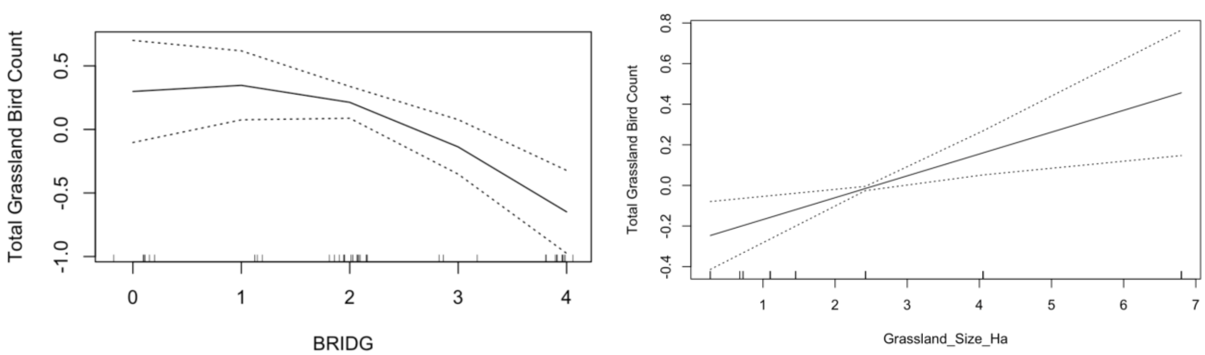

Figure 23: The total grassland bird count vs. variables that showed significant relationships. The model includes: Number of bridges (BRIDGE), % urban cover as a nonlinear variable, % urban cover in the surrounding landscape (Percent_Urban_Cover), and grassland size (Grassland_Size_Ha). The dotted lines indicate the 95% confidence envelopes.

Discussion

1. Grassland Bird Species Richness

The findings from this study, indicating that richness of grassland birds increases with the overall richness of plant species, and particularly overall richness of tree species and woody species along the edge, are consistent with results from previous studies showing that vegetation characteristics at a site, including habitat structure and plant diversity, are important drivers of bird richness (Melles et al. 2003, Paker et al. 2014, Au et al. 2008, Cornelis and Hermy 2004, Dondina et al. 2015, Davis 2004, Hamer et al. 2006, Ference et al. 2014, Houlobek & Jensen 2015, Brauniger et al. 2010, Savard et al. 2000) and these relationships have been demonstrated in other animal taxa as well. The trend of increasing bird richness with increasing plant richness has been demonstrated in urban settings (Nielsen et al. 2013, Melles et al. 2003, Paker et al. 2014, Ferenc et al. 2014, MacGregor-Fors 2008), and tree richness has been found to be particularly important in urban greenspaces (Ferenc et al. 2014). Richness of other animal taxa have also been found to display a positive relationship with plant species richness (Nielsen et al. 2013, McLinney 2002).

A possible mechanism for this trend in birds is suggested by Tallamy and Shriver (2021), who examined concurrent global declines in birds and insects over the last several decades. They discuss previous literature that demonstrated that 96% of landbirds require an abundance of insects, and caterpillars in particular, due to their nutritional value (particularly in carotenoids), to raise their young successfully (Bussman 1933, Brewer 1961, Lawrence 1967, Martin 1971, Stewart 1973, Martin 1987, Seress 2018, Kennedy 2019). Most invasive plants, which can replace native species and reduce species richness in a habitat (Hejda et al. 2009, Adams et al. 2020), support very few native insect herbivores (Tallamy and Shropshire 2009, Burghardt et al. 2010, Richard et al. 2019), and especially the caterpillars on which most songbirds depend (Kennedy 2019). An exception in this study are American Goldfinches, which primarily raise their young on the seeds of Asteraceae plants, especially thistles (Birds of the World 2024, Furlonger et al. 2012). In the context of this study, a dominance of invasive species would provide a lower relative abundance of native plants, which would mean a lower abundance of caterpillars for breeding songbirds to feed their young. It has been found that a reduced number of insect prey due to a high volume of invasive plants can cause decreased reproductive success in birds (Narango et al. 2018). Invasive shrub species, especially *E. umbellata* and *R. cathartica*, were found to be abundant or dominant in or around all three of the grassland areas with the least grassland bird species richness (Bluffs Nature Area, Kuebler Langford Nature Area and Barton 1), which would seem to support this mechanism.

Grassland bird richness seemed to increase with increasing prairie and suburban cover in the surrounding landscape. Both, however, were positively correlated with grassland size, making it difficult to discern the true effects.

The results of this study suggest that plant and grassland bird species richness increase with the area of the grassland within small-patch (1-17 acre) grasslands in an urban park system. It has been well documented that species richness of plant and animal taxa increases with the area of a habitat patch (Arrhenius 1921, Nielsen et al. 2013), and this pattern has been found in urban systems as well (Nielsen et al. 2013, Cornelis and Hermy 2004, Chamberlain et al. 2007).

2. Relationships of total grassland bird abundance to patch-level and landscape-level variables

Both patch-level and landscape-level variables were found to be significant predictors of the total grassland bird abundance. The most consistent significant predictor was the number of bridges in the surrounding landscape, which explained the majority of the deviance in total grassland bird counts in all of the best models. Additionally, urban land cover surrounding the grassland area was present in the best models, although showing no significant effects. This agrees with the results of Rottenborn (1999), who found that the number of bridges and percentage of artificial surfaces surrounding an area were among the strongest predictors of bird density. Potential mechanisms for the relationship between number of bridges and bird abundance include bridges acting as barriers to bird movement, noise from traffic, and bridges being a proxy variable for other urbanization-related variables that act together to negatively impact bird abundance. Urban cover and road density had also been found to be the most important factors influencing structure of bird communities across an urban-rural gradient (Minor and Urban 2011). Potential mechanisms for the relationship between urban cover and bird abundance include the displacement of vegetation volume by paved surfaces and buildings and the associated lack of insect prey, which has been shown to reduce bird reproductive success (Narango et al. 2018).

Notably missing from the best models were the variables that measured habitat structure at a landscape scale (percentage of forest, savanna, prairie, and open water surrounding the area) as well as distances to buildings (DISTBUIL), paved roads (DISTPAVE), and bridges (DISTBRID). This is in contrast to the results of Cunningham and Johnson (2006), who found that tree cover within 200-1600 m of a transect was the most important variable influencing grassland bird distributions. The correlations among these variables could be a reason for this difference. Particularly, BRIDG, DISTPAVE and DISTBUIL were correlated, preventing them from being used in a model together.

3. Conclusions

Grassland bird communities within an urban-suburban landscape are influenced by both patch-level (grassland size and vegetation richness, particularly tree richness and woody plant richness around the edge of the grassland) and landscape-level (land cover and urban features in the surrounding landscape) variables. Maximizing native plant species richness appears critical to supporting a larger abundance and diversity of grassland birds. This is likely due to the comparatively larger amount of insects (particularly caterpillars, which are crucial to breeding success of most songbirds), supported by native plants. Planting a diverse array of native species, and control of invasive species which homogenize the plant community, should be prioritized in grassland restoration efforts. Urban expansion has also made it crucial to consider characteristics of the surrounding urban landscape (including bridges and urban cover) when conducting grassland restoration in order to support the maximum number of grassland birds.

4. Future Research Directions

Future research should aim to continue to characterize grassland bird communities in urban parks. The maximum amount of urban cover in this study constituted less than a quarter of the surrounding landscape; cities that are composed of larger amounts of paved cover could be studied. Suburban landscape warrants more detailed study as the resources available to birds in suburbs are dependent on personal choices of homeowners (for example, planting a diverse native garden versus a traditionally managed lawn), so its effects on the grassland bird community could differ from city to city.

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Appendices

Appendix 1. Point Count Survey Methodology (Becky Hand, Ann Arbor NAP, Personal Communication)

The Point Counts: Surveys are recorded as STATIONARY counts for eBird: A Quantitative Survey done year after year in the same exact location, to establish which species breed at that Point.

1. Counts begin as soon as possible after arrival at the site (I like to settle in for a minute). Earlier visits to the site can establish your orientation and locate your Points, and your Circle Sheet can be prepared ahead of time. Note landmarks and trails on the Circle Sheet, as well as compass orientation, e.g. an arrow pointing North. Note any major habitat breaks on your Circle Sheet.
2. Record all birds seen or heard during a 10 minute period. Counting is done by mapping all birds seen or heard on your Circle Sheet, estimating distances. Be sure to use a different symbol for each bird and whatever symbol you use make sure you know what it is and that you define it for me.
· Example: GF1 GF2 are two male goldfinches on my point counts. GF1 is a goldfinch singing but not seen. You should indicate the breeding behavior so that you'll have that information for eBird entry and to provide richer data about what level of breeding behavior you observed for both survey types.
3. All POINT COUNTS should be done within 2-4 hours after sunrise, or earlier, and in calm winds, with no precipitation.
4. Only one ‘official’ listener/observer per station. There can be a recorder but make sure that you have your “system” down first.
5. Conduct the POINT COUNTS at each park at least twice between May 25 and July 7th, with at least two weeks between sample dates.
6. Please clarify (or redraw) your Circle Sheet ASAP after doing your Point Count and add any details that you need to make the information clear or to indicate the type of activity in which the bird was engaged. Then total the number of each species and transfer the totals to eBird (see eBird instructions) for POINT COUNTS. Point Counts are entered as Stationary Counts.
· Example: 3 singing Tufted Titmice could be recorded as: 3/S (S=singing). You would then record the behavior information on the Point Count survey as “S” if you saw no other higher level of behavior that day. Always indicate if a bird is a “flyover,” that is, not using the habitat, but just flying over it.

7. Always record weather conditions and time of day that you START the point count. Once again, be sure to record the actual time that you spend in the park for your eBird general survey/Hotspot entry.
8. Tentative IDs can be confirmed after the point count. Taking thorough notes helps with making the identification.
9. The inside circle radius = 50 feet. The outside circle radius is 300 feet or "unlimited".
10. You will turn in your Circle Sheets to me, after you have completed your surveys for the season.

Additional Items to consider BEFORE and AFTER you conduct a Point Count:

· Count all birds seen or heard during the 10 minutes. Note obvious females and males (like Red-winged Blackbirds).
· You should use Breeding Codes or your own system to denote the breeding behavior, and you can add male and/or female symbols.
· Make a distance approximation before you do your point count if possible (pace it). Just measure 50 feet from center of your Point or approximate it using a fixed object. The small circle on your point count map is the 50 ft. line. The actual radius you count is approximately 100 meters/300 feet, but you will record all birds that you see or hear. Most of us won't see or hear birds beyond 100 meters. The circumference is actually unlimited in the very technical sense BUT, the important aspect of this is to make sure you don't count the same bird at two Point Count sites.
· Make note of any interesting or unusual behavior and add it later to the Comments section in eBird.
· Birds flushed, flyovers, or new species seen before or after the 10 minute count begins should be recorded on the GENERAL SURVEY.
· Always do your eBird entry as soon as possible after you've conducted your surveys. Details about breeding behavior are lost to time if you wait to record them in eBird until late in the survey season.
· Keep a record of your hours and submit them to me when you are done with the surveys and have recorded your observations in eBird for the season. Record actual time spent in the park (keep this separate from other hours) for each park visit.
· Also record clerical /other hours include driving time between parks, record keeping time, and eBird entry hours, as a combined second total of hours.
· Call or text Juliet at (734) 604-1476 with questions. Email NAPbirds@a2gov.org

Appendix 2: List of plants observed in the 5.4-ha prairie section of Dow Field at Nichols Arboretum (Walters et al. 2018).

Nichols Arboretum

Compiled by Bev Walters, 2011-2012

Alex Dow Field - Prairie

Michigan Natural Plant Community: Dry-mesic Prairie

Open prairie at E end of property dominated by Andropogon gerardii with a mix of native prairie forbs, both naturally occurring and planted

FLORISTIC QUALITY DATA

155	Total Species		
103	Total Native Species	3.47	NATIVE MEAN C
66.5	% Native Species	2.30	W/Adventives
35.18	NATIVE FQI	2.4	NATIVE MEAN W
28.67	W/Adventives	2.7	W/Adventives

C	SCIENTIFIC NAME	COMMON NAME	W	LISTED
0	Acer negundo	BOX-ELDER	0	
5	Acer saccharum	SUGAR MAPLE	3	
1	Achillea millefolium	YARROW	3	
4	Ageratina altissima (Eupatorium rugosum)	WHITE SNAKEROOT	3	
0	Ambrosia artemisiifolia	COMMON RAGWEED	3	
0	Ambrosia trifida	GIANT RAGWEED	0	
5	Andropogon gerardii	BIG BLUESTEM	0	
3	Antennaria neglecta	CAT'S FOOT	5	
2	Antennaria parlinii	SMOOTH PUSSYTOES	5	
3	Apocynum cannabinum (A. sibiricum)	INDIAN-HEMP	0	
*	ARCTIUM MINUS	COMMON BURDOCK	3	
1	Asclepias syriaca	COMMON MILKWEED	5	
5	Asclepias tuberosa	BUTTERFLY-WEED	5	
*	ASPARAGUS OFFICINALIS	GARDEN ASPARAGUS	3	
*	BARBAREA VULGARIS	YELLOW ROCKET	0	
1	Bidens frondosa	COMMON BEGGAR-TICKS	-3	
*	BROMUS INERMIS	SMOOTH BROME	5	
*	CARDAMINE IMPATIENS	BITTER CRESS	3	
*	CARDUUS NUTANS	MUSK THISTLE	3	
10	Carex bicknellii	SEDGE	0	
1	Carex blanda	SEDGE	0	
3	Carex cephalophora	SEDGE	3	
5	Carex hirtifolia	SEDGE	3	
7	Carex muehlenbergii	SEDGE	5	
5	Carex normalis	SEDGE	-3	
4	Carex pensylvanica	SEDGE	5	
1	Carex retroflexa	SEDGE	5	
4	Carex scoparia	SEDGE	-3	
5	Carya glabra	PIGNUT HICKORY	3	
9	Castanea dentata	AMERICAN CHESTNUT	5	E
*	CATALPA SPECIOSA	NORTHERN CATALPA	3	
*	CELASTRUS ORBICULATUS	ORIENTAL BITTERSWEET	5	
5	Celtis occidentalis	HACKBERRY	0	
*	CENTAUREA STOEBE (C. MACULOSA)	SPOTTED KNAPWEED	5	
*	CERASTIUM FONTANUM	MOUSE-EAR CHICKWEED	3	
*	CHELIDONIUM MAJUS	CELANDINE	5	
*	CICHORIUM INTYBUS	CHICORY	3	
2	Circaea canadensis (C. lutetiana)	ENCHANTER'S-NIGHTSHADE	3	
*	CIRSIUM ARVENSE	CANADA THISTLE	3	
*	CIRSIUM VULGARE	BULL THISTLE	3	
0	Conyza canadensis	HORSEWEED	3	
9	Coreopsis palmata	PRAIRIE COREOPSIS	5	T

Appendix 3: List of plants observed in the 1.46-ha savanna section of Dow Field at Nichols Arboretum (Walters et al. 2018).

Nichols Arboretum

Compiled by Bev Walters, 2011-2012

Alex Dow Field - Savanna

Michigan Natural Plant Community: Oak Openings

Mixed oak forest between Dow Field Prairie and railroad tracks, with open canopy, interspersed with small areas of prairie and thickets

FLORISTIC QUALITY DATA

121	Total Species		
90	Total Native Species	3.87	NATIVE MEAN C
74.4	% Native Species	2.88	W/Adventives
36.68	NATIVE FQI	2.6	NATIVE MEAN W
31.64	W/Adventives	2.8	W/Adventives

C	SCIENTIFIC NAME	COMMON NAME	W	LISTED
0	Acer negundo	BOX-ELDER	0	
1	Achillea millefolium	YARROW	3	
4	Ageratina altissima (Eupatorium rugosum)	WHITE SNAKEROOT	3	
5	Andropogon gerardii	BIG BLUESTEM	0	
5	Anemone quinquefolia	WOOD ANEMONE	3	
3	Anemone virginiana	THIMBLEWEED	3	
2	Antennaria parlinii	SMOOTH PUSSYTOES	5	
3	Apocynum androsaemifolium	SPREADING DOGBANE	5	
*	ARCTIUM MINUS	COMMON BURDOCK	3	
1	Asclepias syriaca	COMMON MILKWEED	5	
*	ASPARAGUS OFFICINALIS	GARDEN ASPARAGUS	3	
5	Boechera laevigata (Arabis l.)	SMOOTH BANK CRESS	5	
*	CARDAMINE IMPATIENS	BITTER CRESS	3	
5	Carex hirtifolia	SEDGE	3	
4	Carex pensylvanica	SEDGE	5	
*	CELASTRUS ORBICULATUS	ORIENTAL BITTERSWEET	5	
*	CENTAUREA STOEBE (C. MACULOSA)	SPOTTED KNAPWEED	5	
*	CHELIDONIUM MAJUS	CELANDINE	5	
*	CIRSIUM VULGARE	BULL THISTLE	3	
*	CONVALLARIA MAJALIS	LILY-OF-THE-VALLEY	5	
7	Coreopsis tripteris	TALL COREOPSIS	0	
5	Corylus americana	HAZELNUT	3	
*	DACTYLIS GLOMERATA	ORCHARD GRASS	3	
*	DAUCUS CAROTA	QUEEN-ANNE'S-LACE	5	
5	Desmodium glabellum (D. paniculatum)	TICK-TREFOIL	5	
6	Desmodium illinoense	PRAIRIE TICK-TREFOIL	5	
*	DIANTHUS ARMERIA	DEPTFORD PINK	5	
3	Dichanthelium implicatum (Panicum i.)	PANIC GRASS	0	
5	Dichanthelium latifolium (Panicum l.)	BROAD-LEAVED PANIC GRASS	3	
0	Erigeron annuus	DAISY FLEABANE	3	
4	Euphorbia corollata	FLOWERING SPURGE	5	
3	Euthamia graminifolia	GRASS-LEAVED GOLDENROD	0	
*	FRANGULA ALNUS (RHAMNUS FRANGULA)	GLOSSY BUCKTHORN	0	
2	Fraxinus pennsylvanica	RED ASH	-3	
4	Galium triflorum	FRAGRANT BEDSTRAW	3	
4	Geranium maculatum	WILD GERANIUM	3	
*	GLECHOMA HEDERACEA	GROUND-IVY	3	
5	Helianthus divaricatus	WOODLAND SUNFLOWER	5	
4	Helianthus strumosus	PALE-LEAVED SUNFLOWER	5	
*	HESPERIS MATRONALIS	DAME'S ROCKET	3	
5	Hylodesmum glutinosum (Desmodium g.)	CLUSTERED-LEAVED TICK-TREFOIL	5	
*	HYPERICUM PERFORATUM	COMMON ST. JOHN'S-WORT	5	

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Appendix 4: Plant species abundance and height in this study.

Abundance codes: D=Dominant; A=Abundant; C=Common; U=Uncommon; S=Scarce; L indicates if abundance is Local. Height categories: Overstory: > 20m; Understory: 5-20m; Tall Shrub: 1-5m; Low Shrub: 0.2-1m; Ground: Woody plants < 0.2m; and all herbaceous plants. Height categories: O=Overstory, U=Understory, T=Tall Shrub, L=Low Shrub, G=Ground layer, E=Edge.

Plant Species		Dow Field	Furstenberg	Bluffs	Kuebler Langford	Barton 1	Barton 2	Barton 3	Barton 4
Quercus rubra									
	Overstory	LA	-	-	-	-	-	-	-
	Undersory	LA	S	-	S	A	LU	-	A
	Edge	-	-	-	-	S	-	-	-
Quercus alba									
	Undersory	-	U	-	-	-	-	-	S
	Low shrub	LC	-	-	-	-	-	-	-
	Edge	LU	LU	LA	-	-	-	C	U
Quercus velutina									
	Undersory	-	A	-	-	A	-	-	A
	Tall shrub	LC	-	-	-	-	-	-	-
	Low shrub	LC	-	-	-	-	-	-	-
	Edge	-	A	-	-	-	-	-	-
Quercus macrocarpa									
	Tall shrub	LC	-	-	S	-	-	-	-
	Low shrub	LC	-	-	-	-	-	-	-

	Edge	-	-	-	U	-	-	-	-
Acer saccharum									
	Undersory	-	-	-	-	-	-	-	S
	Edge	S	-	-	-	-	-	-	-
Acer rubrum									
	Undersory	-	-	-	-	-	-	-	S
Acer negundo									
	Undersory	-	U	-	-	U	A	-	-
	Tall shrub	-	-	-	-	-	LU	-	-
	Low shrub	LU	-	-	-	-	A	-	-
	Ground	-	-	-	-	-	-	-	U
Acer platanoides									
	Edge	S	-	S	S	-	-	-	-
Populus deltoides									
	Undersory	-	-	D	D	-	-	-	-
	Tall shrub	-	-	C	-	-	-	-	-
	Low shrub	-	-	C	-	-	-	-	-
	Edge	U	U	A	A	-	-	-	-
Populus grandidentata									
	Overstory	LC	-	-	-	-	-	-	-

	Undersory	-	-	-	-	-	-	-	LU
Prunus serotina									
	Undersory	LC	C	-	-	S	LA	-	A
	Tall shrub	-	-	-	-	-	S	-	LU
	Edge	LA	-	-	-	-	-	-	-
Prunus avium									
	Edge	S	-	-	-	-	-	-	-
Prunus serrulata									
	Edge	S	-	-	-	-	-	-	-
Tilia americana									
	Undersory	-	-	-	-	-	-	-	S
	Low shrub	LA	-	-	-	-	-	-	-
	Edge	LA	-	A	A	-	-	S	-
Carya glabra									
	Low shrub	LC	-	-	-	-	-	-	-
Carya ovata									
	Overstory	-	-	-	-	-	-	-	A
	Undersory	-	C	-	-	-	-	-	A
	Edge	U	S	-	S	-	-	-	-
Cornus racemosa									

Tall shrub	-	-	-	-	-	D	-	-
Low shrub	A	C	-	-	D	D	-	-
Ground	-	-	-	-	-	A	-	-
Edge	-	-	-	S	-	A	-	-
Robinia pseudoacacia								
Tall shrub	-	-	-	-	-	-	-	S
Edge	-	-	LA	-	-	-	-	U
Juglans nigra								
Undersory	-	-	-	-	-	-	-	A
Edge	-	-	-	-	-	-	C	U
Fraxinus americana								
Undersory	-	-	-	-	-	-	U	-
Edge	-	-	-	S	-	-	-	-
Ulmus americana								
Undersory	-	-	-	S	S	-	-	-
Low shrub	LC	-	-	-	-	-	-	-
Edge	U	S	-	-	-	S	-	-
Pinus sylvestris								
Tall shrub	-	-	U	-	-	-	-	-
Pinus resinosa								

	Edge	U	-	-	-	-	-	-	-
Salix humilis									
	Tall shrub	-	-	A	-	-	-	-	-
	Low shrub	-	-	A	-	-	-	-	-
Populus alba									
	Low shrub	-	-	-	LU	-	-	-	-
Morus alba									
	Undersory	-	-	-	-	-	LU	-	-
Malus fusca									
	Low shrub	-	-	-	S	-	-	-	-
Malus spectabilis									
	Undersory	-	-	-	-	-	LC	-	-
Malus pumila									
	Edge	-	U	-	-	-	-	-	-
Salix exigua									
	Tall shrub	-	-	-	-	-	-	A	-
Liriodendron tulipifera									
	Undersory	-	-	-	-	-	-	U	-
	Edge	-	-	-	-	-	-	U	-
Juniperus virginiana									

	Edge	-	-	LA	-	-	-	-	-
Sassafras albidum									
	Edge	S	-	-	-	-	S	-	-
Thuja occidentalis									
	Edge	LC	-	-	-	-	-	-	-
Crataegus sp.									
	Edge	-	-	-	-	-	-	-	S
Ampelopsis glandulosa									
	Edge	-	-	-	-	-	-	-	S
Phytolacca americana									
	Tall shrub	S	-	-	-	-	-	-	-
Rhamnus frangula									
	Undersory	-	-	-	-	-	-	-	A
	Tall shrub	U	-	A	-	-	-	A	-
	Low shrub	C	-	A	A	C	-	-	-
	Ground	-	-	-	-	-	U	-	-
	Edge	-	-	-	-	-	C	-	-
Rhamnus cathartica									
	Undersory	-	-	-	-	-	-	-	U
	Low shrub	-	U	-	-	-	-	-	-

	Edge	-	D	A	-	D	-	-	A
Rhus glabra									
	Tall shrub	-	U	-	-	-	-	-	-
	Low shrub	LU	-	-	-	-	-	-	-
Rhus typhina									
	Tall shrub	-	-	-	-	-	-	-	A
	Low shrub	C	-	-	-	-	-	-	-
	Edge	LA	S	-	-	-	-	-	-
Syringa vulgaris									
	Edge	-	A	-	-	-	-	-	-
Eleagnus umbellata									
	Tall shrub	-	S	D	D	-	-	-	-
	Low shrub	-	-	-	D	-	LU	-	LU
	Edge	-	-	LA	LA	-	-	-	-
Rosa multiflora									
	Ground	-	-	-	S	-	-	-	-
Lonicera maackii									
	Edge	-	A	-	-	-	-	-	-
Rubus allegheniensis									
	Tall shrub	-	-	-	C	-	-	-	-

	Low shrub	-	-	-	A	-	-	-	-
	Ground	-	-	-	C	-	-	-	A
Rubus occidentalis									
	Low shrub	-	-	-	-	-	LA	-	-
	Ground	C	A	S	-	A	-	LU	A
Andropogon gerardii									
	Ground	A	A	A	D	-	A	-	A
Helianthus divaricatus									
	Ground	LA	LA	A	-	-	-	-	-
Heliopsis helianthoides									
	Ground	S	-	S	-	-	LU	-	LU
Sorghastrum nutans									
	Ground	LA	LC	-	-	-	C	-	-
Daucus carota									
	Ground	A	A	LA	A	-	A	A	C
Rumex crispus									
	Ground	S	LC	-	-	-	-	-	-
Toxicodendron radicans									
	Ground	U	S	-	-	-	-	-	U
Parthenocissus quinquefolia									

	Ground	LA	LU	-	-	-	-	-	LU
Centaurea stoebe									
	Ground	LA	LC	-	-	-	A	-	-
Solidago juncea									
	Ground	A	LA	A	A	U	A	LU	C
Solidago speciosa									
	Ground	A	A	-	-	-	-	-	C
Solidago canadensis									
	Ground	A	C	-	S	D	A	A	A
Solidago rigida									
	Ground	C	U	-	C	-	A	-	-
Solidago rugosa									
	Ground	LU	-	-	-	-	-	-	-
Dactylis glomerata									
	Ground	LC	LU	-	LU	-	-	-	-
Monarda fistulosa									
	Ground	C	A	U	S	-	S	-	C
Euphorbia corrollata									
	Ground	A	C	S	LU	-	-	-	LA
Desmodium canadense									

	Ground	-	-	A	-	-	LU	-	S
Desmodium illinoense									
	Ground	C	A	-	-	-	-	-	-
Achillea millefolium									
	Ground	A	C	-	S	-	A	-	A
Symphyotrichum ericoides									
	Ground	C	-	-	-	-	-	-	-
Symphyotrichum laeve									
	Ground	-	-	-	S	-	-	-	-
Symphyotrichum novae-angliae									
	Ground	-	-	S	-	-	-	-	-
Symphyotrichum urophyllum									
	Ground	-	-	-	-	-	LA	-	LU
Silphium terebinthinaceum									
	Ground	S	-	C	LU	-	-	-	-
Rudbeckia hirta									
	Ground	C	C	S	U	-	C	-	LC
Erigeron annuus									
	Ground	U	C	U	LC	U	C	-	U
Vernonia missurica									

	Ground	LC	U	-	-	-	-	LC	S
Vernonia sp.									
	Ground	-	-	-	LU	-	-	-	-
Apocynum cannabinum									
	Ground	S	S	C	-	-	S	-	C
Ratibida pinnata									
	Ground	C	C	S	C	-	C	-	C
Potentilla simplex									
	Ground	S	-	-	-	-	U	-	-
Vitis sp.									
	Ground	LC	U	S	LU	-	S	U	U
Cichorium intybus									
	Ground	S	U	-	S	-	-	-	-
Phleum pratense									
	Ground	LA	-	-	-	-	-	-	-
Panicum virgatum									
	Ground	S	LU	S	LU	-	-	-	-
Verbena urticifolia									
	Ground	LA	-	-	-	LU	-	LA	A
Verbena hastata									

	Ground	-	LU	-	-	-	-	-	-
Juncus tenuis									
	Ground	LA	-	-	-	-	-	LA	-
Juncus torreyi									
	Ground	-	-	LA	-	-	-	-	-
Asclepias syriaca									
	Ground	S	LU	-	-	-	S	-	-
Asclepias tuberosa									
	Ground	-	U	S	S	-	-	-	-
Agrostis gigantea									
	Ground	LU	LA	LC	-	-	-	-	-
Lespedeza capitata									
	Ground	LU	-	-	-	-	-	-	C
Elymus repens									
	Ground	LC	C	-	-	-	-	-	-
Elymus hystrix									
	Ground	-	LU	-	-	U	-	-	LC
Elymus villosus									
	Ground	-	-	-	-	S	-	-	-
Leonurus cardiaca									

	Ground	S	-	-	-	-	-	-	-
Prunella vulgaris									
	Ground	LA	-	-	-	-	-	-	-
Hackelia virginiana									
	Ground	LU	U	-	-	-	-	-	A
Cirsium vulgare									
	Ground	LC	U	-	-	U	A	S	-
Cirsium discolor									
	Ground	-	-	-	-	-	-	-	U
Fragaria vesca									
	Ground	U	-	-	-	-	C	-	-
Teucrium scorodonia									
	Ground	LU	-	-	-	-	-	-	-
Ambrosia trifida									
	Ground	LU	-	-	-	-	-	-	-
Allium cernuum									
	Ground	U	LU	-	-	-	-	-	LU
Bromus inermis									
	Ground	-	LA	-	-	-	-	-	-
Bromus pubescens									

Ground	-	-	-	-	S	-	-	-
Lepidium campestre								
Ground	-	LU	-	-	-	-	-	-
Pycnanthemum virginianum								
Ground	-	-	A	A	-	A	A	-
Echinacea angustifolia								
Ground	-	LA	-	-	-	-	-	-
Conyza canadensis								
Ground	-	C	-	-	-	-	-	-
Oenothera sp.								
Ground	-	U	S	-	-	S	U	U
Penstemon digitalis								
Ground	-	-	S	S	-	-	-	S
Bouteloua curtipendula								
Ground	-	LA	-	-	-	-	-	-
Liatris aspera								
Ground	-	LU	-	-	-	-	-	-
Liatris scariosa								
Ground	-	-	-	LC	-	-	-	-
Verbascum thapsus								

	Ground	-	S	-	-	-	U	-	-
Schizachyrium scoparium									
	Ground	-	U	LA	A	-	-	-	-
Linaria vulgaris									
	Ground	-	LU	-	-	-	-	-	LU
Cyperus odoratus									
	Ground	-	S	-	-	-	-	-	-
Asparagus oficinalis									
	Ground	-	S	-	-	-	-	-	-
Coreopsis lanceolata									
	Ground	-	-	C	-	-	-	-	-
Scirpus pendulus									
	Ground	-	-	C	A	-	-	-	-
Scirpus atrovirens									
	Ground	-	-	-	-	-	-	LU	-
Lythrum salicaria									
	Ground	-	-	U	-	-	-	-	-
Calamagrostis candensis									
	Ground	-	C	-	-	-	-	-	-
Equisetum sp.									

Ground	-	-	C	LU	-	-	-	-
Anemone virginiana								
Ground	-	-	S	-	-	-	-	-
Eupatorium perfoliatum								
Ground	-	-	LA	S	-	-	-	-
Hypericum prolificum								
Ground	-	-	S	-	-	-	-	-
Melilotus albus								
Ground	-	-	S	-	U	-	-	-
Sporobolus vaginiflorus								
Ground	-	-	-	LA	-	-	-	-
Carex vulpinoidea								
Ground	-	-	-	LC	-	-	-	-
Carex stricta								
Ground	-	-	-	-	A	-	A	-
Geum canadense								
Ground	-	-	-	-	S	-	-	LA
Celastrus orbiculatus								
Ground	-	-	-	-	S	-	-	-
Celastrus scandens								

	Ground	-	LA	-	-	-	-	-	A
Spartina patens									
	Ground	-	-	-	-	-	LA	-	-
Eutrochium maculatum									
	Ground	-	-	-	-	-	-	A	LA
Cicuta maculata									
	Ground	-	-	-	-	-	-	C	-
Lycopus americanus									
	Ground	-	-	-	-	-	-	S	-
Calystegia sepium									
	Ground	-	-	-	-	-	-	LA	-
Impatiens capensis									
	Ground	-	-	-	-	-	-	S	-
Securigaria varia									
	Ground	-	-	-	-	-	-	-	LU
Symphorycarpos albus									
	Ground	-	-	-	-	-	-	-	LU
Pteridium acquilinum									
	Ground	-	-	-	-	-	-	-	LA