30 October 2015

Rob Keys
Cornerstone University
1001 E. Beltline Ave. NE
Grand Rapids, MI 49525
616.949.5300 ext. 1306
rob.keys@cornerstone.edu

The influence of habitat and landscape associations on breeding birds in managed grasslands of Southwest Michigan

WHITNEY K. LAMBERT, Cornerstone University, 1001 E. Beltline, NE, Grand Rapids, MI 49525, USA

DARIEN N. LOZON, Cornerstone University, 1001 E. Beltline, NE, Grand Rapids, MI 49525, USA

ROBERT S. KEYS, Cornerstone University, 1001 E. Beltline, NE, Grand Rapids, MI 49525, USA

ABSTRACT Grassland birds are nationally experiencing a significant population decline primarily due to conversion of habitat to agricultural and industrial uses. We conducted 7 weeks of point count surveys, vegetation surveys, and surrounding landscape analyses to determine what habitat characteristics, landscape features, and management practices act as attractors or detriments to grassland birds. Four management types were analyzed for their effect on grassland bird diversity: restored prairie, mixed management, Conservation Reserve Program (CRP), and mowed airport fields. We specifically surveyed the presence of Henslow's sparrows (*Ammodramus henslowii*), grasshopper sparrows (*Ammodramus savannarum*), bobolinks (*Dolichonyx oryzivorus*), song sparrows (*Melospiza melodia*), field sparrows (*Spizella pusilla*), eastern meadowlarks (*Sturnella magna*), and savannah sparrows (*Passerculus sandwichensis*). Mowed airport fields had the greatest mean diversity (H' = 1.436) with CRP fields the second greatest (H' = 0.474). Restored prairies and mixed management sites had the smallest mean diversity (H' = 0.068 and 0, respectively). Among the dominant vegetation types found, fescue grasses (*Festuca spp.*) had the highest correlation with diversity at a magnitude 78.4% greater than goldenrods (*Solidago spp.*) and 123.8% greater than big bluestem (*Andropogon gerardi*). Edge effect was an important indicator of species found during point counts. Our models showed urban areas have a high correlation with diversity, including both fields surrounded by urban areas (1-km radius from center of each field) and fields directly adjacent to urban areas (R^2=0.868 and R^2=0.699, respectively).

KEY WORDS: airport, conservation, diversity, Grasshopper sparrow, grassland birds, Henslow's sparrow, landscape, management, patch size, point counts, Robel pole, vegetation.

INTRODUCTION

Conservation efforts in grassland habitat have become a high priority due to the significant decreases of grassland birds over the past thirty years (Norment 2002, Herkert *et al.* 2003, Ribic and Sample 2001). Nearly 80% of grasslands in the United States have been converted to other uses such as urban development and agriculture with natural plant succession acting as a detriment to grassland habitats (Rahmig et al. 2009, Norment 2002). Available grassland habitats and specific patch sizes are influential to grassland bird species, as many species are area-sensitive (Fletcher and Koford 2002, Norment 2002).

Understanding area sensitivity and its driving processes are important aspects of conservation for grassland birds because both species density and frequency in a patch are closely linked. Area sensitivity is the positive correlation of a species' occurrence relative to patch size (Ribic *et al*. 2009). The ability to determine area sensitivity could be complicated by the difference between how birds perceive and researchers define the size of a field or grassland. Although researchers often use field boundaries to define habitats, these boundaries may not be criteria for a grassland bird when perceiving habitat size. Instead, the bird may determine boundaries based on cover and configuration of habitats. This may account for the variability of data seen in studies regarding area sensitivity (Ribic and Sample 2001).

Conservation of grassland bird communities is largely dependent on habitat management of public and private lands (Ribic and Sample 2001). A large percentage of land is privately owned in the eastern U. S., so several federal and state conservation programs and initiatives focus on habitat restoration on private land (Shake et al. 2012). This not only includes the size of the area these birds inhabit but the diversity of the vegetation therein. Fletcher and Koford (2002) noted that restoration efforts usually aim to transform an ecosystem back to its original state, but Midwestern prairie restoration efforts have often planted areas with only a few species of grasses and forbs. These are most often applied to single crop fields, so vegetation is restored as discrete habitat patches (Shake et al. 2012). The land is considered restored, but some of the grasses are not endemic to the area and the land does not achieve the original diversity of grasses. Although some ecological functions are restored, diversity and structure of native prairies are often lacking. Since the composition of the restored grassland plays a significant role in determining what species are attracted, this may explain why some restored grasslands achieve high species diversity while others do not.

Stabilization of 24 obligate breeding bird species began to occur in the early 1990s due to conservation investments; however, there has still been a "steady and precipitous decline" of eastern grassland birds (NABCI 2014). Grasshopper sparrows (declining) and Henslow's sparrows (IUCN Red List 2012 - Near Threatened, MNRI 2007 - Endangered) are two species whose populations continue to feel the impact of decline. This is largely a result of changing farming practices (NABCI 2014), including early-season mowing of land, which is highly responsible for causing major grasshopper sparrow nest failure (Bollinger et al. 1990). Early-season mowing also reduces the local breeding densities of Henslow's sparrows as they prefer tall and dense vegetation (Herkert et al. 2002). Commercial lands, such as at airports, have often been successful in providing suitable nesting habitat because they do not mow until the end of the breeding season, except for within 10 m of the runways (Melvin 1994). Prescribed burning is another technique used to help maintain habitat. The grasshopper sparrow tends to prefer tracts of land that have been recently burned, inhabiting the land at least one year after the fire (Vickery 1996). Burning generally reduces the breeding densities of Henslow's as they avoid recently burned sites, but rotational burning can be beneficial. The natural succession of vegetation from suppressing the fire is also detrimental to these birds (Herkert et al. 2002).

Henslow's and grasshopper sparrows are both sensitive to patch size and the diversity of vegetation in grasslands. The grasshopper sparrow prefers moderately open grasslands and prairies with patchy bare ground. Vegetation components vary based on the ecosystem, but birds in the Midwest tend to select sparser vegetation and avoid grasslands with extensive shrub cover. In Michigan, they prefer fire-induced grassland glades (Vickery 1996). Comparatively, the specific requirements of Henslow's sparrow habitat are not as well understood (Herkert et al. 2002); however, important components such as thicker vegetation, increased litter density, and field size must be taken into consideration when managing Henslow's sparrow populations (Vickery 1996, Herkert et al. 2002). The influence field size has on these birds within the grassland could be explained through the generally small territory size they protect (Herkert 1994).

In the late summer and fall of 2013, the Pierce Cedar Creek Institute (the Institute) removed fencerow trees between their prairies in order to enlarge the contiguous prairie environments in order to attract grassland birds. The two target species of this prairie modification were the state endangered and federal "species of concern" Henslow's sparrow and the declining grasshopper sparrow (Howell 2015; IUCN 2012). There was only one yearly sighting of Henslow's sparrows over the past five years and no records of grasshopper sparrows in the Institute prairie grasslands (eBird 2014). In contrast, three other regional grassland/prairie sites (Audubon Otis Farm Sanctuary, and Gerald R. Ford International Airport) showed breeding population combinations of Henslow's, grasshopper sparrows, and savannah sparrows, along with bobolink and eastern meadowlarks (eBird 2014).

Over 33 ha of fallow farm field at the Institute has been converted into native tall and short grass prairie using Michigan genotype seed when possible and introducing species historically found in Barry County. The actual plant species, density, and litter of the grass in this prairie were unknown and could play a significant role in bird habitat. Prescribed burning is used to manage the prairie at the Institute to help native species flourish by reducing non-native plant competition. It also aids in preventing shrubs and trees from encroaching the edge and fertilizes the soil with the resulting ash (Howell 2015). Despite the fire management taking place at the Institute, neither grasshopper nor Henslow's sparrow populations seemed to be flourishing in the given area as expected. Our objectives were to determine species richness and density of these grassland birds in relationship to various managed grassland habitats and their surrounding landscapes in Southwest Michigan. While our measures included several grassland birds, our emphasis was on grasshopper and Henslow's sparrows.

METHODS

Study Sites

Using breeding bird sightings from 2010 - 2014 in Kent and Barry Counties, Michigan, USA, we identified three sites having multiple sightings of our target grassland species (eBird 2014). The Institute was our site of concern, given the large grasslands on the site and seemingly small numbers of grassland birds compared to the area of grassland (3 grasslands; 31.82 ha). Our second site was a managed prairie at the Michigan Audubon Sanctuary at Otis Farm (1 grassland; 16 km from the Institute; 13.5 ha). Surveys of the site indicated multiple yearly sightings of bobolink, eastern meadowlark, field sparrow, Henslow's sparrow, and savannah sparrow. Our third site was in southern Kent County at the southern end of the Gerald R. Ford International Airport (GRR; 2 grasslands; 56 km from the Institute; 76.30 ha). Records indicated this site had the highest richness of grassland birds in the two counties, with numerous yearly sightings of bobolink, eastern meadowlark, field sparrow, grasshopper sparrow, Henslow's sparrow, and savannah sparrow. Two other sites were added to our surveys after consulting local landowners and conducting pre-survey on-road point counts. Our fourth site was a Conservation Reserve Program hayfield 1.3 km east of the Institute (2 grasslands; 68.2 ha). Our final site was a managed prairie 0.50 km from the Institute with areas of recent prescribed burns, active hayfield, and fallow fields (2 grasslands; 15.18 ha). Each of the five sites varied in grassland size, surrounding landscape mosaic, and management (prescribed fire management, annual mechanical mowing, and unmanaged fallow) (Table 1).

Table 1. Different management types represented in study field sites in Kent and Barry Counties, Michigan, USA.

	Management	# of Fields	Total Area (ha)
PCCI & Otis Farm	Restored Prairie[1]	4	45.32
Soya Farm	Conservation Reserve Program[2]	2	68.20
Jones Farm	Mixed Management[3]	2	15.18
G.R. Ford Airport	Mowed[4]	2	76.30

[1]Scheduled prescribed burning [2]Land contract for 10-15yrs, no agricultural planting, burned at same time as the Institute [3]Active hayfield, burning, and no management [4]Mowed on annual basis

Bird Survey

We surveyed each site 6 times during the breeding season, 20 May – 26 June 2015 using a 10-minute, 50 m fixed point count method (Ralph et al. 1993). Point count trainings were used to establish distance accuracy for point counts prior to field surveying. Survey points were distributed 100 m apart to provide separation between target species, given territory sizes of Henslow's sparrows (0.324 ha) and grasshopper (1.4 ha) sparrows. We conducted surveys between sunrise and four hours after sunrise when breeding birds are most active. We recorded all target species seen or heard, along with sex of individual (if identifiable). Target species identified while travelling to point sites or outside the area being surveyed were also noted. Points for each survey were determined using ArcGIS. Grids were layered over a digital orthographic projection of each site, with each grid measuring 100 x 100 m. Each grassland cell was considered a potential point count sampling unit. Sites were stratified into sections of potential sampling units based on the sizes of the fields. One randomly selected sampling unit from each stratified section was then sampled during each survey period, with the exception of GRR having two units sampled. This allowed a proportional number of sampling units to be sampled at GRR in relation to its size. Random selection of sampling units ensured the entire range of variability within each site was sampled. Sampling units were not repeated over the 6 survey periods to ensure the most complete sampling of each site (Fletcher and Koford 2002). Point count observations were inputted into ArcGIS 10.2.2 (ESRI 2014) and analyzed with point count buffers based on territory size to avoid pseudoreplication. Territory buffers that overlapped at least 50% between different point count sites were considered one individual bird.

Habitat Measurements

Through visual analysis, dominant vegetation type and litter depth were determined at point-count areas using a 0.25 m^2 quadrat frame (Rahmig et al. 2009). We designated four vegetative plots within each point site: one at the center of the point-count area and three located at 0^o, 120^o, and 240^o along the 50 m radius point count area, with a distance of 30 m between each point (Fletcher and Koford 2002). All dominant vegetation species were then identified in each quadrat. Litter depth (cm) was measured in each vegetative plot by taking the average of the litter depths in each corner of the 0.25 m^2 frame (Rahmig et al. 2009). Vertical density was measured using visual obstruction with a Robel pole (Fletcher and Koford 2002). Determination of density was visually calculated in each of the four cardinal directions through a sight pole 7 m from the Robel pole (Fletcher and Koford 2002). This visual analysis was done by the same person to ensure consistency in measurements. These measurements were obtained while determining dominant vegetation.

Landscape Measurements

We calculated landscape composition and edge-density metrics using 2014 national land cover data, provided by the National Geospatial Database (USGS 2014). Land use patterns were quantified using ArcGIS within a 1 km radius from the center of each site (Fletcher and Koford 2002). Landscape composition was analyzed by converting total land use to percentage of site covered. Edge density was calculated as the ratio of perimeter (m) to the hectares of grassland (Fletcher and Koford 2002). We compared the percent landscape cover and edge density of the five study sites based on five compositional metrics: perennial grasslands, woodlands, wetlands/open water, road/urban/developed/barren, and cultivated crop areas (Blair 1996).

Statistical Analysis

Statistical analyses were modeled after similar studies on grassland birds conducted by Fletcher and Koford (2002) and Rahmig et al. (2009). Species richness was defined as the number of grassland breeding species observed (Fletcher and Koford 2002). We used multiple linear regression to determine the most parsimonious model to explain habitat and/or habitat + landscape relationships using Shannon diversity indices of grassland birds (H') as the response variable for each model. We ran models using all habitat and landscape variables, testing the best habitat model against the best habitat + landscape model to determine the best model selection to explain the differences in bird density between sites (Fletcher and Koford 2002). Best model selection was determined using linear regression of bird diversity as a response variable with best habitat and habitat + landscape models (Fletcher and Koford 2002). We used one-way between subject ANOVA models to test between management types and vegetation types and how they potentially affected bird diversity. Post-hoc Tukey analyses were used to determine significance between variables.

RESULTS

Mean number of grassland birds per point surveyed showed the most grassland birds at mowed and CRP management sites. This was determined after removing duplicate individuals to avoid pseudoreplication from bird territory size. Mean richness indicated the greatest number of grassland bird species at mowed and CRP sites (Table 1).

Table 2. Mean number of grassland birds per point and species richness in four management types (Conservation Reserve Program-CRP, mixed management site-MMS, mowed-MOW, and restored prairie site-RPS), Kent and Barry Counties, Michigan, USA. Maximum species richness is 6.

	PoS[1]	B/P[2]	R (SE)[3]
CRP	50	2.60	3.5 (0.707)
MMS	13	0.46	0.5 (0.707)
MOW	47	4.02	5 (0.000)
RPS	52	0.50	1.25 (0.500)

[1]Number of points surveyed [2]Birds per point [3]Mean species richness with standard error

Mowed and CRP management types also showed significant impact on grassland bird diversity based on our ANOVA model (Fig. 1). There was a significant effect of management type on diversity at the $p < 0.05$ level for the four conditions ($F(3,6) = 34.165$, $p = 0.0004$). A post hoc

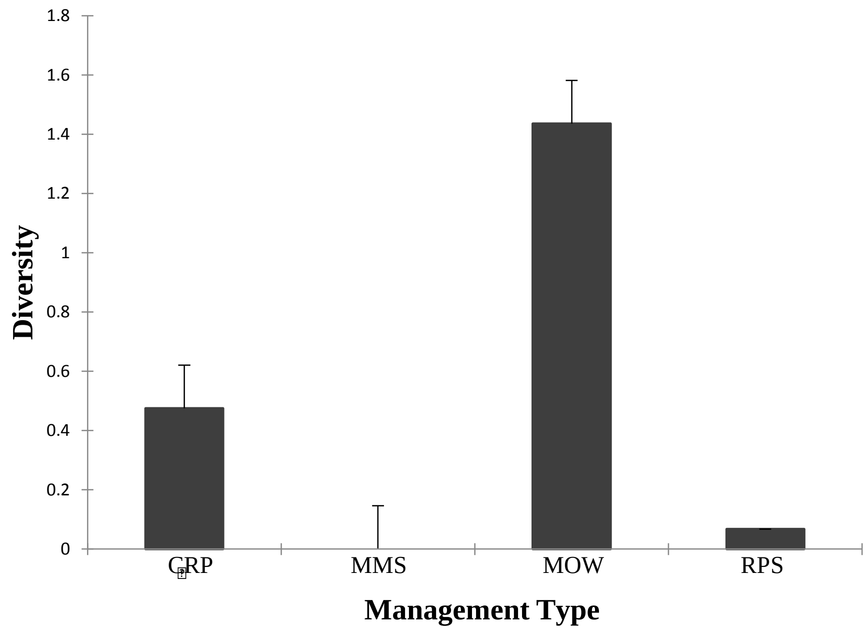

Figure 1. ANOVA for quantifying bird diversity in four management types (Conservation Reserve Program-CRP, mixed management site-MMS, mowed-MOW, and restored prairie site-RPS), Kent and Barry Counties, Michigan, USA. The magnitude of MOW fields was 181.9% greater than RPS. The magnitude of CRP fields was 149.8% greater than RPS.

Tukey test showed the mean diversity in mowed management type (M = 1.436, SE = 0.119) was significantly different than mixed management (M = 0.000, SE = 0.119), conservation reserve program (M = 0.474, SE = 0.119), and restored prairie management (M = 0.068, SE = 0.084). Magnitude of diversity was 181.9% greater at mowed sites and 149.8% greater at CRP sites than restored prairie sites.

Vegetative analysis of litter depth and vertical density did not show differences in the effects on grassland bird diversity. A one-way between subjects ANOVA comparing the effect of dominant vegetation on grassland bird diversity in fescue, big bluestem, and goldenrod dominant fields showed a significant effect of dominant vegetation on diversity at the $p < 0.05$ level for the three conditions ($F(2,81) = 71.877$, $p < 0.0001$) (Fig. 2).

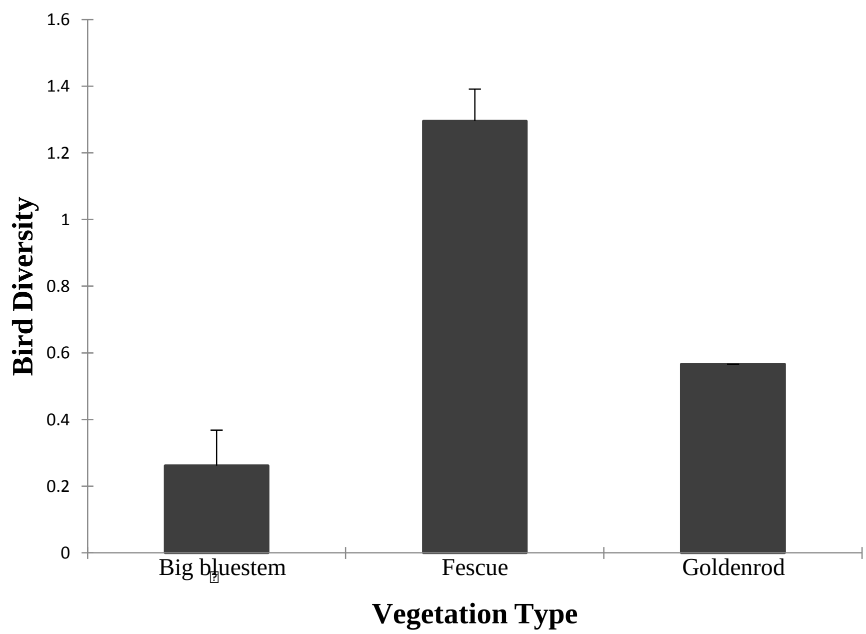

Figure 2. Mean grassland bird diversity by dominant vegetation type, Kent and Barry Counties, Michigan, USA. Magnitude of fescue was 123.8% greater than big bluestem and 78.4% greater than goldenrod.

A post hoc Tukey test showed the mean grassland bird diversity in fescue (M = 1.295, SE = 0.056) had a magnitude 123.8% greater than big bluestem (M = 0.261, SE = 0.072) and 78.4% greater than goldenrod (M = 0.566, SE = 0.079).

Differences in the effect of adjacent and surrounding landscape types showed that urban edges had the most impact on grassland bird diversity. A simple linear regression was calculated to predict diversity based on road-urban edge and a significant regression equation was found (F (1,8) = 18.618, $p > 0.003$), with an R^2 of 0.699 (Fig. 3). A significant regression for grassland bird diversity based on surrounding urban landscapes present was also found (F (1, 9) = 91.680, $p < 0.0001$), with an R^2 of 0.868 (Fig. 4).

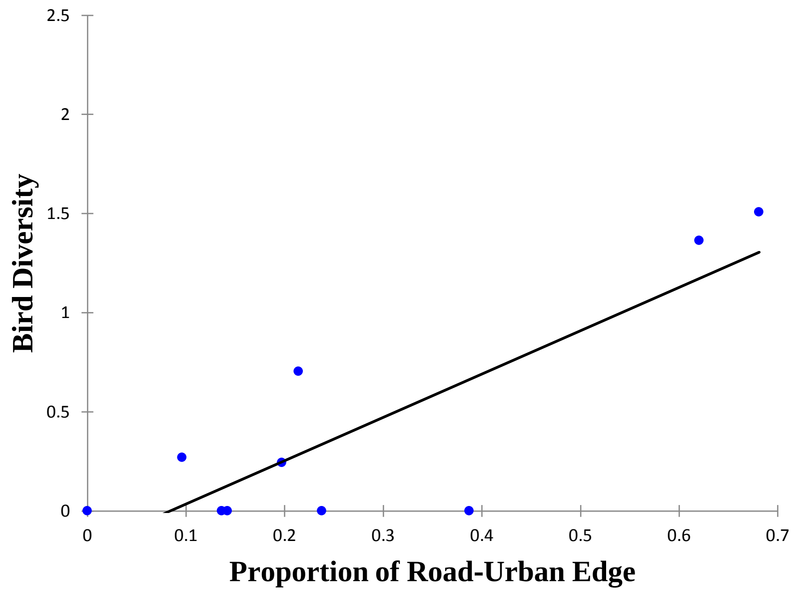

Figure 3. Linear regression of grassland bird diversity compared to road-urban edge (R^2 = 0.699) in four management types, Kent and Barry Counties, Michigan, USA.

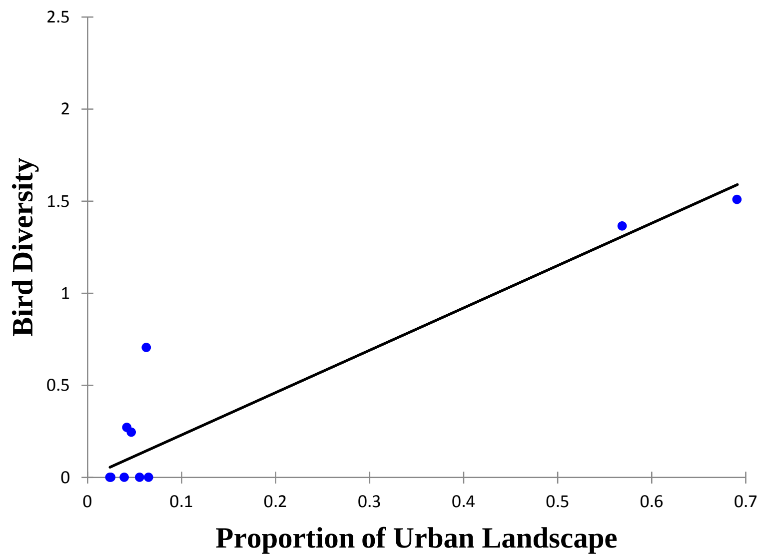

Figure 4. Linear regression of grassland bird diversity compared to surrounding urban landscapes (R^2 = 0.868) in four management types, Kent and Barry Counties, Michigan, USA.

DISCUSSION

Management type has been shown to have significant influence on birds observed at field. The mowed and CRP field sites showed the greatest mean grassland bird richness when compared to mixed management and restored prairie fields. Mean number of grassland birds per point surveyed were also significantly greater at mowed and CRP fields. Bird diversity was 181.9% greater at mowed sites than restored prairie sites (Fig. 1). Along with diversity, overall species richness was greater in mowed fields than in any other management type surveyed (Table 2). The combination of higher mean birds per point, increased species richness, and large magnitude difference, shows that mowing was the most productive management type correlated with grassland bird diversity.

Vegetative composition and structure are important, as spatial heterogeneity provides a greater breadth of habitat and increases the variety of grassland bird communities (Fuhlendorf *et al.* 2006). The vegetative composition at mowed and CRP fields could be an important influencing factor. Big bluestem was the dominant vegetation type in restored prairie sites where few birds were present. However, mowed fields had a variety of vegetation with the most dominant type being *Fescue spp*., which was highly correlated with bird diversity. Mowing has been found to produce the most noticeable changes in vegetation by reducing tall shrub cover. This causes mowed areas to have greater grass cover, litter depth, and shorter shrubs (Zuckerberg and Vickery 2006). Therefore, the increased grass cover and litter depth at the mowed and CRP sites may play a role in attracting grassland birds.

Another influential variable within management type is surrounding landscape type. Our models showed a high correlation of bird diversity with urban areas directly adjacent to the fields (Fig. 3). Urban development often produces more edge habitat, so the changes brought by urbanization facilitate different responses by individual species (Blair 1996). A field observation while conducting point counts was grasshopper sparrow preference for the fence surrounding the airport runways, which may be an indication that edge promotes diversity. An important note to make is how edge influences area sensitivity. Several grassland birds are known to be area sensitive, so they are negatively affected by habitat fragmentation. Increased density and species diversity are often found in large rather than small prairie fragments (Winter and Faaborg 1999). However, the way breeding species use patches may be modified by landscape context, which affects how patterns of area sensitivity could be produced in the breeding system (Ribic et al. 2009).

Along with edge effects, patch size can make a lasting impact on the diversity found within the fields. Among all of our fields surveyed, grasshopper sparrows were found only at GRR. This may be explained through their high area sensitivity, leading them to need greater area in order to successfully inhabit a grassland (Davis 2004). In this case, grasshopper sparrows seemed to favor the 118 ha field at GRR rather than the fragmented 2-3 ha fields at the Institute.

Urban areas surrounding the fields also showed a high correlation with grassland bird diversity (Fig. 4). It is important to note that there were multiple variations of urban landscape types (e.g. open space and low, medium, and high intensities). Many of these were found near the mowed fields because the airport had urban landscape located on their property. It is unknown whether our data was skewed from this urban influence.

Despite the removal of hedgerows at the Institute, the results are understandable given the surrounding habitat. Grassland species often avoid small fields enclosed by hedgerows or tree lines. Continuous patches of arable land were found to increase local densities. Encroachment of trees and shrubs into open habitats is a type of fragmentation that can be detrimental to grassland specific birds (Moreira et al. 2005). Presence of woody vegetation (even solitary trees) in the surrounding landscape appears to be associated with lower occurrences and densities of grassland birds in the focal patch (Ribic et al. 2009). Traditional grassland management follows models of intermediate disturbance with the objective of moderate, uniform disturbance resulting in homogenous vegetation structure (Fuhlendorf et al. 2006). Although the Institute appears to follow this traditional management, the dominance of big bluestem in the restored prairies may explain the absence of birds.

Fire-grazing interactions provides an interesting alternative management strategy that should be mentioned because it is found to increase grassland bird and field vegetation heterogeneity. Our results showed that mowing was correlated with higher grassland bird diversity. The impact of grazing regimes on birds can be compared to that of mowing. Although mowing differs in that it is non-selective, both alter predation pressure and abundance of food along with the availability of preferred vegetation types (Fuhlendorf *et al.* 2006, Vickery *et al.* 2001). Regimes that most closely mimic evolutionary regimes are expected to have a better response to species composition and diversity. Patch-level spatial heterogeneity can be increased by applying fire to discrete patches and allowing grazing animals to select among the burned and unburned patches. This mimics the fire-grazing interactions that existed in the North American Great Plains before European settlement occurred (Fuhlendorf *et al.* 2006).

Further research in nest success and persistent grasses would be helpful for conservation and better understanding the preferences of declining grassland bird populations. Nest success would help identify how habitat and landscape structure affect the breeding populations and their demographic parameters (Fletcher and Koford 2002).

ACKNOWLEDGEMENTS

We would like to thank the Willard G. Pierce and Jesse M. Pierce Foundation, Pierce Cedar Creek Institute, and Cornerstone University for funding our project. Michigan Audubon Society provided us with permissions to access Otis Farm in Hastings, MI, along with Joan Soya and her family as well as Alice Jones with permissions to conduct surveys on their properties. We would also like to thank Joel Burgess and the Kent County Department of Aeronautics at Gerald R. Ford International Airport for access to the fields surrounding their runways.

LITERATURE CITED

Ammodramus henslowii. 2012. BirdLife International. International Union for Conservation of Nature [IUCN]. [accessed 2015 Oct 30]. http://www.iucnredlist.org/details/22721138/0

Blair RB. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6:506–519.

Bollinger EK, Bollinger PB, Gavin TA. 1990. Effects of hay-cropping on Eastern populations of the Bobolink. Wildlife Society Bulletin (1973-2006) 18:142–150.

Davis SK. 2004. Area sensitivity in grassland passerines: effects of patch size, patch shape, and vegetation structure on bird abundance and occurrence in Southern Saskatchewan. The Auk 121:1130–1145.

eBird. 2014. EBD_relAug-2014. Cornell Lab of Ornithology, Ithaca, New York.

Fletcher RJ, Koford RR. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands. Journal of Wildlife Management 66:1011–1022.

Fuhlendorf SD, Harrell WC, Engle DM, Hamilton RG, Davis CA, Leslie DM. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 16:1706–1716.

Herkert JR. 1994. The effects of habitat fragmentation on Midwestern grassland bird communities. Ecological Applications 4:461–471.

Herkert JR, Reinking DL, Wiedenfeld DA, Winter M, Zimmerman JL, Jensen WE, Finck EJ, Koford RR, Wolfe DH, Sherrod SK, et al. 2003. Effects of prairie fragmentation on the nest success of breeding birds in the midcontinental United States. Conservation Biology 17:587–594.

Herkert JR, Sample DW, Warner RE. 1996. Management of Midwestern grassland landscapes for the conservation of migratory birds.

Herkert JR, Vickery PD, Kroodsma DE. 2002. Henslow's Sparrow (Ammodramus henslowii). Poole A, Gill F, editors. The Birds of North America Online. [accessed 2015 Jan 15]. http://bna.birds.cornell.edu/bna/species/672/articles/habitat

Howell J. 2015. Current prairie management practices at Pierce Cedar Creek Institute, Barry County, Michigan.

Melvin SM. 1994. Military bases provide habitat for rare grassland birds. Nat Herit. News Mass Div Fish Wildl 4:3.

Moreira F, Beja P, Morgado R, Reino L, Gordinho L, Delgado A, Borralho R. 2005. Effects of field management and landscape context on grassland wintering birds in Southern Portugal. Agriculture, Ecosystems and Environment 109:59–74.

Norment C. 2002. On grassland bird conservation in the northeast. The Auk 119:271–279.

North American Bird Conservation Initiative. 2014. The State of the Birds 2014 Report. Washington, DC: U.S. Department of Interior.

Rahmig CJ, Jensen WE, With KA. 2009. Grassland bird responses to land management in the largest remaining tallgrass prairie. Conservation Biology 23:420–432.

Ralph CJ, Geupel GR, Pyle P, Martin TE, DeSante DF. 1993. Handbook of field methods for monitoring landbirds. Lincoln, NE: USDA Forest Service, University of Nebraska - Lincoln.

Ribic CA, Koford RR, Herkert JR, Johnson DH, Niemuth ND, Naugle DE, Bakker KK, Sample DW, Renfrew RB. 2009. Area sensitivity in North American grassland birds: patterns and processes. The Auk 126:233–244.

Ribic CA, Sample DW. 2001. Associations of grassland birds with landscape factors in southern Wisconsin. The American Midland Naturalist 146:105–121.

Shake CS, Moorman CE, Riddle JD, Burchell MR. 2012. Influence of patch size and shape on occupancy by shrubland birds. The Condor 114:268–278.

U.S. Geological Survey [USGS]. 2014. National land cover data. Multi-Resolutional Land Characteristics Consortium.

Vickery JA, Tallowin JR, Feber RE, Asteraki EJ, Atkinson PW. 2001. The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. Journal of Applied Ecology 38:647–664.

Vickery PD. 1996. Grasshopper Sparrow (Ammodramus savannarum). Poole A, Gill F, editors. The Birds of North America Online. [accessed 2015 Jan 15]. http://bna.birds.cornell.edu/bna/species/239/articles/habitat

Winter M, Faaborg J. 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13:1424–1436.

Zuckerberg B, Vickery PD. 2006. Effects of mowing and burning on shrubland and grassland birds on Nantucket Island Massachusetts. The Wilson Journal of Ornithology 118:353–363.