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Bird community response to field-level integration of prairie strips

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ABSTRACT

Grassland birds are under threat worldwide due to loss of habitat to agriculture. Prairie strips are a new agricultural conservation practice composed of linear strips of reconstructed diverse, native, herbaceous, perennial vegetation designed to promote land sharing among agriculture and biodiversity, while also addressing soil and water conservation goals. We evaluated bird community response to establishment of prairie strips on commercial row-crop fields (corn [(*Zea mays*] and soybean [*Glycine max*]) in Iowa, USA compared to controls fields without prairie strips, from 2015 to 2020. We found a 2.94-fold higher density of grassland birds on fields with prairie strips compared to control fields, and a 1.87-fold higher density of birds overall. Time since prairie strip establishment was a significant predictor of grassland bird density, with significant increases between years 1 and 2 and years 3 and 4. Species with the strongest positive response to prairie strips were Red-winged Blackbird (*Agelaius phoeniceus*), Common Yellowthroat (*Geothlypis trichas*), Western Meadowlark (*Sturnella neglecta*) and two species of greatest conservation need: Dickcissel (*Spiza americana*) and Eastern Meadowlark (*Sturnella magna*). Diversity measures (e.g., Shannon's and Simpson's indices) did not differ between fields with prairie strips versus those without. Prairie strips provide quality breeding habitat for a suite of species, including grassland species and those of conservation concern. While improving several bird community measures, prairie strips do not provide habitat for area-sensitive grassland birds. Larger grassland patches are needed, potentially managed as land-sparing reserves, to achieve overall biodiversity goals in agricultural landscapes.

1. Introduction

Loss of natural areas to agriculture has long been considered the largest threat to biodiversity (Sala et al., 2000, Hoekstra et al., 2004, Green et al., 2005, Tscharntke et al., 2005). Agricultural land uses now cover 38% of the Earth's land surface, 23% of which is devoted to the monocultural production of a few commodity crops, including cereal, sugar, vegetable, tuber, oil, and fruit crops (FAO, 2023). Agricultural land uses continue to expand in area as well as intensify in management, dominated by larger fields of monocultures that support fewer natural species, in efforts to support a growing human population (Kremen and Merenlender, 2018, Ramankutty et al., 2018).

Grasslands are particularly threatened by agricultural expansion and intensification, given their climate and soils tend to be well suited for agricultural production, and thus so too are grassland obligate species (Roy et al., 2001, Bardgett et al., 2021, Douglas et al., 2023). In North America, 71.2% of all tallgrass prairie has been lost through conversion to row-crop agriculture (White et al., 2000), and only 1% of the original tallgrass prairie remains in most states and provinces (Knopf 1994, Samson and Knopf 1994). Grassland birds in North America have experienced a 53% overall decline since 1970, the steepest reduction of any bird community (Rosenberg et al., 2019).

Reserving large areas for nature – sometimes referred to as 'land sparing' — is a prominent, effective strategy in meeting conservation goals in many locations, but economically, socially, and politically challenging in agroecosystems (Chouinard et al., 2008, Fischer et al., 2008, Atwell et al., 2009). An alternative strategy of 'land-sharing' focuses on improving habitat quality of agricultural landscapes, and may

Abbreviations: AIC, Akaike's Information Criterion; CI, Confidence Interval; SGCN, Species of Greatest Conservation Need; STRIPS, Science-based Trials of Row-crops Integrated with Prairie Strips; USDA, United States Department of Agriculture.

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be a viewed more favorably by farmers and landowners than establishing extensive reserves (Atwell et al., 2009, Arbuckle, 2013, Zimmerman et al., 2019b, Bardgett et al., 2021). In row-crop production landscapes, targeting perennial cover to field margins or to small areas that are agronomically less productive for annual crops can provide considerable ecological improvements, such as water purification, hydrological regulation, pollination services, and greater resilience to climate change and extreme disturbances, while also minimizing the cost of conservation (Asbjornsen et al., 2013, Brandes et al., 2016, Zimmerman et al., 2019a, Westemeyer et al., 2023). Many bird species positively respond to small patches of perennial vegetation embedded in and around crop fields (Heath et al., 2017, de Zwaan et al., 2022, Gil-Mendoza et al., 2024), including some grassland birds (Best et al., 1995, Conover et al., 2009, Berges et al., 2010, Walk et al., 2010).

Prairie strips are linear features of reconstructed diverse, native, herbaceous, perennial vegetation that are strategically seeded and integrated within crop fields with the intent of improving conservation outcomes. They offer a new opportunity to improve biodiversity outcomes from agricultural landscapes, including birds (Schulte et al., 2016, Schulte et al., 2017). Since 2019 in the United States, croplands converted to prairie strips are eligible for enrollment in the Conservation Reserve Program offered by the United States Department of Agriculture (USDA) Farm Service Agency as a part of the Clean Lakes, Estuaries, and Rivers (CLEAR) Initiative. The new conservation practice, CP43, allows flexibility in the amount and location of reconstructed prairie vegetation on farms: prairie strips can comprise up to 25% of a field and be located within the interior, at the perimeter, in terrace channels, on areas adjacent to waterways, and in center-pivot irrigation corners (USDA 2019). Prairie strips are different than other linear conservation practices previously available through USDA, such as filter strips and contour buffers, in that participants are required to establish and maintain a mixture of diverse, native grass and forb species. Flexibility in siting the practice and its ability to address multiple conservation outcomes simultaneously is resulting in rapid and widespread adoption. As of October, 2023, there were 9162 ha of CP43 in 14 states (Fig. 1; USDA, 2023).

Prairie strips were first investigated by the STRIPS (Science-based Trials of Row-crops Integrated with Prairie Strips; www.prairiestrips.org) team based at Iowa State University, Ames, Iowa, USA. An initial catchment-scale (0.47–3.19 ha) experiment, conducted by the team at Neal Smith National Wildlife Refuge in central Iowa, indicated positive response of multiple environmental indicators at levels higher than expected given the areal extent of prairie strips (Schulte et al., 2017). In terms of bird abundance, species richness, and diversity, catchments with prairie strips had 1.53 – 2.88 times more birds, 1.53 – 2.13 times more bird species, and 1.40 – 1.98 times greater diversity compared to those entirely in row-crop production. These patterns were driven by several species of grassland and shrubland nesters — specifically Eastern Kingbird (*Tyrannus tyrannus*), American Robin (*Turdus migratorius*), and Common Yellowthroat (*Geothlypis trichas*) — which were more abundant in catchments with prairie strips (Schulte et al., 2016). State-listed species of greatest conservation need (SGCN; IDNR, 2015) found in catchments with prairie strips included Grasshopper Sparrow (*Ammodramus savannarum*), Eastern Meadowlark (*Sturnella magna*), Dickcissel (*Spiza americana*), and Field Sparrow (*Spizella pusilla*) compared to catchments that did not have prairie strips. The community of birds using prairie strips changed over time, with increases in abundance, species richness, and diversity after the establishment year. Prairie strips also reduced soil loss, nutrient loss, and greenhouse gas emissions and increased water retention and abundance and diversity of beneficial insects, including pollinators (Schulte et al., 2017). Detriments associated with prairie strips include reduced cropland area and increased operational complexity for farmers.

In this study, we extended the investigations of Schulte et al. (2016) to fields (7.7 – 93.1 ha) under commercial row-crop production. In addition to addressing a knowledge gap by assessing bird use of prairie strips within and at the scale of commercial farming operations, we assessed the influence of surrounding land use. Landscape composition is an important component of habitat for grassland birds (Winter et al., 2010, Shahan et al., 2017, de Zwaan et al., 2024), and the density and occupancy rates of many species have been found to increase as the amount of surrounding grassland cover increases (Best et al., 2001, Bakker et al., 2002, Davis et al., 2013). If grassland bird response to prairie strips is landscape-dependent, then more strategic selection of establishment sites would be warranted. While initial STRIPS experimental results suggest prairie strips are a cost-effective way to provide habitat for birds and other species (Schulte et al., 2016), the landscape matrix surrounding the pilot study was restored grassland managed for

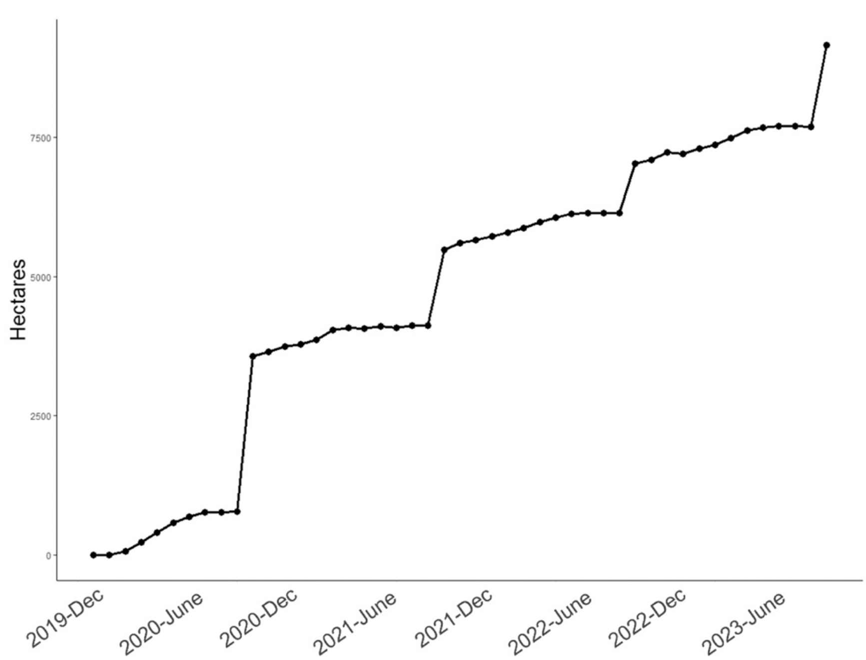

Fig. 1. Monthly enrollment in CP43 Prairie Strips, a farmland Conservation Program offered by the United States Department of Agriculture (USDA) Farm Service Agency as part of the Clean Lakes, Estuaries, and Rivers (CLEAR) Initiative. CP43 was first made available for enrollment in December, 2019.

conservation value and not typical of row-crop agricultural landscapes. Studies conducted in landscapes more typical of agricultural production would provide additional insight into the conservation value of prairie strips for grassland and other birds.

Our specific objectives were to (1) compare bird communities of crop fields without (control) and with prairie strips (treatment), (2) examine how the effects of prairie strips on grassland birds change over time, and (3) evaluate the effect of local and landscape vegetation attributes on grassland bird density in fields with prairie strips. This third objective addresses a knowledge gap in how variation in the land cover composition within versus around a field with prairie strips affects bird use. We hypothesized: (a) fields with prairie strips would have higher densities and diversity of grassland birds than those without, (b) grassland bird density would increase as prairie strip age increased, (c) edge-adapted grassland species such as Dickcissel (Sousa et al., 2022) and Red-winged Blackbirds (*Agelaius phoeniceus*, Yasukawa and Searcy, 2020) would respond more strongly than area-sensitive species such as Grasshopper Sparrow (Vickery, 2020) to prairie strip establishment, and (d) grassland bird density would be increase concomitantly with the proportion of prairie in treatment fields.

2. Materials and methods

2.1. Study area

The study region is dominated by commodity corn (*Zea mays*) and soybean (*Glycine max*) production (USDA, 2017), with annual cropland covering 61.4% of the study landscapes. The remaining land cover is composed of exotic cool-season grasses (mostly smooth brome [*Bromus inermis*], reconstructed native vegetation (hereafter, 'prairie'), woody vegetation, developed areas, and water (Appendix A). The region has a humid continental climate, with average statewide monthly temperature during the period of observation (May – July) of 26.4 degrees Celsius, and average monthly precipitation during this period of 12 cm (NOAA NWS, 2022). Landscapes are undulating with a maximum and minimum elevations of 128 – 602 m above sea level (USGS 2022).

At the time of its initiation in 2015, this study comprised a census of all known commercial corn and soybean farms with installations of prairie strips within 150-km distance of Ames, Iowa (Fig. 2, Appendix B). Each of the nine study farms included a paired comparison of control and treatment fields. The assignment of control and treatment fields was randomized at four farms (hereafter, 'randomized farms'); control and treatment fields were directly adjacent to each other at these farms. At the remaining five farms, the farmer and/or farmland owner chose to implement prairie strips on a specific field to address soil erosion, and thus control and treatment fields were not randomized; the distance between control and treatment fields ranged 0 – 4.7 km at these non-randomized farms. In all cases, crop type and management were consistant among control and treatment fields, and topography and soil types were similar. Control fields ranged 14.1– 93.1 ha in size, averaging 36.1 ha (standard deviation [sd] 27.0 ha). Treatment fields ranged 7.7 – 85.0 ha in size, averaging 23.4 ha (standard deviation [sd] 22.9 ha). At each site, the amount of area sampled was constant between control and treatment fields for data comparatibility (Appendix B). Land cover within 500 m of the center point of each field was similar but for the amount of prairie vegetation; treatment fields had, on average, 14.8% more prairie than control fields (Appendix A).

2.2. Field methods

We placed between three and six point count stations, spaced 200-m apart in a staggered grid from a randomly selected starting point, in each control and treatment field (Buckland et al., 2001). We determined the number of point count stations by field size, with smaller fields allocated fewer stations. We conducted bird point counts three times per field per year between May 15 and July 15, coinciding with bird-breeding season in Iowa, for six years (2015 – 2020). Trained observers navigated to point count stations with a handheld GPS unit and began surveys as early as 15-min before sunrise and as late as one hour after sunrise. This period coincides with peak vocal activity in most songbirds (Robbins, 1981, Robbins et al., 1989).

After arriving at a station, the observer remained stationary and silent for 2 min to allow birds to resume natural behavior. The observer then identified species, sex, and age (juvenile or adult) to each bird seen or heard during a 5-min survey period. Using a laser rangefinder, the observer also estimated the perpendicular distance of each individual bird detected. Exact distance estimations were not made for birds greater than 200 m from the observer. Surveys were not conducted during periods of rainfall or wind speeds exceeding 16 km/h (Manuwal and Carey, 1991, Mikol, 1980). Air temperature, wind speed, and

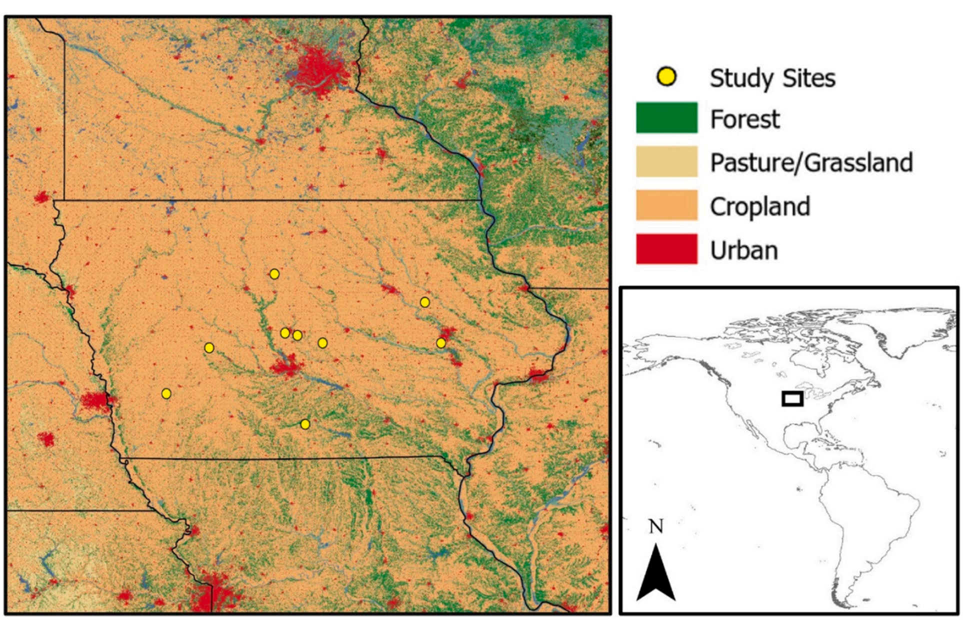

Fig. 2. Location of commercial farms where bird point count surveys were conducted in Iowa, USA during 2015–2020. Land cover imagery provided by 2019 National Land Cover Database (Dewitz, 2021).

percent cloud cover were recorded using hand-held monitors before and after surveys.

2.3. Land cover analysis

We calculated local and landscape spatial covariates of study sites using interpretation and digitization of aerial imagery in a geographical information system (ArcGIS version 10.8.2, ESRI, Redlands, CA). Observers interpreted digitized land cover from high-resolution digital aerial images provided by the USDA National Agriculture Imagery Program (USDA NAIP, 2020). Land cover attributes at each study site were classified into one of six land cover types — crop, developed (roads, buildings, etc.), grass, prairie, woody, and water — and summarized within a 1-km radius of each survey grid. Uncertainties during digitalization were corrected by in-person, field-based verification of land cover. We created 500-m (local) and 1-km (landscape) buffers around each survey grid for estimating land cover metrics to account for variation in the scale of response among grassland birds: some species respond more strongly to variation in local habitat characteristics while others respond to variation in landscape characteristics (Boscolo and Metzger, 2009, Thompson et al., 2014, Shahan et al., 2017, de Zwaan et al., 2022). Using the digitized landscapes, we calculated percent cover of the six land cover types at the local and landscape scales, and summed the number of unique grass and prairie patches ($\geq$ 10 m^2) visible in satellite imagery. Grass cover consisted of lower diversity areas dominated by cool-season non-native grass species, usually smooth brome, and typically was located in grassed waterways and on terraces in crop fields, filter strips around surface water, and roadside ditches. Prairie cover consisted of vegetation dominated by native grass and forb species (English 2021). To evaluate any landscape effects, we calculated the number of grassland patches (combination of grass and prairie patches) within 1 km of each survey grid.

2.4. Statistical analyses

Prior to all statistical analyses, we vetted the raw data for recording or transcription errors. Any updated erroneous or ambiguous data were corrected based on field data sheets. We then performed statistical analysis on cleaned data. We calculated species richness, Shannon's Index, and Simpson's Index as measures of diversity in the R package "vegan" (Oksanen et al., 2017) for each field for each year. Shannon's Index is a measurement of community heterogeneity and gives more weight to rare species (Shannon and Weaver, 1949). Simpson's Index incorporates proportional abundance or evenness of the community and gives more weight to common species (Simpson, 1949). The grassland bird community was defined based on the classification of Peterjohn and Sauer (1993). For density estimation, we used only territorial male detections based on vocalizations (Buckland et al., 2001, Newson et al., 2008). We sorted distances into 20-m bins from 0 to 100 m to remove potential bias of estimating distances (Buckland et al., 2001). We removed all detections beyond 100 m from analyses due to unreliable detection beyond that distance. Because 91% of Brown-headed Cowbirds (*Molothrus ater*) detections were flyovers and could not be used in a distance sampling analysis, we compared the apparent abundance of cowbirds detected per survey in control and treatment fields.

We first analyzed data from all sites to examine trends in bird communities. To evaluate a potential cause-effect relationship of prairie strips and birds, we used data from just the four randomized farms for a separate analysis. We used two-factor analysis of variance with type III sum of squares to test for a difference in grassland bird diversity and richness between control and treatment fields and across years. We conducted this analysis using data from just the randomized sites and then for all sites. We followed with a Tukey HSD to examine pairwise differences between significant independent variables.

We employed hierarchical distance sampling using the *gdistsamp* function in the package "unmarked" (Fiske and Chandler, 2011) to estimate bird densities. A hierarchical modeling structure allows for generalization of the abundance, availability, and detection so that each process can be modeled to vary by site and survey occasion and with covariates (Sillet et al., 2012). Site-level abundance is treated as a random effect and analysis is based on the integrated likelihood or on a function of the parameters in the detection functions, detection covariates, abundance, and abundance covariates (Royle et al., 2004, Chandler et al., 2011). We assumed a closed population of singing males during each year. To investigate the effect of treatment and other spatial covariates on bird density, we constructed separate model sets for all birds, all grassland birds, and all individual species with greater than 80 total detections (Buckland et al., 2001). Before modeling, we standardized all covariates and tested for correlations among covariates using variance inflation factor to avoid multicollinearity included in the same model. We avoided highly correlated combinations ($|r| > 0.7$). For modeling detection, we evaluated the fit of the hazard rate, half-normal, and uniform key functions with and without cosine adjustments. We evaluated temperature, wind speed, cloud cover, and crop type as covariates to model heterogeneity in detection probabilities. We used an Akaike's Information Criterion (AIC) framework and goodness-of-fit tests to determine the most appropriate detection probability model (Burnham et al., 2004). We used treatment type as a predictor of density to evaluate the effect of prairie strips on birds, grassland birds, and individual species. We used detections from treatment fields and prairie strip age as a categorical variable to evaluate the temporal effect of prairie strip establishment of grassland bird density.

To examine local and landscape effects on birds within fields with prairie strips, we included only detections from treatment fields. All models with spatial covariates were tied to an *a priori* biological hypothesis aimed at explaining potential predictors of bird density. We included three spatial variables: the amount of grass cover within 500-m of each survey grid, the amount of prairie cover within 500-m of each survey grid, and the number of grassland patches within 1-km of each survey grid. The global model of each set was an additive model consisting of each covariate in the set. We tested the global model for zero inflation and overdispersion, and considered models within $\Delta AIC_c = 2.0$ to be competitive (Burnham and Anderson, 2002). We used statistical analysis program R 4.1.2 (R Core Development Team, 2021) for all analyses.

3. Results

3.1. Diversity and density on farms with randomized treatment

Across the four farms where assigment of control and treatment fields were randomized, we made a total of 5317 detections of 69 species between 2015 and 2020. Sixteen species detected were grassland-obligate species (Appendix C). The total number of birds observed per survey ranged from 1 to 52 individuals, and the total number of species ranged from 1 to 14 per survey. The half-normal function with temperature as a covariate and without cosine adjustment provided the best fit for detection probability of grassland birds as a community.

Measures of diversity did not differ with treatment or year. The number of species detected per survey trended higher in fields with prairie strips (9.45, 95% confidence interval (CI): 8.30, 10.60 species) compared to those without (9.04, 95% CI: 8.02, 10.06), but not significantly so (treatment: $F_{1,46}$=0.32, p=0.57; year: $F_{5,42}$=2.35, p=0.07). Shannon's diversity index was similar in treatment fields (3.33) and control fields (3.28), with no effect of treatment ($F_{1,46}$=1.06, p=0.31) or year ($F_{5,42}$=0.85, p=0.53). We found the same pattern with Simpson's diversity index (treatment fields = 0.960; control fields = 0.958; treatment: $F_{1,46}$=1.40, p=0.25; year: $F_{5,42}$=1.10, p=0.38).

The presence of prairie strips did have a significant effect on bird density (β=0.332, 95% CI: 0.238 – 0.427). We found a 1.40-fold increase with prairie strips with 2.43 birds/ha (95% CI: 2.24–2.62 birds/ha) in treatment fields and 1.73 birds/ha (95% CI: 1.59–1.90 birds/ha) in control fields. We also found a strong response to the presence of prairie strips among grassland birds as a subset of the whole bird community (β=0.627, 95% CI: 0.517 – 0.737), with a 1.88-fold higher density in treatment fields. There was an average of 1.65 grassland birds/ha (95% CI: 1.51 – 1.81 birds/ha) in treatment fields and 0.88 birds/ha (95% CI: 0.079–0.98 birds/ha) in control fields.

3.2. *Diversity and density on all farms*

Across all nine farms surveyed, we made a total of 14,710 detections of 81 bird species, including 17 grassland-obligate species (Appendix C). The five most commonly detected species — Red-winged Blackbird, Dickcissel, Common Yellowthroat, Eastern Meadowlark, and Western Meadowlark (*Sturnella neglecta*) — comprised 96.4% of all grassland bird detections and 97.3% of the difference in density between treatment and control fields. The total number of birds observed per survey ranged from 1 to 62 individuals, and the total number of species observed ranged from 1 to 14 species per survey.

Species richness was higher in fields with prairie strips when considering all sites: we detected 1.24 times more species per survey in fields with prairie strips (6.42, 95% CI: 6.02–6.82 species) than those without (5.16, 95% CI: 4.78–5.54 species). The association between species richness and year was significant (F_{5102}=5.74, p<0.001), but the association with treatment was only marginally significant (F_{1106}=2.98, p=0.09). Shannon's and Simpson's diversity indicies did not differ by treatment or year. Shannon's diversity for control sites was 3.30 and for treatment sites was 3.33 (treatment: F_{1106}=1.56, p=0.21; year: F=1.65, p=0.15). Simpson's diversity for control sites was 0.959 and treatment sites was 0.963 (treatment: F_{1106}=1.82, p=0.18; year: F_{5102}=1.70, p=0.15).

There was a significant relationship between the presence of prairie strips and bird density (β=0.628, 95% CI: 0.565 – 0.691); we found a 1.87-fold increase with prairie strips with 2.53 birds/ha (95% CI: 2.40–2.66 birds/ha) in treatment fields and 1.35 birds/ha (95% CI: 1.27–1.44 birds/ha) in control fields (Fig. 3, Table 1). We also found a significant relationship to the presence of prairie strips and the density of grassland birds as a subset of the whole bird community (β=1.065, 95% CI: 0.996 – 1.138), with a 2.90-fold higher density in treatment fields. Treatment fields averaged 2.03 grassland birds/ha (95% CI: 1.90–2.16 birds/ha) compared to 0.69 grassland birds/ha (95% CI: 0.065–0.76 birds/ha) in control fields (Fig. 3, Table 1).

Detections included 17 Iowa SGCN species (Appendix C), the most common of which were Dickcissel, Eastern Meadowlark, and Field Sparrow. Among non-SGCN species, the most common were Brown-headed Cowbird, Killdeer (*Charadrius vociferus*), and Song Sparrow (*Spiza melodia*). Brown-headed Cowbird abundance did not differ; there

Table 1
Means and 95% confidence intervals of density of singing male birds per ha (grassland species with greater than 80 detections) in commercial row-crop fields (corn [*Zea mays*], and soybean [*Glycine max*]) without and with prairie strips in Iowa, USA, 2015–2020.

Species	Control(Crops without Prairie Strips)	Treatment (Crops with Prairie Strips)
All Birds	1.35 (1.27–1.44)	2.53 (2.40–2.66)
All Grassland Birds[a]	0.70 (0.65–0.76)	2.03 (1.90–2.16)
Common Yellowthroat (*Geothlypis trichas*)[a]	0.08 (0.06–0.11)	0.27 (0.23–0.33)
Dickcissel (*Spiza americana*)[a,c]	0.17 (0.15–0.20)	0.72 (0.64–0.80)
Eastern Meadowlark (*Sturnella magna*)[c]	0.03 (0.02–0.04)	0.07 (0.05–0.09)
Grasshopper Sparrow (*Ammodramus savannarum*)[b,c]	0.01 (0.01–0.02)	0.05 (0.03–0.07)
Horned Lark (*Eremophila alpestris*)[b]	0.03 (0.01–0.05)	0.02 (0.01–0.03)
Red-winged Blackbird (*Agelaius phoeniceus*)[a]	0.43 (0.38–0.48)	1.04 (0.94–1.15)
Sedge Wren (*Cistothorus stellaris*)[b,c]	0.002 (0.001–0.004)	0.04 (0.03–0.05)
Vesper Sparrow (*Pooecetes gramineus*)[b]	0.06 (0.05–0.07)	0.02 (0.01–0.04)
Western Meadowlark (*Sturnella neglecta*)	0.02 (0.01–0.03)	0.04 (0.03–0.05)

[a] Predictors of density evaluated with spatial models (Table 2)
[b] Naïve density
[c] Iowa species of greatest conservation need (IDNR, 2015)

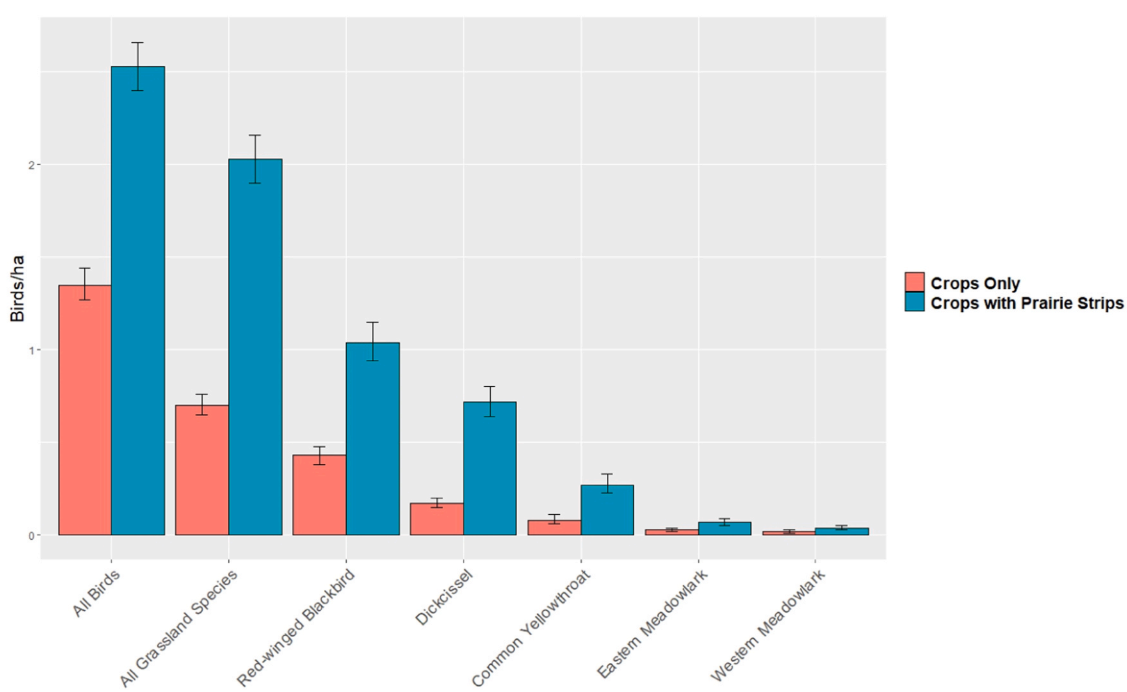

Fig. 3. Mean densities of all birds, all grassland birds, and five commonly detected grassland species in commercial corn (*Zea mays*) and soybean (*Glycine max*) crop fields with and without prairie strips in Iowa, USA, 2015–2020. Error bars are 95% confidence intervals.

were 2.63 (95% CI: 2.01–3.24) cowbirds per survey in treatment fields and 2.97 (95% CI: 2.49–3.45) cowbirds per survey in control fields.

Among species with greater than 80 detections, densities of Red-winged Blackbird, Dickcissel, Common Yellowthroat, and Eastern Meadowlark, were higher in treatment fields (Table 1) as were naïve densities of Grasshopper Sparrow and Sedge Wren (*Cistothorus stellaris;* both species with less than 80 detections). Densities of Horned Lark (*Eremophila alpestris*) and Vesper Sparrow were higher in control fields (Table 1). Among other grassland species, Ring-necked Pheasant (*Phasianus colchicus*) and Upland Sandpiper (*Bartramia longicauda*) were most often detected at distances beyond 200 m.

Prairie strip age was a significant predictor of grassland bird density; grassland bird density in crop fields with prairie strips had a positive trend in the years following the initial establishment of prairie strips while density in contol fields did not vary by year (Fig. 4). We found statistically significant increases in density between the first (1.49 birds/ha, 95% CI: 1.29–1.73) and second (2.03 birds/ha, 95% CI: 1.79–2.28; $p < 0.001$) survey year, and between the third (2.27 birds/ha, 95% CI: 2.03–2.54) and fourth (3.12 birds/ha, 95% CI: 2.84–3.43; $p < 0.001$) survey year.

3.3. Effect of local and landscape attributes on grassland bird detectability and density for fields with prairie strips

Local prairie cover was the most competitive model for predicting grassland bird density (Table 2) and had a significant positive relationship with density (Table 3, Fig. 5; β=0.101, 95% CI: 0.051–0.151). We developed spatial models for the three most commonly detected species: Red-winged Blackbird, Dickcissel, and Common Yellowthroat. The half-normal function with no covariates provided the best fit for detection probability of Red-winged Blackbird. The half-normal function with temperature as a covariate provided the best fit for detection probability of Dickcissel. The half-normal function with temperature as a covariate provided the best fit for detection probability of Common Yellowthroat.

The number of grassland patches on the landscape was the most competitive model for predicting Red-winged Blackbird density

Table 2
Model selection results estimating the influence of spatial variables in fields with prairie strips on the density of all grassland birds and the three most common species: Red-winged Blackbird (*Agelaius phoeniceus*), Dickcissel (*Spiza americana*), and Common Yellowthroat (*Geothlypis trichas*). Local variables were characterized within 500-m of each survey grid and landscape variables within 1-km of each survey grid. All models included site as a random effect. K = the number of parameters in each model; AIC = Akaike's Information Criterion; AIC_c = AIC corrected for small sample sizes; and w_i = Akaike weight.

Species	Model	*K*	AIC_c	ΔAIC_c	w_i
All Grassland Birds	Local Prairie Cover	4	4632.76	0	0.68
	Local Prairie Cover + Local Grass Cover	5	4634.85	2.09	0.24
	Global	6	4637.16	4.40	0.08
	Null	3	4645.55	12.79	0.00
	Local Grass Cover	4	4647.11	14.35	0.00
	Landscape Grassy Patches	4	4649.36	16.60	0.0
Red-winged Blackbird	Landscape Grassy Patches	3	3768.79	0	0.84
	Global	5	3772.13	3.34	0.16
	Local Grass Cover	3	3780.97	12.18	0.00
	Local Prairie Cover + Local Grass Cover	4	3782.86	14.07	0.00
	Null	2	3785.38	16.59	0.00
	Local Prairie Cover	3	3787.40	18.61	0.00
Dickcissel	Global	6	3303.80	0	0.96
	Local Prairie Cover + Local Grass Cover	5	3311.57	7.76	0.02
	Local Prairie Cover	4	3311.88	8.07	0.02
	Landscape Grassy Patches	4	3315.79	11.98	0.00
	Local Grass Cover	4	3319.66	15.85	0.00
	Null	3	3322.54	18.74	0.00
Common Yellowthroat	Local Prairie Cover + Local Grass Cover	5	1981.42	0	0.48
	Local Grass	4	1982.16	0.74	0.33
	Global	6	1983.29	1.87	0.19
	Landscape Grassy Patches	4	2015.75	34.32	0.00
	Null	3	2028.00	46.58	0.00
	Local Prairie Cover	4	2029.80	48.38	0.00

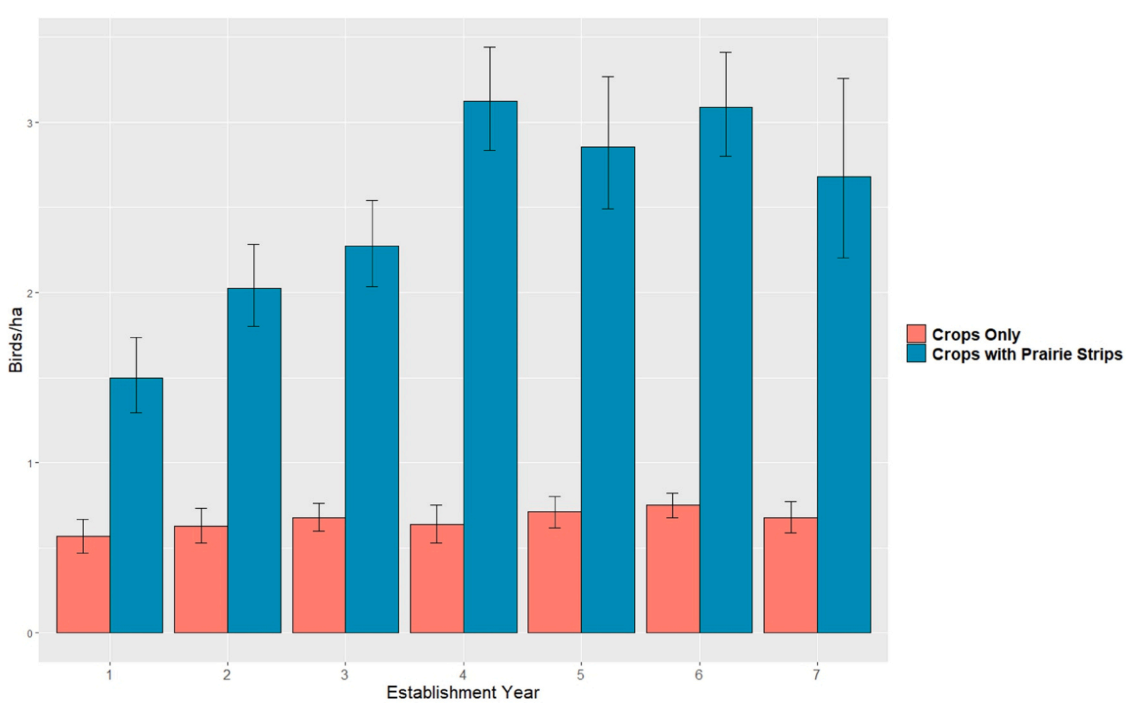

Fig. 4. Mean densities of grassland birds in commercial corn (*Zea mays*) and soybean (*Glycine max*) crop fields with and without prairie strips in Iowa, USA, 2015–2020, including year since prairie strip establishment. Error bars are 95% confidence intervals.

Table 3
Parameter estimates and 95% lower (LCI) and upper (UCI) confidence intervals of most competitive models for predicting density of grassland birds as a community, Red-winged Blackbird (*Agelaius phoeniceus*), Dickcissel (*Spiza americana*), and Common Yellowthroat (*Geothlypis trichas*) in commercial row-crop fields (corn [Zea mays], and soybean [Glycine max]) with prairie strips in Iowa, USA, 2015–2020. Local variables were characterized within 500-m of each survey grid and landscape variables within 1-km of each survey grid.

	β	LCI	UCI
Grassland Birds			
Intercept	0.810	0.723	0.897
Local Prairie Cover	0.101	0.051	0.151
Red-winged Blackbird			
Intercept	0.052	-0.062	0.167
Landscape Grassy Patches	-0.187	-0.272	-0.102
Dickcissel			
Intercept	-0.358	-0.521	-0.194
Local Prairie Cover	0.191	0.095	0.288
Local Grass Cover	-0.013	-0.138	0.111
Landscape Grassy Patches	0.185	0.070	0.299
Common Yellowthroat			
Intercept	-1.567	-1.829	-1.304
Local Prairie Cover	-0.119	-0.254	0.017
Local Grass Cover	0.669	0.472	0.867

(Table 2), and had a significant negative relationship with density (Table 3; β=-0.187, 95% CI: −0.272 - −0.102). The global model was the most competitive for predicting Dickcissel density (Table 2). Among covariates (Table 3), local prairie cover (β=0.191, 95% CI: 0.095–0.289), and the number of grassland patches on the landscape (β=0.185, 95% CI: 0.070–0.299), had significant positive relationships with Dickcissel density. The most competitive model for Common Yellowthroat included an additive effect of local prairie and local grass cover (Table 2). Among covariates on this model (Table 3), local grass cover had a significant positive relationship with their density (β=0.669, 95% CI: 0.472–0.867). Local grass cover and the global model were also competitive (ΔAIC<2.0).

4. Discussion

Given that many areas of the world historically dominated by grassland are now in agricultural land uses (Bardgett et al., 2021, Gil-Mendoza et al., 2024), novel approaches are needed to balance competing production and conservation goals. Farmers in the U.S. agricultural state of Iowa indicate a strong willingness to install prairie strips — linear features of reconstructed native grassland vegetation established to address farmland conservation goals (Arbuckle, 2019, 2020). Since 2019, farmer and farmland owner adoption of prairie strips has also been facilitated through the U.S. federal Conservation Reserve Program (USDA FSA 2019); there are currently 9162 ha of prairie strips established through this program (Fig. 1, USDA, 2023).

In North America, grassland birds have declined more than any other avian community since 1970 (Rosenberg et al., 2019). We investigated grassland bird community response to prairie strips on commercial corn and soybean fields to better understand the effectiveness of prairie strips as a landsharing conservation strategy. We found a strong positive effect of prairie strips on the density of grassland birds and birds overall (Fig. 3), including on farms where treatment and control fields were randomly assigned. Red-winged Blackbird, Dickcissel, and Common Yellowthroat were most responsive to prairie strip establishment (Table 1); additionally, Eastern Meadowlark, Grasshopper Sparrow, Sedge Wren, and other species of conservation concern responded positively (Table 1, Appendix C). Prairie strip age was an important predictor of grassland bird density (Table 2), with significant increases between years 1 and 2 and years 3 and 4 following prairie strip establishment (Fig. 4).

Contrary to expectation, we did not find strong differences in bird community diversity measures between fields with and without prairie strips, although our results suggest a trend toward higher bird species richness on fields with prairie strips. Our sample size of nine pairs may have been too limited to detect differences given the level of variablility in the data. Horned Lark and Vesper Sparrow — which prefer short, sparse vegetation such as crop residue and crop field edges (Beason, 2020, Jones and Cornerly, 2020) — were the only species more common on control fields. Furthermore, area-sensitive grassland birds, such as Bobolink (*Dolichonyx oryzivorus*) or Henslow's Sparrow (*Centronyx*

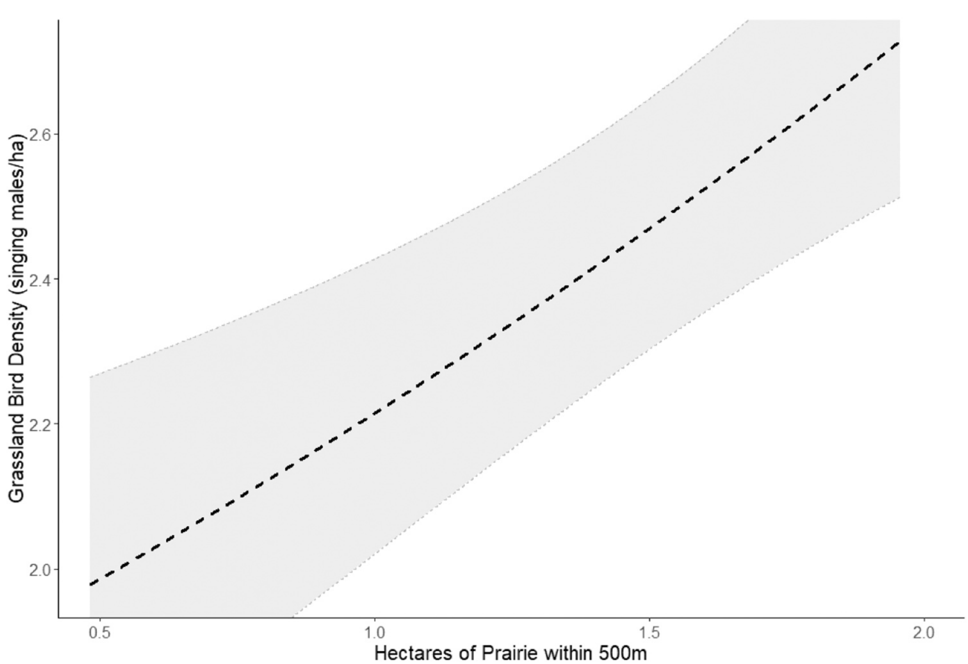

Fig. 5. Relationship between grassland bird density and the amount of local prairie in commercial corn (*Zea mays*) and soybean (*Glycine max*) crop fields, with prairie strips, in Iowa, USA, 2015–2020. Shaded area indicates 95% confidence intervals of the estimate.

henslowii), were largely absent from the fields we surveyed.

Our results were consistent with Schulte et al. (2016) and others who documented increased bird use of crop fields with perennial or semi-natural vegetation (Jobin et al., 2001, Vickery et al., 2009, Walk et al., 2011, Heath et al., 2017, Stanton et al., 2018, de Zwaan et al., 2022). Many of the community-level and species-level responses (e.g., Eastern Kingbird and American Robin) detailed by Schulte et al. (2016), however, were likely driven by vegetation surrounding the study area. Similarly, the more simplified, commercial agricultural landscapes around our study sites resulted in a more noticeable response of grassland bird to prairie strips. The landscape surrounding study sites used by Schulte et al. (2016) was dominated by natural vegetation, predominantly reconstructed prairie but also woodland. In contrast, our study sites were located in a landscape dominated by commercial corn and soybean production, 67.3% and 55.6% in the case of control and treatment fields, respectively (Appendix A).

Bird species in our study responded differently to local and landscape spatial predictors, as expected (Table 3). The density of Dickcissels was predicted by the number of grassland patches on the landscape and the amount of local prairie cover. The density of Common Yellowthroats was best predicted by the amount of local grass cover. For Red-winged Blackbirds, the number of grassland patches on the landscape was the most important spatial predictor, but surprisingly had a negative relationship with density. One potential explanation is that lower availability of grassland patches on the landscape results in higher competition for nesting territories among breeding Red-winged Blackbirds in prairie strips, and thus smaller breeding territories and higher density of breeding males. Red-winged Blackbird breeding territory size varies signficantly across land cover types with smaller territories in more suitable habitats (Searcy and Yasukawa, 1995). Other studies have found variable effects of landscape patch density and habitat amount on Red-winged Blackbird bird abundance (Forcey et al., 2015) and nest density (Davis et al., 2006, Stephenson, 2022).

Also consistent with Schulte et al. (2016), time since prairie strip establishment affected bird use of prairie strips in our study. Signficant increases in grassland bird density between years 1 and 2 and years 3 and 4 correspond with changes in vegetation and vegetation management. We expect this pattern to relate to changes in vegetation composition and management rather than a delay in birds colonizing newly established habitats. Typical vegetation management protocol associated with prairie strip establishment include 2–4 mowings in first year to suppress annual weeds (STRIPS, 2020). Our qualtiative field observations indicate that these frequent disturbances affect the bird species using prairie strips, their abundance, and their behavior in prairie strips; for example, bird species associated with short grass vegetation will use prairie strips, especially for foraging, but use for nesting is limited. While establishment mowing can occur in years 2 and 3, it is typically less frequent, and mowing equipment is set to a greater height. By the fourth year, prairie strips typically have greater expression of native species, their percent cover, and greater vegetation cover overall in comparison to previous years (Hirsh et al., 2013).

Prairie strips also provide nesting habitat for grassland birds, in addititon to supporting increases in bird species richness and density. In a companion study, Stephenson (2022) documented higher nest densities and nest success in prairie strips compared to other available cover types, including other farmland conservation features such as grass filter strips, terraces, and large grassland patches, on a subset of the corn and soybean farms included in this study. Stephenson (2022) also found that vegetation density and diversity were important predictors of nest survival of grassland birds as a community and of Red-winged Blackbird. Previous research in the region indicates that grasslands greater than 1000 ha in size are required for reproductive success of grassland bird species (Herkert et al., 2003), but that even small (<150 ha) grassland patches can contribute to the reproduction of species that are not area-sensitive (Walk et al., 2010). Patch size is a not reliable predictor of nest survival in every region, though, and general recommendations for conservation of grassland birds will require a better understanding of predation (Benson et al., 2013). The results of our study and those of Stephenson (2022) collectively suggest, however, that prairie strips offer an improvement to the breeding habitat typically available to birds in Midwestern agricultural landscapes, including larger patches of grassland if they are dominated by nonnative cool-season grasses. We further expect the value of prairie strips for breeding birds will increase with additional time for establishment, beyond the six year scope of study, as expected increases in native plant cover and diversity provide more suitable nest sites. The timing of grassland management activities, however, will continue to affect bird nest and fledgling success (Wolcott et al., 2023).

Land-sharing practices, like prairie strips, integrate production and biodiversity conservation and effectively promote ecosystem services in agricultural landscapes (Egan and Mortensen, 2012, Schulte et al., 2017, Grass et al., 2019, Gil-Mendoza et al., 2024). Though protection of larger patches in the form of land-sparing reserves is often seen as advantageous, both strategies can contribute to effective biodiversity conservation (Fischer et al., 2008). The land-sharing concept also has applications in grazing systems where potential exists to improve larger patches of grasslands for biodiversity (Shapira et al., 2020). Patch-burn grazing methods hold promise for enhancing habitat for grassland birds by creating heterogeneity even in relatively small patches (Pillsbury et al., 2011, Duchardt et al., 2016). The potential for the expansion of biofuels adds further complexity to the debate between land-sharing and land-sparing (Anderson-Teixeira et al., 2012; Schulte et al., 2022).

Protection of large patches of grasslands is needed and could benefit many grassland-obligate species, including the 32 grassland-obligate bird species in North America (Herkert et al., 2003, Vickery et al., 1999), but is challenging in agricultural landscapes (Asbjornsen et al., 2013, Bardgett et al., 2021). In addition to providing soil, air, water, and biodiversity conservation benefits to farms and more broadly (Schulte et al., 2017), prairie strips may serve as corridors between larger grassland patches (Mayer, 2023). Small, isolated patches in landscapes dominated by agriculture reduce the isolation of large reserves, providing crucial stepping stones for mobile taxa (Saura et al., 2014, Herrera et al., 2017, Stephenson et al., 2024).

5. Conclusion

Prairie strips expand bird use of agricultural landscapes and appear to provide quality habitat for a suite of species, including some grassland species and some of conservation concern. As prairie strips do not provide habitat for area-sensitive grassland birds, such as Bobolink and Henslow's Sparrow, larger patches of grassland patches are needed to reverse grassland bird declines and achieve biodiversity goals in agricultural landscapes. Whether these larger grassland patches can be managed to jointly produce agricultural and biodiversity outcomes under a land-sharing model, and thus be attractive to people dependent on agriculture for income, or whether they need to be managed as land-sparing reserves, needs further examination.

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CRediT authorship contribution statement

Jordan C. Giese: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Lisa A. Schulte:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization. **Robert W. Klaver:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

I have provided the link to data and code in a public repository

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No Revision Notes

None.

Appendix A. Land cover characteristics within 500 m of study field center point at commercial row-crop fields (corn [*Zea mays*], and soybean [*Glycine max*]) where bird point count surveys were conducted May – July, 2015 – 2020, in Iowa, USA. SD = standard deviation

Site Name	Field Type	%Crop	%Grass	%Prairie	%Woody	%Developed	%Water
ARM	Control	60	22	0	13	5	0
ARM[a]	Treatment	75	8	13	0	4	0
EIA	Control	80	12	8	0	0	0
EIA[a]	Treatment	40	28	21	6	5	0
GUT	Control	76	18	6	0	0	0
GUT	Treatment	73	9	18	0	0	0
MCN	Control	47	31	4	5	6	7
MCN[a]	Treatment	62	12	8	2	0	16
RHO	Control	75	14	0	3	8	0
RHO[a]	Treatment	48	7	15	19	11	0
SMI	Control	77	23	0	26	0	0
SMI	Treatment	49	22	19	2	0	8
SLO	Control	59	21	0	12	8	0
SLO	Treatment	72	6	22	0	0	0
WHI	Control	76	10	0	10	4	0
WHI	Treatment	43	19	26	7	5	0
WOR	Control	56	23	7	9	5	0
WOR[a]	Treatment	38	14	16	27	3	2
Mean	Control	67.33	19.33	2.78	8.67	4.00	0.78
SD	Control	11.55	6.48	3.30	7.96	3.26	2.32
Mean	Treatment	55.56	13.89	17.56	7.00	3.11	2.89
SD	Treatment	14.15	7.17	5.01	9.08	3.48	4.46

[a] Randomized treatment field

Appendix B. Commercial farms where bird point count surveys were conducted May – July, 2015 – 2020, in Iowa, USA. SD = standard deviation. Field area sampled was kept constant between control and treatment fields at each site

Site Name	County	Control Field Size (ha)	Treatment Field Size (ha)	Field Area Sampled (ha)	Area Restored to Prairie (ha)	Year Restored
ARM	Pottawattamie	28.16	8.09	18.84	0.77	2014
EIA[a]	Linn	24.78	20.23	25.12	2.27	2015
GUT	Story	26.55	25.50	18.84	2.14	2014
MCN[a]	Lucas	30.67	29.14	31.4	2.02	2014
RHO[a]	Marshall	23.12	12.95	18.84	1.05	2015
SMI	Wright	93.14	7.69	25.12	1.62	2015
SLO	Buchanan	78.93	84.98	25.12	1.82	2013
WHI	Guthrie	23.18	22.66	31.4	6.31	2015
WOR[a]	Story	17.89	11.74	18.84	0.85	2015
Mean	–	38.49	24.78	23.72	2.09	–
SD	–	25.85	22.48	4.93	1.58	–

[a] Randomized site

Appendix C. Eighty-one species detected during bird point counts using unlimited distance surveys, including flyovers, in commercial row-crop fields (corn [*Zea mays*], and soybean [*Glycine max*]), without and with prairie strips, in Iowa, USA, 2015–2020

Species	Control (Crops without Prairie Strips)	Treatment (Crops with Prairie Strips)
American Crow (*Corvus brachyrhynchos*)	64	48
American Goldfinch (*Spinus tristis*)	161	150
American Robin (*Turdus migratorius*)	296	199
Bald Eagle (*Haliaeetus leucocephalus*)[a]	-	3
Baltimore Oriole (*Icterus galbula*)	30	10
Barn Swallow (*Hirundo rustica*)	212	112

(*continued on next page*)

(*continued*)

Species	Control (Crops without Prairie Strips)	Treatment (Crops with Prairie Strips)
Black-capped Chickadee (*Poecile atricapillus*)	11	10
Belted Kingfisher (*Megaceryle alcyon*)	-	1
Bell's Vireo (*Vireo bellii*)[a]	1	-
Brown-headed Cowbird (*Molothrus ater*)	503	371
Blue Jay (*Cyanocitta cristata*)	39	33
Bobolink (*Dolichonyx oryzivorous*)[a,b]	36	52
Brown Thrasher (*Toxostoma rufum*)	81	54
Blue-winged Teal (*Spatula discors*)	-	2
Canada Goose (*Branta canadensis*)	58	1
Carolina Wren (*Thryothorus ludovicianus*)	-	1
Cedar Waxwing (*Bombycilla cedrorum*)	37	3
Chipping Sparrow (*Spizella passerine*)	45	28
Chimney Swift (*Chaetura pelagica*)[a]	6	2
Cliff Swallow (*Petrochelidon pyrrhonota*)	2	5
Common Grackle (*Quiscalus quiscula*)	84	73
Cooper's Hawk (*Accipiter cooperii*)	1	1
Common Nighthawk (*Choreiles minor*)[a]	1	1
Common Yellowthroat (*Geothlypis trichas*)[b]	282	580
Dickcissel (*Spiza americana*)[a,b]	734	1425
Downy Woodpecker (*Dryobates pubescens*)	2	1
Eastern Bluebird (*Sialia sialis*)	11	17
Eastern Kingbird (*Tyrannus tyrannus*)	26	22
Eastern Meadowlark (*Sturnella magna*)[a,b]	261	355
Eastern Phoebe (*Sayornis phoebe*)	1	2
Eastern Towhee (*Pipilo erythropthalmus*)	-	2
Eastern Wood-peewee (*Contopus virens*)	10	2
Eurasian Collared-dove (*Streptopelia decaocto*)	4	4
European Starling (*Sturnus vulgaris*)	42	20
Field Sparrow (*Spizella pusilla*)[a,b]	89	61
Great Blue Heron (*Ardea herodias*)	17	7
Great Egret (*Ardea alba*)	-	1
Great Crested Flycatcher (*Myiarchus crinitus*)	0	1
Gray Catbird (*Dumetella carolinensis*)	40	13
Grasshopper Sparrow (*Ammodramus savannarum*)[a,b]	53	103
House Finch (*Haemorhous mexicanus*)	3	1
Horned Lark (*Eremophila alpestris*)[b]	99	38
House Sparrow (*Passer domesticus*)	72	17
House Wren (*Troglodytes aedon*)	86	52
Indigo Bunting (*Passerina cyanea*)	69	53
Killdeer (*Charadrius vociferus*)	340	304
Lark Sparrow (*Chondestes grammacus*)[b]	2	2
Least Flycatcher (*Empidonax minimus*)[a]	1	-
Mallard (*Anas platyrhynchos*)	11	7
Mourning Dove (*Zenaida macroura*)	108	93
Northern Bobwhite (*Colinus virgninianus*) [a,b]	14	25
Northern Cardinal (*Cardinalis cardinalis*)	134	56
Northern Flicker (*Colaptes auratus*)	2	4
Northern Harrier (*Circus hudsonius*)[a]	-	1
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	4	3
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	7	2
Ring-billed Gull (*Larus delawarensis*)	1	-
Red-bellied Woodpecker (*Melanerpes carolinus*)	29	11
Red-headed Woodpecker (*Melanerpes erythrocephalus*)[a]	10	10
Ring-necked Pheasant (*Phasianus colchicus*)[b]	243	215
Rock Pigeon (*Columba livia*)	17	6
Red-tailed Hawk (*Buteo jamaicensus*)	4	2
Ruby-throated Hummingbird (*Archilochus colubris*)	3	3
Red-winged Blackbird (*Agelaius phoeniceus*)[b]	1527	2378
Savannah Sparrow (*Passerculus sandwichensis*)[b]	12	-
Sedge Wren (*Cistothorus stellaris*)[a,b]	12	91
Song Sparrow (*Melospiza melodia*)	161	223
Spotted Sandpiper (*Actitis macularius*)[b]	1	8
Tree Swallow (*Tachycineta bicolor*)	25	54
Turkey Vulture (*Cathartes aura*)	8	6
Upland Sandpiper (*Bartramia longicauda*)[a,b]	43	69
Vesper Sparrow (*Pooecetes gramineus*)[b]	219	80
Warbling Vireo (*Vireo gilvus*)	6	6
White-breasted Nuthatch (*Sitta carolinensis*)	1	-
Western Meadowlark (*Sturnella neglecta*)[b]	182	223
Willow Flycatcher (*Empidonax traillii*)	2	-
Wild Turkey (*Meleagris gallopavo*)	5	4
Wilson's Phalarope (*Phalaropus tricolor*)[a]	-	1
Wood Duck (*Aix sponsa*)	-	1
Yellow-billed Cuckoo (*Coccyzus americanus*)[a]	2	3
Yellow Warbler (*Setophaga petechia*)	26	9

[a] Iowa species of greatest conservation need (IDNR, 2015)

[b] Considered a grassland species (Peterjohn and Sauer, 1993)

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