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Prairie strips as a mechanism to promote land sharing by birds in industrial agricultural landscapes

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ABSTRACT

Reserving large patches of perennial vegetation has been shown to facilitate biodiversity conservation in industrial agricultural landscapes, but high demand for agricultural products challenges their establishment. Responding to this situation, in 2007, we experimentally integrated diverse native perennial vegetation (i.e., prairie) within annual row crops as a part of the Science-based Trials of Rowcrops Integrated with Prairie Strips (STRIPS) project in Iowa, USA. Four treatments were applied to small (0.47–3.19 ha) watersheds and included: 100% row crops (0% prairie) farmed on a soybean (*Glycine max*)—maize (*Zea mays*) rotation, and three treatments with prairie strips comprising 10% or 20% of the watershed area with the remaining area in row crops. This study evaluated bird response to these treatments between 2007 and 2012. We observed a total of 52 species using the experimental sites across six years of study, with 16 species comprising 99% of the observations. Bird abundance, species richness, and diversity positively responded to prairie within row-crop fields: we specifically recorded 1.53–2.88 times more birds, 1.53–2.13 times more bird species, and 1.40-1.98 times greater diversity in treatments with prairie compared to the 0% prairie control. Several generalist species – Eastern kingbird (*Tyrannus tyrannus*), American robin (*Turdus migratorius*), and common yellowthroat (*Geothlypis trichas*) – were statistically more abundant in treatments with prairie, and song sparrow (*Melospiza melodia*) were more abundant in one specific prairie treatment, whereas no species was statistically more abundant in the 0% prairie control. We found few differences between 10% and 20% prairie treatments, but recorded increases in bird abundance, richness, and diversity from 2007 to post-establishment years. This experiment suggests that incorporating prairie strips into annual row crops has the potential to increase agricultural land sharing by birds.

1. Introduction

While producing phenomenal crop yields for human benefit, extensive industrial agriculture is also associated with substantial environmental degradation (Foley et al., 2005; Robertson and Swinton, 2005), including profound impacts on native biodiversity (Sala et al., 2000; Tscharntke et al., 2005). Taxa dependent on low-intensity agricultural and grassland habitats have experienced particularly precipitous declines, including birds (Herkert et al., 2003; Murphy, 2003; Voříšek et al., 2010). Population declines for farmland and grassland birds in both Europe and North America are strongly connected to the intensity of agricultural land use (Donald et al., 2001; Murphy, 2003).

Reserving or setting aside whole fields is a proven mechanism for reducing agricultural intensity and fostering biodiversity in well-developed agricultural regions (Ryan et al., 1998; Van Buskirk and Willi, 2004), but can be socially, economically, and politically challenging. For example, high crop prices place pressure on farmers to farm both more intensively and more land, which negatively influences enrollment in the USDA Conservation Reserve Program (Lark et al., 2015), the principal mechanism for land set asides in the US (McGranahan et al., 2013). Research suggests farmers and farm landowners in the Midwestern US may be more amenable to land-sharing strategies – those that address conservation goals within agricultural production fields (Fischer et al., 2008) – targeted to achieve multiple benefits (Atwell et al., 2009; Arbuckle, 2013; Arbuckle et al., 2015). Targeted perennial practices, which strategically interject small amounts of perennial cover into annual row-crop fields, are expected to achieve substantial environmental gains while only removing a small

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amount of land from crop production (Berry et al., 2003; Schulte et al., 2006; Walter et al., 2007). While often developed to meet traditional soil and water goals, targeted practices could be constructed to also support biodiversity (Tscharntke et al., 2005; Fischer et al., 2006; Asbjornsen et al., 2013), and specifically bird populations (Van Buskirk and Willi, 2004; Clark and Reeder, 2007; Hiron et al., 2013; Bright et al., 2015). Many bird species respond positively to the presence of small patches of perennial vegetation such as grassed waterways (Bryan and Best, 1991, 1994), field borders (Marshall and Moonen, 2002; Conover et al., 2009), and riparian buffers (Henningsen and Best, 2005; Berges et al., 2010) in or adjacent to annual row-crop fields. In the Midwestern US, Best et al. (1995) found greater bird species richness in linear perennial habitats embedded in agricultural landscapes (e.g., farmstead shelterbelts, grassed waterways) compared to other agricultural habitat types.

A remaining question is whether the biodiversity and other benefits provided by targeted land-sharing approaches could be amplified by incorporating diverse native plant communities rather than non-native monocultures, such as the exotic cool-season brome (*Bromus* spp.) or fescue (*Festuca* spp.) grasses typically used in the US. Previous research across plant, spider, insect, and bird taxa documents higher species richness associated with diverse, native communities (Van Buskirk and Willi 2004). Reconstructed native prairie communities are expected to perform especially well in the Midwestern US (Liebman et al., 2013), given that prairie was the predominant vegetation in the region for several millennia leading up to Euro-American settlement in the 1800s and it is well-adapted to the region's environmental conditions.

As part of the Science-based Trials of Row crops Integrated with Prairie Strips (STRIPS; www.prairiestrips.org) project, we sought to understand the biodiversity and other impacts of integrating small strips of diverse, native grassland vegetation – prairie strips – into row-crop agricultural fields. Using prairie in a farmland conservation practice is novel in the US, where exotic brome (*Bromus* spp.) or fescue (*Festuca* spp.) grasses are more typically used. The project includes an experiment conducted at Neal Smith National Wildlife Refuge (hereafter, Neal Smith NWR or "the refuge") in central Iowa, USA, in which strips of prairie plant species were strategically sowed within small agricultural watersheds (0.47–3.19 ha) farmed on a soybean (*Glycine max*)—maize (*Zea mays*) rotation. We previously established that prairie strips are a cost-effective agricultural conservation option for the region (Tyndall et al., 2013).

In this study, we specifically assessed the response of bird abundance, richness, and diversity to this targeted land-sharing approach; other components of the STRIPS project address impacts on plant and insect biodiversity (Hirsh et al., 2013; Cox et al., 2014), soil and water (Zhou et al., 2010; Helmers et al., 2012; Pérez-Suárez et al., 2014; Zhou et al., 2014), and heat-trapping gases (Iqbal et al., 2015). We hypothesized that the bird community and populations would respond positively to (1) treatments with prairie compared to those entirely in row-crop production, (2) treatments with a greater percentage of prairie, and (3) time following prairie establishment. We expected the responses of individual bird species to be variable with treatment, amount of prairie, and time. More specifically, we expected greater abundance of species preferring open conditions (e.g., killdeer, *Charadrius vociferous*; vesper sparrow, *Pooecetes gramineus*) in the treatment without prairie and greater abundance of grassland generalist species (e.g., red-winged blackbird, *Agelaius phoeniceus*; common yellowthroat, *Geothlypis trichas*) in treatments with prairie. We did not expect grassland interior species (e.g., bobolink, *Dolichonyx oryzivorus*; Henslow's sparrow, *Ammodramus henslowii*) to be present within our treatments.

2. Materials and methods

2.1. Study area

Neal Smith NWR where the STRIPS experiment is located is situated on steeply rolling, well-drained terrain formed by the erosion of glacial deposits (Prior, 1991). Historically, this region was covered by tallgrass prairie interspersed with oak savannas and riparian forests, but is now dominated by cropland and pasture. The climate is humid continental, with an average annual temperature of 10 degrees Celsius, and annual precipitation amounting to 88 cm on average (NOAA NWS, 2015). Most of the land was farmed before the refuge was established in 1991, but the majority has since been restored to native plant communities. The STRIPS experiment is located on portions of the refuge that have not yet been restored and are currently in row-crop production.

Experimental units for this project included 12 small watersheds (hereafter referred to as "sites") ranging in size from 0.47 to 3.19 ha with boundaries determined topographically (Table 1); slopes ranged 6.1–10.5%. Treatments consisted of varying amounts (i.e., 0%, 10%, 20%) and positions (i.e., all at the footslope, multiple strips on the contour) of prairie. The four treatments included sites with: (1) the entire area planted to row crops (0% prairie); (2) 10% of the area planted to prairie at the footslope, and the remaining 90% in row crops; (3) 10% of the area planted to prairie in multiple strips on the contour, and the remaining 90% in row crops; and (4) 20% of the area planted to prairie in multiple strips on the contour, with the remaining 80% in row crops. The 0% prairie was the control because it is representative of standard agricultural

Table 1
Distribution of treatments among blocks, number of surveys, and site size for the STRIPS experiment at Neal Smith National Wildlife Refuge. The remaining percentage of the experimental sites is in annual row crop production, either soybean (odd years) or maize (even years).

Block	Treatment	Area (ha)	Number of surveys					
			2007	2008	2009	2010	2011	2012
Basswood	0% prairie (control)	0.81	7	11	10	21	19	10
Basswood	10% prairie bottom	0.55	8	12	10	21	22	10
Basswood	10% prairie strips	0.56	8	12	10	21	22	10
Basswood	10% prairie strips	1.31	8	12	10	21	20	10
Basswood	20% prairie strips	0.57	8	12	10	21	21	9
Basswood	20% prairie strips	0.61	8	12	10	21	21	10
Interim	0% prairie (control)	0.61	8	12	10	19	22	10
Interim	10% prairie bottom	3.24	8	12	10	19	22	10
Interim	10% prairie strips	3.10	8	12	10	19	22	10
Orbweaver	0% prairie (control)	1.24	8	12	8	19	23	10
Orbweaver	10% prairie bottom	1.25	8	12	10	20	23	10
Orbweaver	20% prairie strips	2.51	8	12	8	20	24	10

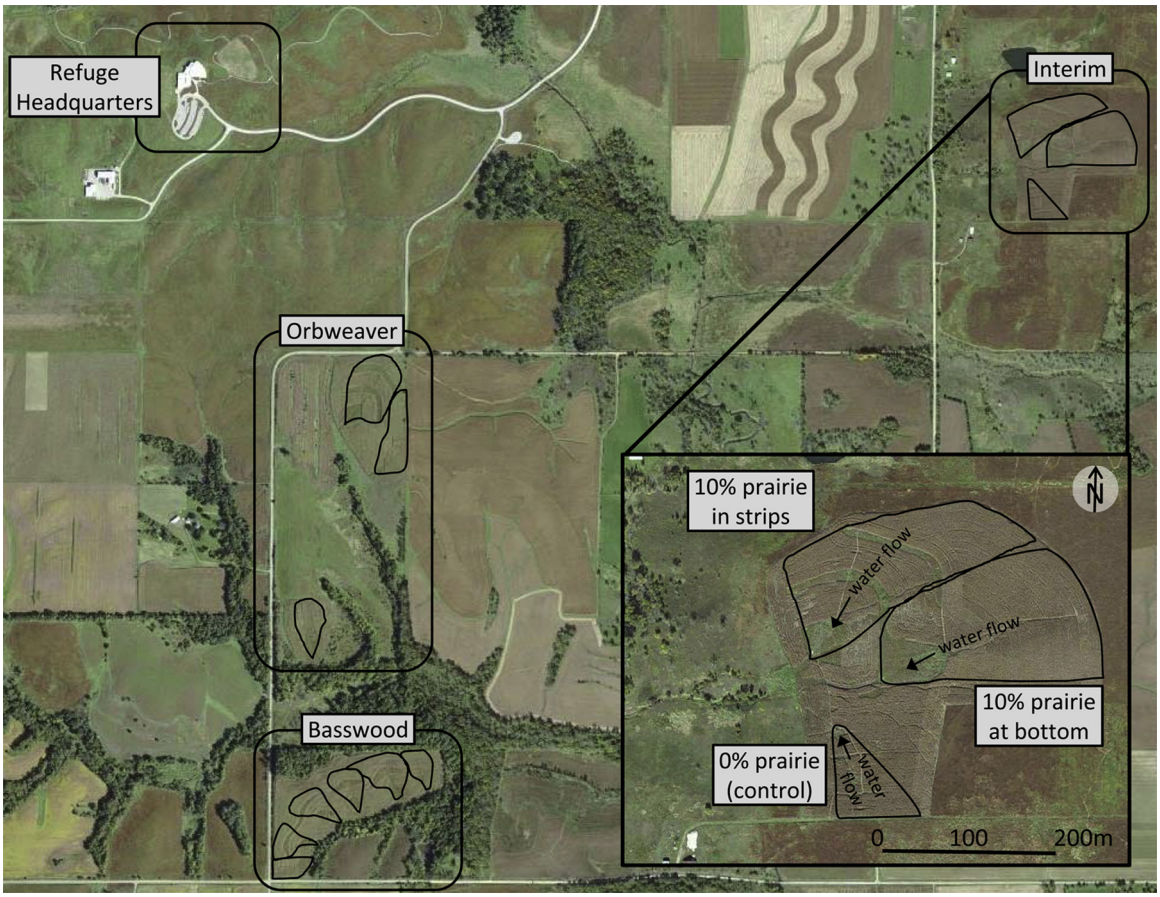

Fig. 1. Map of STRIPS experimental sites at Neal Smith National Wildlife Refuge grouped by block (Basswood, Interim and Orbweaver). The inset provides more detail on how prairie strips are distributed within row crops.

practices in the region. Three replications of each treatment were randomly established in an incomplete block design with only two replicated treatment-block combinations (Fig. 1, Table 1). The specific size and location of prairie areas within row-cropped sites were determined by the assigned treatment, the size of the site, and the distance necessary to accommodate farming equipment between prairie areas. The lengths and widths of strips vary with watershed size in addition to percent prairie in the treatment. Upslope contour strips vary 100–185 m in length and 3–10 m in width. Prairie in the footslope position varies 37–78 m in width, defined as the distance parallel to the flow of water in this watershed-based experiment, and 15–75 m in length. A full description of the experimental design can be found in Helmers et al. (2012).

Prior to treatment establishment, all research sites were in mixed grasses, primarily smooth brome (*B. inermis*), for at least 10 years with no application of fertilizer. Sites were prepared in 2006 by uniformly tilling them with a mulch tiller. Beginning in 2007, all sites were planted to a two-year soybean-maize rotation with no-till management, including standard no-till weed- and nutrient-management practices (e.g., herbicide and fertilizer applications). The prairie strips were planted to a diverse prairie seed mixture using a broadcast seeder on July 7, 2007. The seed mixture was collected from an established prairie on the refuge and contained seven native grasses, 12 native forbs, and 13 species considered to be agricultural weeds; the 19 non-weed native species accounted for 91% of the seed weight in the mix (Hirsh et al., 2013). An additional native forb (*Anemone canadensis*) was sown in the spring of 2008 to provide nectar resources for pollinators in early spring because the initial seed mix lacked plant species fulfilling this role. Prairie strips were mowed in the summer of 2008 and 2009 to control weeds during establishment. Strips were subsequently mowed and baled in the fall of 2010, 2011, and 2012 to reduce litter and increase prairie growth in the spring.

Vegetation surveys conducted from 2008 to 2011 showed sites with prairie strips had higher plant diversity at 50.6 species on average compared to an average of 13.3 species in the 0% prairie sites (Hirsh et al., 2013). We found no differences in native and perennial species, percent cover, and diversity among the treatments with prairie strips, but the percent cover of perennial species (30.5 to 103.9), native species (38.2 to 68.7), and native perennial species (17.7 to 66.4) increased over time (Hirsh et al., 2013). Dominant native perennial species included *Andropogon gerardii*, *Sorghastrum nutans, Cyperus esculentus*, *Monarda fistulosa*, *Symphyotrichum pilosum*, *Solidago canadensis*, and *Ratibida pinnata*. Dominant exotic species included *Poa* spp., *B. inermis*, *Setaria* spp., *Phalaris arundinacea*, and *Daucus carota*.

2.2. Field methods

We conducted bird surveys during the breeding seasons of 2007–2012 using area search methods based on spot-mapping techniques (Ralph et al., 1993). These methods allowed for consistent effort per unit of area surveyed, given variation in the size of research sites, and allowed us to capture information about which habitat (crop or prairie) birds were using. Each site was surveyed by walking at an even pace (1 km/h) through the entire site at $\leq$50 m intervals. We recorded all birds observed by sight and

sound on a detailed site map, including individual birds' locations (crop or prairie) and subsequent movements, their species, sex, and behavioral activity (e.g., singing, foraging, perching). This information was used to more accurately estimate the number of birds observed within a survey. Surveys were conducted between 30 min before sunrise to 4 h after sunrise on days with suitable weather conditions. A total of 976 surveys were conducted by six surveyors across the 12 sites over the course of the six-year study period; surveyors included the first two authors or technicians trained by the first two authors. Between seven and 24 spot-mapping surveys were completed for each study site in each year, with an average of 13.6 surveys of each site in each year. The respective earliest and latest dates of survey were May 11 and July 27, and individual surveys were regularly spaced between first and last dates. The fewest surveys were conducted in 2009 and the survey period ended early on June 24 because of mowing for weed control associated with establishing the prairie. Although we recorded fly-over observations (e.g., foraging swallows) during surveys, they were excluded from subsequent summaries and analyses because their presence was more likely influenced by the broader landscape context rather than the experimental sites themselves. We also conducted nest searching and monitoring in 2010-2012, but found too few nests to robustly estimate fecundity (MacDonald, 2012).

Detection rates are expected to vary among observers and species, and with increased distance from observer (Diefenbach et al., 2003). Detectability might also change over time during a given breeding season due to increasing vegetation height, especially of maize in this study. We did not include the observer variable in our analyses because the majority of surveys in a given year were conducted by one person and, thus, observer is largely confounded with year. Diefenbach et al. (2003) found that detection rates were less than 100% at distances greater than 25 m, and 60% of birds could go undetected at distances greater than 50 m. To minimize variation in detectability, we standardized our methodology within and among years, conducted our surveys by walking through the entire site at a maximum distance of 50 m, and conducted the majority of our surveys prior to when the maize was tall enough to provide substantial visual or auditory obstruction. Although detectability could be an issue, we expect it was minimized by our survey methods, minimally biased the data, and our data represent an index of bird abundance (Johnson 2008).

2.3. Data analysis

Field data were combined with site information to form a dataset with the following variables: individual, species, sex, date, treatment, site, block, site area, area in crops, area in prairie, number of prairie patches, Julian date, survey, and observer. We analyzed bird community response using total bird abundance, species richness, and diversity. We also analyzed the total abundance of 16 individual species that comprised greater than 1% of all observations. Total bird abundance was calculated using all individuals, including females and unidentified species, observed in a site during each survey. Species richness included the number of individual species and/or taxa observed in a site during each survey. Unidentified species were not included in species richness unless they were the only observation or if the taxon (e.g., unknown sparrow, unknown flycatcher) was not already represented by an identified species. We also calculated Simpson's diversity index ($1/D$, where $D = \sum_{i}^{S} p_i^2$ and p_i = proportion of individuals belonging to species i; S = number of species) as a measure of diversity using identified species in all surveys; unknown species were removed from the dataset to avoid inflating diversity values, with the exception of 31 surveys where an unidentified species (e.g., unknown bird, unknown sparrow) was the only observation during a survey. Data included all surveys; surveys with no observations were included as zero.

We modeled the yearly average of the logarithm of avian abundance, richness, and diversity (adding one, the smallest value of each response, to avoid taking the logarithm of zero) using a weighted, mixed effect linear regression model with weights equal to the number of survey periods for that site-year. Block, treatment, and the logarithm of site size were treated as fixed effects and the block-treatment interaction and year were treated as random effects. We also included a binary explanatory variable indicating the establishment year for the treatment plots. We estimated contrasts for the effect of any treatment, i.e. the average of the three prairie treatments, versus control as well as paired comparisons of the different prairie treatments versus control. To assess the need for a spatial model, we computed variograms from geo-located residuals from our models. We found these variograms to be inconsistent with a spatial random field model since the variograms were either flat or decreasing with increasing distance. Thus, we present the results from non-spatial models

Table 2
Confidence intervals (95%) for the multiplicative relationship of treatment (10–20% prairie) versus the control (0% prairie) and for the prairie establishment effect on mean abundance for 16 species comprising 99% of the observations between 2007 and 2012 in the STRIPS experiment at Neal Smith National Wildlife Refuge.

Common name	Scientific name	Treatment	10% prairie bottom	10% prairie strips	20% prairie strips	Establishment
Common yellowthroat	*Geothlypis trichas*	(1.14,1.64)	(1.03,1.54)	(1.12,1.82)	(1.13,1.77)	(0.59,0.87)
American robin	*Turdus migratorius*	(1.02,1.15)	(0.99,1.14)	(1.03,1.21)	(0.99,1.15)	(0.88,1.05)
Eastern kingbird	*Tyrannus tyrannus*	(1.01,1.09)	(1.00,1.09)	(1.03,1.14)	(0.98,1.07)	(0.93,1.11)
Song sparrow	*Melospiza melodia*	(0.99,1.24)	(1.06,1.36)	(0.93,1.24)	(0.92,1.22)	(0.86,1.06)
Brown thrasher	*Toxostoma rufum*	(0.98,1.07)	(0.96,1.05)	(0.97,1.08)	(0.99,1.10)	(0.91,1.05)
Grasshopper sparrow[a]	*Ammodramus savannarum*	(0.98,1.10)	(0.95,1.09)	(0.95,1.12)	(0.99,1.14)	(1.30,1.50)
Brown-headed cowbird	*Molothrus ater*	(0.97,1.10)	(0.96,1.11)	(0.94,1.11)	(0.96,1.11)	(0.73,1.07)
Eastern meadowlark[a]	*Sturnella magna*	(0.97,1.13)	(0.94,1.11)	(0.95,1.15)	(0.98,1.18)	(0.91,1.15)
Vesper sparrow	*Pooecetes gramineus*	(0.96,1.12)	(0.94,1.11)	(0.93,1.14)	(0.96,1.16)	(1.20,1.55)
American goldfinch	*Spinus tristis*	(0.95,1.52)	(0.87,1.47)	(0.86,1.62)	(0.97,1.77)	(0.70,0.88)
Lark sparrow	*Chondestes grammacus*	(0.95,1.06)	(0.94,1.06)	(0.93,1.06)	(0.95,1.08)	(0.92,1.03)
Red-winged blackbird	*Agelaius phoeniceus*	(0.95,2.67)	(0.80,2.59)	(0.81,3.28)	(0.87,3.40)	(0.57,1.18)
Dickcissel[a]	*Spiza americana*	(0.94,2.07)	(0.73,1.83)	(0.81,2.37)	(0.99,2.84)	(0.70,0.95)
Killdeer	*Charadrius vociferous*	(0.87,1.14)	(0.85,1.14)	(0.83,1.18)	(0.87,0.20)	(0.84,1.24)
Indigo bunting	*Passerina cyanea*	(0.81,1.25)	(0.75,1.23)	(0.79,1.44)	(0.74,0.31)	(0.68,1.06)
Field sparrow[a]	*Spizella pusilla*	(0.46,1.60)	(0.46,1.97)	(0.36,1.96)	(0.34,1.82)	(0.68,0.97)

[a]Species of greatest conservation need (IDNR, 2007).

here. We report results as 95% confidence intervals for these contrasts according to the approach promoted by Yoccoz (1991). Analysis was performed using the statistical software R and the R packages lme4 and lsmeans (R Core Team, 2011).

3. Results

We observed a total of 52 species from 2007 to 2012, ranging between 20 and 37 species in each year. Sixteen species comprised 99% of all observations, including many generalist species and four species of greatest conservation need (Table 2). The total number of birds observed per survey ranged from 0 to 33 individuals, and the total number of species observed ranged from 0 to 14 species per survey.

Mean annual bird abundance, species richness, and Simpson's diversity index were all affected by establishment year, block, treatment, and the logarithm of site area (Table 3, Fig. 2). Response measures were positively associated with site area, which was expected due to the survey design (i.e., more time was spent surveying larger sites). Responses for sites in the Basswood block were generally lower than those for sites in the Interim or Orbweaver blocks, which was also expected based on site size (Table 1; Figs. 1 and 2). We organized the remainder of our results according to our hypotheses.

3.1. Presence of prairie strips

We found that the bird community positively responded to the establishment of prairie strips within row crops, with large shifts in total abundance, species richness, and diversity from 0% prairie to 10–20% prairie treatments; specifically, we found 1.50–2.88 times more birds, 1.53–2.13 times more bird species, and 1.40–1.98 times greater diversity in treatments with prairie strips compared to the 0% prairie control (Table 4, Fig. 2). Eastern kingbird (*Tyrannus tyrannus*), American robin (*Turdus migratorius*), and common yellowthroat were more abundant in any treatment with prairie compared to the control; the song sparrow (*Melospiza melodia*) was additionally more abundant in the 10% footslope prairie treatment compared to the control (Table 2, Fig. 3, Appendix A). American goldfinch (*Spinus tristis*), red-winged blackbird, dickcissel (*Spiza americana*), and song sparrow trended toward greater abundance in all treatments with prairie (Appendix A). As expected, we did not find grassland interior species (e.g., bobolink, Henslow's sparrow) using our treatments. Contrary to expectations, no species were statistically more abundant in the 0% prairie control.

Table 3
Estimates of the fixed effects (standard errors) and random effects standard deviations for weighted, linear, mixed effect models of mean annual bird abundance, richness, and Simpson's diversity index for birds observed between 2007 and 2012 in the STRIPS experiment at Neal Smith National Wildlife Refuge.

Parameter	Abundance	Richness	Diversity
(Intercept)	0.69 ± 0.19	0.50 ± 0.12	0.50 ± 0.12
log(total area)	0.46 ± 0.12	0.23 ± 0.07	0.21 ± 0.07
Establishment	−0.26 ± 0.17	−0.19 ± 0.18	−0.15 ± 0.16
Block: Interim	0.62 ± 0.21	0.51 ± 0.11	0.40 ± 0.11
Block: Orbweaver	0.33 ± 0.20	0.28 ± 0.11	0.22 ± 0.11
Treatment: 10% prairie bottom	0.60 ± 0.18	0.51 ± 0.09	0.45 ± 0.10
Treatment: 10% prairie strips	0.74 ± 0.22	0.61 ± 0.11	0.52 ± 0.12
Treatment: 20% prairie strips	0.85 ± 0.21	0.65 ± 0.10	0.56 ± 0.11
Block × Treatment	0.19	0.08	0.09
Year	0.13	0.15	0.13
Residual	0.89	0.63	0.56

3.2. Percent prairie

We did not find significant differences among our prairie treatments in terms of total bird abundance, richness, or diversity. We did, however, record higher levels of each in treatments with multiple prairie strips compared to the treatment of a single prairie strip located at the footslope and the treatment with 20% compared to 10% prairie (Tables 3 and 4), which was directionally consistent with our initial hypotheses. Additional replication is needed to elucidate these patterns.

3.3. Time

We recorded higher levels of total bird abundance, richness, and diversity in post-establishment years compared to 2007, although not significantly so (Table 4, Fig. 2). We did observe significant difference between 2007 and subsequent years for six species (Table 2, Fig. 3, Appendix A): the vesper sparrow (*Pooecetes gramineus*) and grasshopper sparrow (*Ammodramus savannarum*) were found in greater abundance in the establishment year, while the common yellowthroat, field sparrow (*Spizella pusilla*), dickcissel, and American goldfinch were subsequently found in greater abundance. These species plus the Eastern kingbird, American robin, song sparrow, red-winged blackbird, and brown-headed cowbird (*Molothrus ater*) were the most commonly observed species across all years.

4. Discussion

Our objective was to evaluate the strategic integration of diverse native perennial vegetation within annual row crops as a mechanism to promote land sharing within industrial agricultural landscapes of the Midwestern US, a region that produces record quantities of maize and soybean but has also experienced substantial environmental degradation (Robertson and Swinton, 2005; Schulte et al., 2006). We specifically sought to understand bird response to the establishment of prairie strips within annual row crops, based on the presence of prairie, the amount of prairie, and the years since establishment of the prairie. We found positive responses in bird abundance, richness, and diversity to the experimental inclusion of prairie over six years of study, but no statistical differences in these measures as a result of the amount of prairie or time since prairie establishment. We also found positive responses to prairie strips for several grassland generalist bird species, and did not find negative impacts on any of the 16 species commonly observed in this study. Among the 16 commonly observed bird species were four species of conservation concern (Table 2), but we did not detect statistical differences in the abundance of these species based on treatment (Appendix A).

Our results are consistent with other studies documenting substantial improvement in the habitat value of agricultural landscapes that include small patches of semi-natural vegetation (Best, 1983; Camp and Best, 1993, 1994; Hultquist and Best, 2001; Le Couer et al., 2002; Marshall and Moonen, 2002), especially where agriculture is extensive and simplified (Van Buskirk and Willi, 2004). Grassed waterways, field borders, filter strips, and riparian buffers have been shown to increase bird abundance and richness compared to the surrounding farmland in several studies (Bryan and Best, 1991; Marshall and Moonen, 2002; Henningsen and Best, 2005; Conover et al., 2009; Berges et al., 2010). Best et al. (1990) observed about five times more birds using the perimeters of maize fields than the centers, and found that bird abundance in maize fields decrease logarithmically with increases in field size. As farming intensifies, fencerows and other uncultivated areas are removed (Tscharntke et al., 2005), thereby removing small refuges

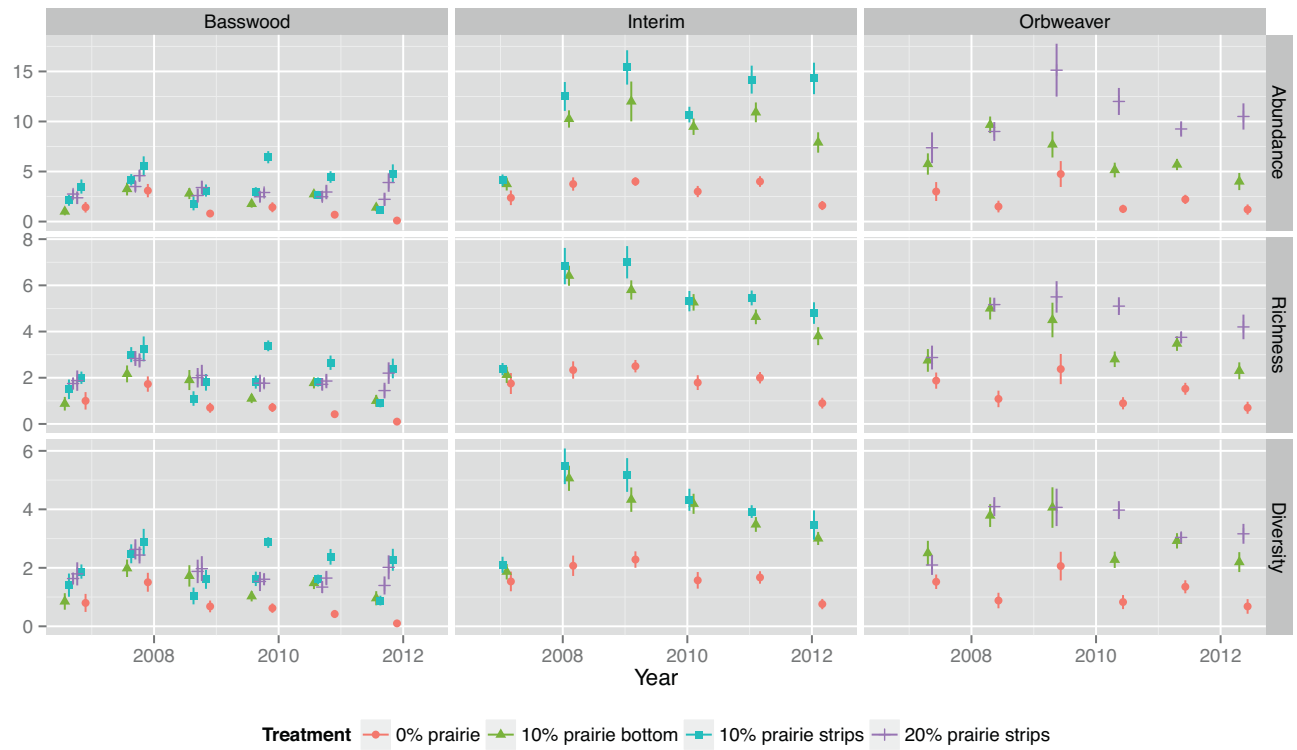

Fig. 2. Mean annual abundance, species richness, and Simpson's diversity index and standard errors by treatment for bird observed between 2007 and 2012 in the STRIPS experiment at Neal Smith National Wildlife Refuge.

Table 4
Confidence intervals (95%) for the multiplicative relationship of the treatment (10–20% prairie) versus the control (0% prairie) and the prairie establishment effect on mean annual bird abundance, richness, and Simpson's diversity index for birds observed between 2007 and 2012 in the STRIPS experiment at Neal Smith National Wildlife Refuge.

Response	Treatment–Control	10% prairie bottom–Control	10% prairie strips–Control	20% prairie strips–Control	Establishment
Abundance	(1.50,2.88)	(1.27,2.61)	(1.36,3.25)	(1.55,3.55)	(0.55,1.09)
Richness	(1.53,2.13)	(1.39,2.00)	(1.47,2.29)	(1.56,2.36)	(0.58,1.17)
Diversity	(1.40,1.98)	(1.29,1.89)	(1.34,2.12)	(1.42,2.18)	(0.63,1.17)

that provide escape cover, foraging sites, and nesting sites (Best, 1983; Marshall and Moonen, 2002).

In comparison to other research assessing the impacts of small patches of semi-natural vegetation, a unique aspect of STRIPS is incorporating prairie, a diverse native perennial vegetation type adapted to regional climate, soils, and biodiversity. Improved habitat quality might be expected with prairie strips in comparison to other agricultural conservation cover types employed in the region, such as grass waterways or field borders of exotic brome or fescue, filter strips of these species or monocultural switchgrass (*Panicum virgatum*), or even multispecies riparian buffers. For example, Van Buskirk and Willi (2004), in their meta-analysis of 127 studies, found a substantial increase in species richness associated with diverse, naturally revegetated agricultural set asides compared to depauperate sown areas. While differences in research design precludes direct comparison with other studies from the region, our results are at least qualitatively similar to those of Henningsen and Best (2005).

Despite the positive response of birds to small patches of semi-natural habitats, such practices are not a conservation panacea: the majority of species using such habitats tend to be generalists and nest success tends to be lower for linear habitats compared to block habitats, even though nest densities may be higher (Best et al., 1995; Clark and Reeder, 2007). In the US, many bird species of conservation concern tend to be area-sensitive, and a number of studies have documented their dependence on large habitat patches (Herkert, 1994; Vickery et al., 1994; Walk and Warner, 1999). While area requirements can vary among species and regions (Herkert, 1994; Johnson and Igl, 2001), linear habitats generally and specifically prairie strips are unlikely to provide adequate breeding habitat for species with strong area sensitivity. For example, Henslow's sparrows and bobolinks – two species of greatest conservation need that exhibit area sensitivity (IDNR 2007) – both occur in adjacent areas of the refuge, but Henslow's sparrows have never been observed within our study sites and bobolinks rarely venture into them from nearby large patches of grassland habitat (Fig. 1). Creating, protecting, and managing large blocks of habitat is critical to stemming biodiversity declines in the US and elsewhere (Fischer et al., 2006; Quinn et al., 2012), especially area-sensitive species (Ryan et al., 1998; Walk and Warner, 1999; Ribic et al., 2009). While prairie strips are not a replacement for large habitat blocks, they could augment a reserve system by helping to create a more structurally diverse habitat mosaic for birds and other taxa (Vickery et al., 1994; Benton et al., 2003). Encouraging a more diverse agricultural matrix may be a critical to achieving overall conservation goals, as some research suggests large blocks of habitat by themselves may not be adequate: increasing the connectivity of large habitat blocks is likely also important (With et al., 2008).

Although our experimental results suggest prairie strips may provide habitat for bird communities and populations in landscapes dominated by industrial maize and soybean production,

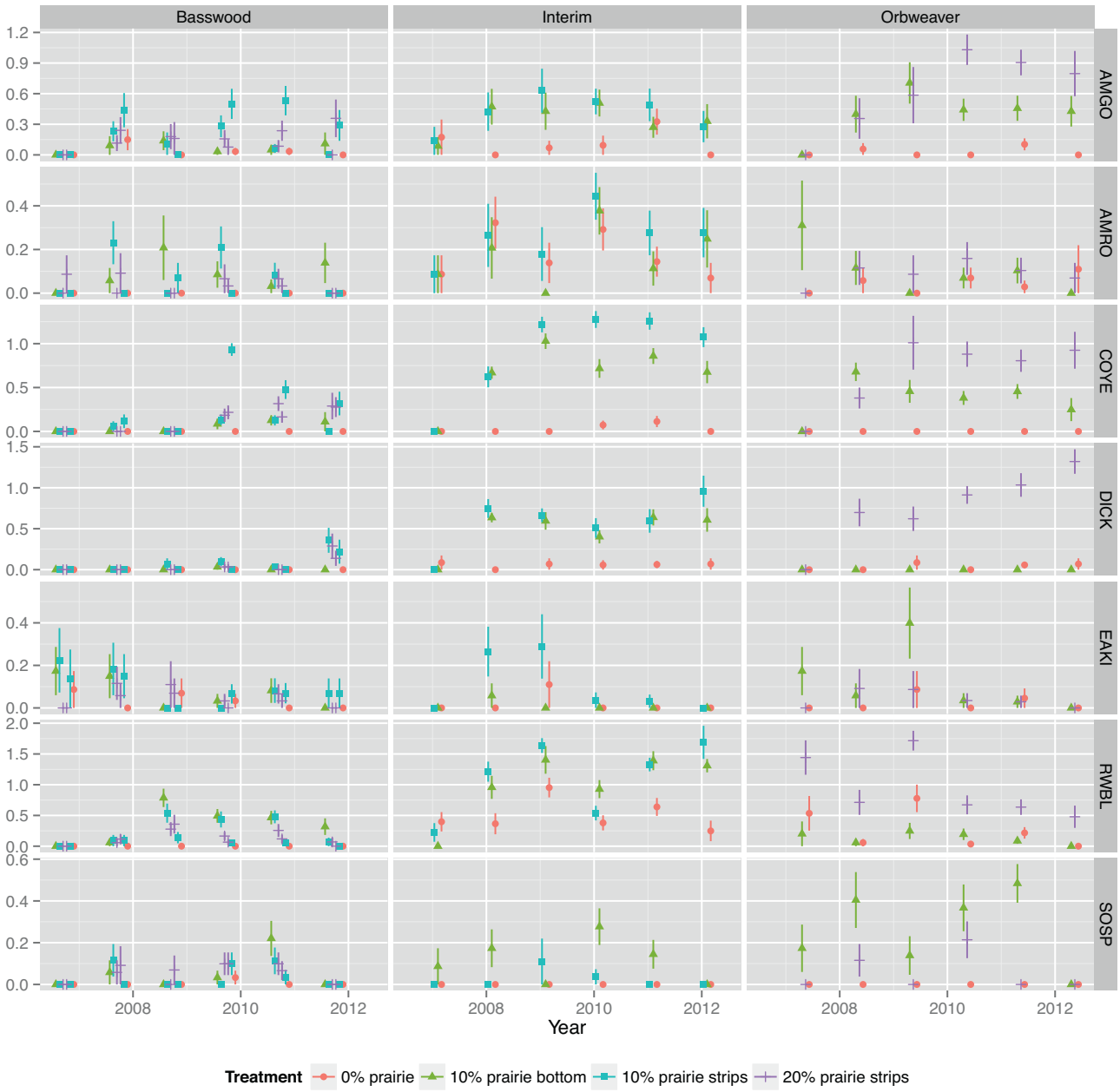

Fig. 3. Mean annual abundance of bird species with significant differences at the 80% level and standard errors by treatment for birds observed between 2007 and 2012 in the STRIPS experiment at Neal Smith National Wildlife Refuge. AMGO = American goldfinch, *Spinus tristis*; AMRO = American robin, *Turdus migratorius*; COYE = common yellowthroat, *Geothlypis trichas*; DICK = dickcissel, *Spiza americana*; EAKI = Eastern kingbird, *Tyrannus tyrannus*; RWBL = red-winged blackbird, *Agelaius phoeniceus*; and SOSP = song sparrow, *Melospiza melodia*.

two caveats are in order. The first of these is landscape context, which is known to impact habitat use by many bird species (Walk and Warner, 1999; Ribic and Sample, 2001; Bakker et al., 2002). Our experiment was located in a 2,300 ha wildlife refuge and surrounded by a heterogeneous matrix of prairie, riparian forests, and additional agricultural land. Whether prairie strips provide the same benefit to birds in simpler agricultural landscapes is unknown, but we now have the opportunity to validate our results in landscapes more typical of the region: in the last two years we have implemented prairie strips on over 20 commercial farm fields across Iowa and northern Missouri. Fields range between 11.7 and 85.0 ha in size, one-to-two orders of magnitudes larger in extent than the initial experiment reported on here; research on these sites began in May 2015. This new research will also help address our second caveat, which is whether prairie strips function as source, neutral, or sink habitat for birds and other taxa.

5. Conclusion

Our experimental research suggests that strategically integrating small amounts of diverse, native, perennial vegetation as prairie strips into annual row crops can promote land sharing by birds. Over six years, we documented a positive response in overall bird abundance, species richness, and diversity to the inclusion of prairie strips in annual row crops. We also found a positive response for four of the 16 bird species commonly observed within our study, and no negative impacts. These results, combined with

others from the STRIPS experiment at Neal Smith NWR (Zhou et al., 2010; Helmers et al., 2012; Hirsh et al., 2013; Cox et al., 2014; Iqbal et al., 2015; Zhou et al., 2014), indicate that prairie strips can address many environmental concerns associated with industrial maize and soybean agriculture in a cost-effective manner (Tyndall et al., 2013). Additional research is now being conducted on commercial farm fields across Iowa and northern Missouri to validate these results and also to understand the impacts of prairie strips on bird fecundity.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2016.01.007.

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