THE INFLUENCE OF AGRICULTURAL PRACTICES ON AVIAN ABUNDANCE IN MIDWESTERN AGRICULTURAL FIELDS

BY

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THESIS

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ABSTRACT

Row crop agriculture has become the predominant land use throughout the Midwest over the last century causing population declines in migratory and resident bird species. To mitigate these declines, we must understand the effect of current agricultural practices on species to make recommendations to farmers and land managers to help support bird populations. I evaluated the use of cover crops on agricultural fields during avian spring migration and evaluated in-field and edge-of-field practices during their breeding season.

Cover crops are a fairly new agricultural practice being adopted at increasing rates throughout the Midwest, but the effect on bird species during their spring migration is unknown and unquantified. Bird surveys were conducted on four field types (corn stubble, corn stubble plus a cover crop, soybean stubble, and soybean stubble with a cover crop) during the spring of 2015 and 2016 in central Illinois to calculate relative bird abundance. To assess the value of the four field types for birds of conservation concern, an Avian Conservation Significance (ACS) value was calculated. Bird species richness and overall abundance were greater in cover crop fields compared to non-cover crop fields, with corn stubble plus a cover crop having the greatest overall bird abundance. Species that preferred cover crop fields were grassland species and a majority of species preferred corn stubble to soybean stubble. ACS values were greatest on cover crop fields, and in particular, on corn stubble plus a cover crop. ACS values were primarily driven by one grassland species, the Eastern Meadowlark (*Sturnella magna*), which is of high conservation concern and an early breeder to which cover crops could serve as an important resource during the early part of the breeding season.

To understand the dynamics of in-field and edge-of-field practices on individual bird species, bird surveys were conducted during the breeding season of 2015 and 2016 throughout central Illinois. In-field practices were crop type, use of a cover crop, tillage usage, and organic management. Edge-of-field practices included the percentage of herbaceous mowed, woody linear, Conservation Reserve Program (CRP), water, and landscape, the amount of area in cash crop production surrounding a field. Overall bird abundance was most influenced by in-field practices and was greatest on wheat fields, no-till fields, fields with a cover crop, and organically managed fields. Wheat fields and cover crop fields may appear important for species because they provide early green habitat in the season that would be attractive to migrants. The most common edge-of-field practice in species' top models was the percentage of CRP which on average made up <2% of the fields it was located on. ACS values were most influenced by in-field practices primarily wheat fields and an additive effect was achieved when in-field practices were paired with the edge-of-field practice, woody linear. ACS values during the breeding season were primarily driven by Dickcissel (*Spiza americana)*, a grassland species of high conservation concern, and wheat fields were very important in supporting their abundance.

This research is the first attempt into understanding which species use cover crop fields and in what abundances compared to non-cover crop fields under the most common management practices (cereal rye and herbicide termination). This research also furthers our understanding of how in-field and edge-of-field practices explain individual species relative abundances as well as how these practices influence birds of greater conservation concern.

To my parents (Tim and Donna) who have always supported me and pushed me to achieve my dreams and gave me the experiences in nature to nurture my love for our Heavenly Father's creation.

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CHAPTER 1

GENERAL INTRODUCTION

Over the last century, land use across the United States has drastically changed with agriculture becoming the dominant land use (Walk et al., 2010) resulting in large areas of monoculture fields with little natural habitat left (Samson and Knopf, 1994). As a result of this loss of habitat, many wildlife species have experienced population declines (Mankin and Warner, 1999, Stuart et al., 2004), with especially drastic declines in the bird community (Herkert, 1995; Walk et al., 2010; Warner, 1994). In order to stop or slow down bird population declines, it is critical to understand how birds use these habitats.

Several species experience their highest mortality rates during their migration to and from their wintering and summer breeding grounds (Brown et al., 2001; Sillett and Holmes, 2002; Sillett and Thomas, 2005; Klaassen et al., 2014). Millions of birds migrate through the Midwest's agricultural landscape and use these lands for cover, foraging, or resting (Hedenström and Alerstam, 1998). Agricultural practices influence how species use fields during migration (Pearse, et al., 2011; Stodola et al., 2014) and it is imperative to understand how new agricultural practices influence species during this time.

One such new, yet ancient, practice is the use of cover crops, which are plants sown into a field for various purposes, but primarily for nutrient management and soil erosion (SAN, 2007). Cover crops are effective at keeping nitrogen on fields thus their inclusion in multiple states' nutrient reduction strategies that were developed to address water quality issues and the Hypoxic zone in the Gulf of Mexico (IDALS et al., 2013; IDA and IEPA, 2015; ISDA and IDEM, 2015). With increased adoption of cover crops in the last decade (SARE et al., 2016), these fields represent potentially beneficial habitat for migrating and early breeding species, but little research has been conducted on birds in these fields.

Possibly the most important period of a birds' life cycle is their breeding season where agricultural practices can either be beneficial or detrimental in supporting their populations (Best et al., 1995; Tews et al., 2013). Agricultural practices can be classified as in-field, where the cash crop is grown, or edge-of-field, areas within or surrounding fields where the cash crop is not grown. Most studies look at one agricultural practice at a time, such as tillage versus no-till or minimal tillage (Duebbert and Kantrud, 1987; Basore et al., 1986; Higgins, 1977; VanBeek et al., 2014) or types of fence rows (Best, 1983; Shalaway, 1985; Sykes and Hannon, 2001), but do not compare the importance of in-field practices versus edge-of-field practices for individual species. Edge-of-field practices have greater potential for management changes (i.e., wildlife habitat can be planted adjacent to fields) versus in-field practices that are more driven by agronomic and economic goals.

Further understanding how in-field practices, such as cover crops, and edge-of-field practices, such as fence rows, influence bird species during their breeding season allows us to make better management recommendations to farmers and land managers. I addressed these knowledge gaps by studying relative bird abundance and the conservation value of birds in cover crop fields during their spring migration and studying the influence of in-field and edge-of-field practices' influence on relative bird abundance and birds of conservation concern during their breeding season.

THESIS ORGANIZATION

This thesis is organized into four chapters: Chapter 1 is a general introduction, followed by Chapter 2 that discusses relative bird abundance in corn stubble, corn stubble plus a cover crop, soybean stubble, and soybean stubble plus a cover crop fields and the possible management implications of cover crop fields for bird populations. Chapter 3 investigates relative bird abundance in in-field and edge-of-field practices during the breeding season. Chapter 4 summarizes conclusions from the previous two chapters and identifies important research gaps for future research.

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CHAPTER 2: USE OF COVER CROP FIELDS BY MIGRATORY AND RESIDENT BIRDS IN THE MIDWEST[1]

ABSTRACT

Cover crops, established between the growing seasons of primary crops to improve soil and water quality, have become increasingly popular in the Midwest; however, the impact on migratory and resident birds is largely unknown. I conducted avian surveys on corn stubble with cover crop, corn stubble only, soybean stubble with cover crop, and soybean stubble only fields in east central Illinois in the spring of 2015 and 2016. For each field type, I calculated relative bird abundance and the Avian Conservation Significance value (ACS). Relative bird abundance was greater in cover crop fields than non-cover crop fields, with the corn fields planted with cover crops providing the greatest value (nearly twice the number of individuals and twice the species compared with non-cover crop soybean fields). The most common species were Red-winged Blackbird (*Agelaius phoeniceus*), Common Grackle (*Quiscalus quiscula*), and American Robin (*Turdus migratorius*). ACS values were most influenced by the Eastern Meadowlark (*Sturnella magna*), a species of high conservation concern. Many agricultural landscapes lack habitat in the spring and cover crop fields may be important areas to provide shelter and forage for birds. While I documented greater use of these fields more research is needed to understand why birds use these fields; more explicitly are birds finding cover, foraging, or attempting to breed in cover crop fields? As the amount of cover crop area increases, the value of these fields for migratory and resident bird use may increase. While habitat for wildlife is a secondary consideration when planting cover crops, my research suggests the use of cereal rye and later

[1]This chapter is in review at Agriculture, Ecosystems and Environment since March 3, 2017

termination of cover crops benefits birds. Cover crops will not replace natural habitats for birds, but the widespread use of cover crops may benefit some bird populations.

INTRODUCTION

Modernization of agricultural practices has led to dramatic changes in the landscape. Today, less than 1% of the historical 24.2 million hectares of grassland in the Corn Belt states of Iowa, Illinois, and Indiana remain (Samson and Knopf, 1994). As a consequence of this habitat loss, many species have experienced drastic population declines across taxa, such as mammals and amphibians (Mankin and Warner, 1999, Stuart et al., 2004). Also, many breeding bird populations that reside in agricultural landscapes have exhibited long-term declines (Herkert, 1995; Walk et al., 2010; Warner, 1994). Additionally, many migratory birds that pass through similar landscapes during migration are declining (Brown et al., 2001; Skagen, 2006; Stodola et al., 2014). In these landscapes where agriculture is the predominant land cover, effective conservation of wildlife will only be accomplished by implementing agricultural practices that benefit wildlife populations.

Few agricultural practices exist that truly benefit wildlife species and the ones that have been shown to be beneficial are those that try to replicate or emulate more natural habitat. They emulate more natural habitats through changes in tillage practices or through the addition of non-tillable ground, that provides more suitable habitat for foraging and nesting. No-till fields, where the ground is not tilled post-harvest and the next crop is planted directly into the previous crops' stubble, support more bird species, greater nest density, and greater nest success than tilled fields for songbirds and waterfowl (Basore et al., 1986; Duebbert and Kantrud, 1987; Higgins, 1977; VanBeek et al., 2014). Presumably because these fields offer some areas for safe nesting and roosting in comparison to traditional practices. Even reduced or minimum tillage, where grain stubble is left standing until spring then plowed, can increase bird abundance and the number of productive territories (Flickinger and Pendleton, 1994; Martin and Forsyth, 2003) for the same reasons. Aside from changes in tillage practices, adding additional habitat, through the creation of buffer and filter strips, as well as grassed waterways can also be beneficial. Grassed waterways, which are channels that transport water off fields, have been shown to support greater abundance of birds and species richness compared to surrounding fields (Bryan and Best, 1994; Fiener and Auerswald, 2003). Similarly, filter strips, herbaceous vegetation strips bordering streams adjacent to agricultural fields, and buffer strips, herbaceous vegetation strips located along any field edge, also support greater bird abundance, species richness, and host more birds of conservation concern (Blank et al., 2011; Josefsson et al., 2013). A growing agricultural practice that could potentially benefit bird populations throughout their annual cycle are cover crops, because the practice may create safe resting and roosting sites, increase insect abundance, and/or provide more suitable nesting habitat.

A cover crop is a plant sown into a field to slow erosion, improve nutrient availability and soil health, increase water availability, and suppress weeds, and control insects and diseases (Creamer, et al., 1995; Dabney et al., 2001; Villamil et al., 2006). The type of cover crop used, whether a grass, brassica, or legume, depends on the landowner's management goals. Cereal rye, a grass, scavenges a large amount of excess nitrogen (N), prevents soil erosion, adds organic matter, and suppresses weeds. Crimson clover, a legume, is a source of N, and also prevents soil erosion, and suppresses weeds. An example of a brassica is radish, which reduces soil compaction, in addition to preventing soil erosion, scavenging nutrients, suppressing weeds, and controlling nematodes (SAN, 2007). In North America, cover crops have been heavily promoted recently and incorporated into several state nutrient reduction plans in response to the Gulf Hypoxia Task Force Action Plan (2008) and the EPA's guidance memorandum (Stoner, 2011) on water quality issues. A thirty-one percent reduction in nitrate was reported with the use of a rye cover crop (IDALS et al., 2013), and out of all field practices, cover crops were estimated to reduce the most N, thus making cover crops a vital component in reducing nutrient runoff (IDA and IEPA, 2015). The 2012 Census of Agriculture (NASS, 2012) reported that Illinois, Indiana, and Iowa combined had over 2.8 million acres in cover crops, and the amount of area in cover crops continues to expand (ISDA and IDEM, 2015; IDALS et al., 2013; SARE et al., 2016).

Cover crops are often promoted as being beneficial to wildlife; however, there is little evidence on its benefits. Some research suggests that cover crops can be used to control pest insects (Bottenberg et al., 1997; Liang and Huang, 1994; Tillman et al., 2004), and provide floral resources for native bees (Ellis and Barbercheck, 2015), yet the benefits to other wildlife remains poorly understood. The only study linking the benefits of cover crops to birds comes from a European study that found more declining farmland bird species in seed bearing cover crops along field edges during the winter months (Stoate et al., 2003). However, cover crops are utilized in vastly different ways in the Midwest than they were in the two previously mentioned studies. In the Midwest, they are planted on whole fields after the main cash crop has been harvested and terminated in early spring before flowering and going to seed if they did not die over winter.

Given the current and projected extent of cover crops, I was interested in investigating its potential benefits to wildlife. Specifically, I investigated how various suites of birds used cover crop fields compared to fields without cover crops during spring migration. I also investigated if there was a difference in relative bird abundance between cover crops planted in corn or soybean stubble fields. After determining the relative avian use of cover crop versus non-cover crop fields, I investigated how these fields contributed to supporting bird species of conservation concern during spring migration using Partners in Flight (PIF) conservation concern scores (Carter et al., 2000). Finally, I discuss the overall impact of cover crops on bird communities in agricultural landscapes.

METHODS

I used sites located in Champaign, McLean, Livingston, and Vermilion counties in central Illinois. I identified farmers using conservation practices and cover crops through local Soil and Water Conservation District (SWCD) and Natural Resources and Conservation Service (NRCS) offices. I selected sites that were in corn-soy or corn-soy-wheat rotation, practicing minimal tillage or no-till, located in predominately agricultural landscapes (>85% cultivated land). Landscape cover type composition was determined by 2014 orthophotographs and United State Department of Agriculture's (USDA) CropScape data layer (USDA NASS, 2014).

Fieldwork was conducted from March through June in 2015 and 2016. Cover crop and non-cover crop fields of corn and soybeans were surveyed, resulting in four combinations: corn stubble only, corn stubble with cover crop, soybean stubble only, and soybean stubble with cover crop. Average field size was as follows: corn only, 37.4 ha (SD 21.1, range 9.0-76.8); corn with cover crop, 30.2 ha (SD 12.0, range 9.1-64.3); soybean only, 42.8 ha (SD 27.5, range 4.1-122.5); soybean with cover crop, 30.8 ha (SD 17.2, range 15.6-84.7).

Cover crops were planted in the fall either immediately before or after harvest of the main crop by drill or broadcast seeding equipment. The majority of cover crops went dormant in the winter and continued growing in the spring, but a few were winter-killed species (oats, radishes). Cover crops can be classified into three broad categories: grass (cereal rye *Secale* *cereale*, annual ryegrass *Lolium multiflorum*, winter wheat *Triticum aestivum*, oats *Avena sativa*, sorghum-sundangrass *Sorghum bicolor* × *Sorghum bicolor* var, *Sudanese*), legume (crimson clover *Trifolium incarnatum*, winter pea *Pisum sativum subsp Arvense*, sunn hemp *Crotalaria juncea*), or non-legume broadleaves (penny cress *Thlaspi arvense*, turnip *Brassica rapa*, rapeseed/canola *B. napus*, oilseed radish *Raphanus sativus*). Thirty-five out of the total 44 cover crop fields surveyed used one cover crop, but 9 used multiple plant species, which is commonly referred to as a "cocktail mix." I constructed four groupings from the three cover crop categories: grass (n=34), non-legume broadleaf (n=4), grass and non-legume broadleaf (n=1), and a grass, legume, and non-legume broadleaf combination (n=5). Within the grass category, cereal rye was the predominant type of cover crop (n=31). Within the two mixed categories, various combinations of annual rye grass, crimson clover, radish, winter pea, and oats were used. The non-legume broadleaves category consisted of pennycress (n=1) and a mixture of radish, rapeseed, and turnip (n=3). All cover crops were terminated with herbicide in the spring at varying times.

Bird Surveys

Bird surveys were conducted from mid-March to mid-May via line transects using auditory and visual detection to identify birds, recording the distance and angle that individual birds were from the transect line (Buckland et al., 2001). Transects started at the perimeter of a field and the observer walked perpendicular to the perimeter towards the center of a field for approximately 10 minutes and then angled back to the edge (not the edge where the survey began). This allowed for both the center and edge of field to be surveyed with approximately the same amount of effort. On average, a field was visited four times, with a minimum of one week in between visits, and transects were walked for fifteen minutes. Surveys were conducted from sunrise to no later than 1200. To control for potential observer bias, fields surveyed by more than one observer were alternately surveyed. To reduce bias due to environmental variables, transects were not conducted in rain nor when wind speeds were above 24 km/hr. Individual fields were sampled at different times in the morning to avoid bias due to time of day. To account for differences in effort, the number of meters walked per transect was recorded using GPS and used to calculate relative bird abundance. I did not include birds flying over fields in analyses.

Birds are categorized into five groups based off their habitat preferences as described in Poole et al. (1992-2002) and as categorized in Vickery et al. (1999); generalists (all habitats), grassland, wetland, tundra, shrub, or forest. Two categories of grassland birds were used; facultative and obligate, where facultative grassland birds may use grasslands at some point in their life cycle, but are not dependent on grasslands like obligates (Vickery et al., 1999). Species that only migrate through the study area were classified as tundra to highlight migratory species utilizing these agricultural fields.

Vegetation Surveys

I quantified vegetation structure in four randomly placed 0.5 m × 0.5 m quadrat vegetation plots the same day bird surveys were conducted for a given field. At each plot, I estimated ground cover by measuring the percentage of bare ground, live vegetation, and dead vegetation. I also measured maximum and average vegetation height (cm) and vertical density (decimeters-dm). Vertical density was measured using the visual obstruction method (VOB) with a Robel pole (Robel et al., 1970). Robel measurements are reported in dm. Previous studies indicate each of these variables are important indicators of habitat use for bird species (Fisher and Davis, 2010).

Statistical Analyses

I calculated relative bird abundance as the total number of birds per 100 meters walked for each transect to control for effort. Because all fields were relatively open and contained similar vegetation structure, I did not account for differences in detection probability among field types. Species with less than 34 observations were excluded from analysis because of lack of inference given the small sample size (Benson, et al., 2011) and there was a natural break in the data at 34. General linear mixed models were created in R version 3.3.1 (R Core Team, 2016) using the package lme4 (Bates et al., 2015) to examine the differences in species relative abundances for the fixed effects of cover and crop type. Year and field were included as a random effect to control for multiple visits within the same year to a field and to control for two years of surveys. I investigated whether the distribution of abundance for species was normal given that several species were relatively rare. I found that given the large number of zeros in the data set the data were not normally distributed, I therefore log transformed the data. ANOVA (type II) was used to examine the differences in species relative abundances between cover and crop types.

I calculated the Avian Conservation Significance (ACS) value (Jessop et al., 2015; Norris et al., 2009; Twedt, 2005; Twedt and Somershoe, 2009; VanBeek et al., 2014) for each transect using the Partners in Flight (PIF) conservation concern scores from bird conservation region (BCR) 22, the eastern tallgrass prairie (PIF, 2012). For species that migrate through my study area, such as plovers, longspurs, and waterfowl, conservation concern scores from their breeding region, BCR 7, the Taiga Shield and Hudson Plain, were used (Carter et al., 2000; PIF, 2012). PIF concern scores reflect population trends, species vulnerability across their entire life cycle and geographic range, and indicates their need for management; scores range from 7 to 35. The total number of birds per 2000 meters was used to calculate species relative abundance for ACS evaluation to avoid negative ACS values for species with low abundance. Although species diversity indices are often used as an indicator of habitat quality, they are less informative when a study system contains species that are very common and of little conservation concern and species experiencing large population declines and are of great conservation concern (Sauer et al., 2013).

I evaluated ACS values using linear mixed models in R version 3.3.1 (R Core Team, 2016) using the package lme4 (Bates et al., 2015). Models included the variables date, year, crop type, and cover type (cover vs no cover) as fixed effects. Assumptions for general linear mixed were tested and residuals were inspected using qqplot and histograms; all models meet the assumptions for general linear mixed model testing. I included the variable field as a random effect to account for non-independence between samples and year to control for year effects. I used leveneTest in the package car (Fox and Weisberg, 2011) in R to assess the assumption of homogeneity among groups for crop type and cover type. The assumption of homogeneity among groups was violated for cover type using a cut off value of 0.05, thus a statement for heterogeneous variance within cover type was included. Models were evaluated using Akaike's Information Criterion (AICc) for small sample sizes and model weight using the AICcmodavg package in R (Burnham and Anderson, 2002; Dochtermann and Jenkins, 2011; Mazerolle, 2016). A candidate model set to evaluate ACS scores included date, crop type, and cover type (cover vs no cover) for main effects and for interactions between crop and cover type (**Table 1**). Model fit improved with the quadratic relationship for date, thus the linear relationship of date was dropped from the candidate model set.

All vegetation variables were averaged by field and year; thus if a field was visited four times, there were 16 vegetation samples taken and thus averaged to get one measurement per field and year combination. Two-sided *t*-tests were used to evaluate vegetation variables' mean values in corn only compared to corn with cover crop fields, as well as soybean only compared to soybean with cover crop fields. Change in vegetation density through time was assessed by using a repeated measures ANOVA using the lsmeans package (Lenth, 2016) in R.

RESULTS

A total of 52 bird species and 6,133 individuals were detected, with 13 species accounting for 90% of all birds detected. The most common species were Red-winged Blackbird (*Agelaius phoeniceus*, 27.5%), Common Grackle (*Quiscalus quiscula*, 10.4%), and American Robin (*Turdus migratorius*, 10%; **Appendix A**). Of the species of which over 40 individuals were detected, there were a total of eight temperate breeding grassland species (six obligate grassland species and two facultative grassland species). There were six generalist species, four species that breed in the tundra, two forest breeding species, and one shrubland breeding species. Relative bird abundance was greater in cover crop fields (3.9 birds/100 m, 95% CI = 3.1, 4.8, n=172) than non-cover crop fields (2.3 birds/100 m, 95% CI = 1.7, 3.0, n=89; t_{268} = 2.5, P = 0.01). Corn with cover crop had greater relative bird abundance than corn only (t_{146} = -2.0, P = 0.05), but the relative abundance of birds in soybean with cover crop was not significantly different than soybean only (t_{111} = -1.0, P = 0.31; **Table 2**).

Relative abundance of individual species varied across corn only, corn with cover crop, soybean only, and soybean with cover crop fields (**Table 3**). Of the six obligate grassland species, two had greater abundance in corn with cover crop fields (Grasshopper Sparrow, *Ammodramus savannarum*; Savannah Sparrow, *Passerculus sandwichensis*), one had marginally greater abundance in corn with cover crop fields (Vesper Sparrow, *Pooecetes gramineus*), one had greater abundance in cover crop fields (Eastern Meadowlark, *Sturnella magna*;), one had greater abundance in soybean only fields (Horned Lark, *Eremophila alpestris*), and one did not show a difference in abundance between cover crop and non-cover crop fields (Dickcissel, *Spiza americana*; **Table 3, Figure 1**). One of two facultative grassland species (Killdeer, *Charadrius vociferous*) showed no difference in abundance in cover or crop type, but the other (Brown-headed Cowbird, *Molothrus ater*) had greater abundance in soybean plus a cover crop, but avoided corn plus a cover crop. Of the six generalist species, three had no difference in abundance in cover or crop type (American Robin, Common Grackle, European Starling, *Sturnus vulgaris*), one had greater abundance in cover crop fields (Mourning Dove, *Zenaida macroura*), one had greater abundance in corn with cover crop fields (Red-winged Blackbird), and one had greater abundance in corn only fields (Barn Swallow, *Hirundo rustica*). Two tundra breeding species showed no difference in abundance in cover or crop type (American Golden-Plover, *Pluvialis dominica*; American Pipit, *Anthus rubescens*), one had greater abundance in corn only fields (Smith's Longspur, *Calcarius pictus*), and one showed no difference in abundance in cover or crop type (Lapland Longspur, *Calcarius lapponicus*).

On average, cover crop fields had greater vegetation density (0.63 dm, 95% CI = 0.47, 0.8, n=44; 0.11 dm, 95% CI = 0.05, 0.17, n=31; t_{73}=5.16, P<0.01) and taller vegetation (15.26 cm, 95% CI = 12.75, 17.78; 3.57 cm, 95% CI = 2.48, 4.65; t_{73}=7.52, P<0.01) compared to non-cover crop fields. On average, the percentages of live and dead vegetation and bare ground were similar among cover crop fields (27.5% live, 95% CI = 23.6%, 31.4%; 44.3% dead, 95% CI = 39.5%, 49.1%; 28.2% bare, 95% CI = 23.4%, 32.9%), but non-cover crop fields were primarily composed of dead vegetation and bare ground (1.5% live, 95% CI = 0.6%, 2.5%; 51.6% dead, 95% CI = 44.0%, 59.4%; 46.9% bare, 95% CI = 39.2%, 54.6%). All vegetation measurements differed between corn only and corn with cover crop fields, as well as soybean only and soybean with cover crop fields, except percentage of dead vegetation in soybean only and soybean with cover crop fields ($t_{33} = 1.3$, $P = 0.20$). Soybean only fields were on average 59% bare, 40% dead vegetation, with less than 1% live vegetation, and all vegetation was less than 2.0 cm in height. Soybean with cover crop fields were on average 40% bare, 33% dead vegetation, 27% live vegetation, moderately dense (0.52 dm) with tall vegetation (11.9 cm). Corn only fields were on average 30% bare, 68% dead vegetation, with less than 2% live vegetation, moderately dense (<0.25 dm), with vegetation height of 6.2 cm. Corn with cover crop fields had on average small amounts of bare ground (20%), moderate levels of live (28%) and dead (52%) vegetation, high vegetation density (0.70 dm), and tall vegetation (17.4 cm). Vegetation density increased over time in both corn with a cover crop ($P < 0.01$) and soybean with a cover crop fields ($P < 0.01$), but decreased in corn only fields ($P = 0.05$) and remained constant in soybean only fields ($P = 0.36$; **Figure 2**).

Both corn and soybean fields with a cover crop hosted a community of birds of greater conservation value than corn and soybean only fields (**Figure 3**). The ACS value for corn with cover crop fields (57.80, 95% CI = 52.50, 63.10, n=113) was greater than corn only fields (39.44, 95% CI = 30.57, 48.31, n=37; $t_{148} = 3.46$, $P<0.01$), and the average score in soybean with cover crop fields (44.69, 95% CI = 35.95, 53.44, n=60) was greater than soybean only fields

(24.60, 95% CI = 18.94, 31.26, n=50; t_{108} = 3.70, P<0.01). The model that best predicted ACS values included the quadratic effect of date ($Date^2$), cover type (cover crop vs non-cover crop), and crop type (**Table 1, Figure 3**). To investigate the relative impact of different species in cover crop and non-cover crop fields, ACS scores per visit were summed, then divided by the total number of visits to all fields. The species driving high ACS scores (a combination of greater abundance and high PIF scores) in cover crop fields were the Eastern Meadowlark and the Red-winged Blackbird (**Appendix D**).

Sixty-three percent of cover crop fields were in the grass category (cereal rye, winter wheat, annual rye grass), and thus we were unable to statistically determine if bird density differed amongst cover crop types. However, of the species with greater abundances in cover crop fields, all except for three species (American Robin, Killdeer, Lapland Longspur) had greater abundances in fields planted with a single grass cover crop than with cocktail mixes (**Appendix C**).

The average termination date of cover crops did not differ between 2015 (April 29th) and 2016 (April 21st, 95% CI = -3.2, 19.2, t_{41}, P = 0.16), but differed based on what cash crop was to be grown (95% CI = 1.8, 22.7, t_{41} = 2.36, P = 0.02). Average termination date of cover crops in corn stubble was April 28th (range: March 28th - May 25th), while average termination date of cover crops in soybean stubble was April 16th (range: March 26th - May 15th).

DISCUSSION

Cover crops are positively associated with the abundances of bird species of high conservation concern. Bird abundance was greater in cover crop fields than non-cover crop fields, with the highest avian abundances found in corn with a cover crop. The preference for cover crop fields is likely a result of greater vegetative cover of cover crops in addition to crop residue. On the whole, when additional habitat structure is added to agricultural fields it becomes more suitable for bird use (Bryan and Best, 1994; Galle et al., 2009; Hultquist and Best, 2001). VanBeek et al. (2014) reported that no-tilled soybean fields hosted a community of birds of greater conservation concern due to increased vegetation structure. Cover crop fields had over five times greater vegetation density than non-cover crop fields and provided greater maximum vegetation height which can be linked to greater grassland bird nesting success in grassland habitats (Granfors et al., 1996; Hubbard et al., 2006; Warren and Anderson, 2005).

This study was the first step in understanding the importance of cover crop fields for birds, and as such it raises several questions; the first of which is, why are birds more likely to use cover crop fields? While the vegetation structure in cover crop fields is more robust, there are at least three hypotheses why birds would use these fields: areas to forage, areas of cover from both predators and the elements, and areas in which to breed. The reasons why certain species use these fields is likely associated with their life history. Migratory birds passing through the region may be using the cover crop fields to forage and rest. As birds spend the majority of their spring migration at stopover sites to rest and forage (Hedenström and Alerstam, 1998), and research shows birds experience the highest mortality rates during migration (Klaassen et al., 2014; Sillett and Holmes, 2002; Sillett and Thomas, 2005), stopover sites are important. High-quality stopover sites are also important as birds that arrive on their breeding grounds earlier in the year typically have greater reproductive success (Harvey et al., 1979; Harvey et al., 1984). The individuals that breed in the area may also be using cover crop fields to build reserves and potentially use these fields for nesting. Given the intensity of agriculture in the Midwest there is limited habitat in which to breed and thus large, dense cover crop fields in spring may be an attractive breeding site for birds; however, whether birds can reproduce in these sites or if they are ecological traps (Battin, 2004) is a subject for further investigation.

My data showed cover crop fields hosted a community of birds of greater conservation concern that was primarily driven by the Eastern Meadowlark. The Eastern Meadowlark, a species of high conservation concern and early migrant, had the greatest abundance in cover crop fields than non-cover crop fields, and roughly one-third (32.1 %) of their population is located in the Eastern Tallgrass Prairie region of the Midwest (PIF, 2012), the region in which this study was conducted. As meadowlarks arrive early in spring, the limited cover due to the majority of landscape being non-cover crop fields may concentrate this species in cover crop fields. Cover crop fields could be beneficial by providing temporary habitat at the time when meadowlarks are migrating through the area or preparing to breed. Meadowlarks could also be attempting to breed in these fields; while searching the cover crop fields for nests was beyond the scope of this study, I observed behavior that suggests meadowlarks may be attempting to breed in these fields.

Given that cover crop fields may be important for migrating and potentially breeding birds, the type of cover crop and how it is managed could improve the fields for bird use. The most common type of cover crop used in my study was grass and the majority of these fields were planted to cereal rye. Cereal rye also may provide the most benefits to birds, as most species that had greater abundances in cover crop fields were found in even greater abundance in cereal rye fields (**Appendix C**). While these fields are a monoculture of grass, they are often vegetatively dense. The structure alone may attract birds; in addition, these fields may harbor more potential food items such as spiders, beetles, and worms compared to fields without a cover crop (Jackson and Harrison, 2008; Lundgren and Fergen, 2010; Rogers et al., 2004). My sample size for other types of cover crops was small and additional research is needed on the value of different cover crops for birds.

The termination of cover crops is likely the major activity that both has the greatest influence on birds and could be “managed” to help birds. Termination of cover crops is tightly related to what cash crop is to be planted. Currently, cover crops are terminated fairly early in the spring; April 16th when corn is planted and April 28th when soybean is planted on average in my study area, to provide sufficient time to prep fields for the ensuing cash crop. Timing of planting varies greatly annually and by crop; on average from 2011-2016, 52% of corn and 7% of the soybean crop were planted by the first week in May in Illinois (USDA, 2016). If cover crop termination was delayed to early May, early breeders may experience a net gain in nest success, while neutralizing the possible negative effects of termination for later breeders. More research is needed, but it seems clear that the later the termination date is, the better for birds, except for the caveat that if birds are breeding in these fields, early termination may result in the birds not attempting to breed and thus expending energy on a doomed nesting attempt.

The use of cover crops is a growing practice in the Midwest primarily because of the benefits to farmers and their agricultural system. Cover crops can suppress weeds and weed seeds (Creamer, et al., 1995), reduce soil erosion (De Baets, et al., 2011), and the longer cover crops grow, the more N is recovered (Komatsuzaki and Wagger, 2015), thus more N is available when the cash crop needs it, possibly reducing the reliance of chemical N sources. Given the hypoxia issues associated with N coming from agricultural fields, cover crops stand to help improve this environmental issue (IDALS et al., 2013; IDA and IEPA, 2015; ISDA and IDEM, 2015). Beyond the value that cover crops provide the farmer and to improving water quality, cover crops could provide important habitat for migrating and breeding birds.

TABLES AND FIGURES

Table 1. Model ranks for Avian Conservation Significance (ACS) values per transect for main effects of Date^2, Crop type, and Cover type (cover vs no cover) and interactions between Crop type and Cover type in central Illinois, 2015-2016. All bird species were included in calculating ACS values.

Model	K	AIC_c	Δ	w_i
Date^2 + Cover type + Crop type	9	2420.35	0.00	0.68
Date^2 + Cover type * Crop type	10	2422.42	2.06	0.24
Date^2 + Cover type	8	2425.54	5.18	0.05
Date^2 + Crop type	7	2427.15	6.80	0.02
Date^2	6	2435.03	14.67	0.00
Crop type + Cover type	7	2480.83	60.48	0.00
Crop type * Cover type	6	2484.13	63.78	0.00
Crop type	5	2485.60	65.25	0.00
Cover Type	6	2489.83	69.48	0.00
Null	4	2497.17	76.82	0.00

Table 2. Total bird species relative abundances (# birds/100 m) and number of species by field type with 95% confidence intervals. Number of fields (n) and total number of individuals detected per field type are also included. Surveys were conducted in east-central Illinois, 2015-2016.

Field Type	Fields (n)	Individuals Detected	# of Birds / Effort (100 m)	Species (n)
Corn	13	516	2.2 (1.5, 2.9)	28
Corn + Cover Crop	27	3431	4.4 (3.2, 5.6)	44
Soybean	18	938	2.4 (1.5, 3.4)	23
Soybean + Cover Crop	17	1248	3.0 (2.3, 3.7)	34
Totals	75	6133	3.4 (2.8, 4.0)	52

Table 3. Species relative abundance (# of birds/100 m) results in cover and crop type, and the interaction between cover and crop type with habitat where greatest abundance occurred. Species are grouped by order. Only birds with 40 or more observations were included for analysis. Surveys were conducted in east-central Illinois, 2015-2016.

		Chisq value (p-values)			Response		
Species	**Alpha Code**	**Cover**	**Crop**	**Interaction**	**Cover**	**Crop**	**Interaction**
American Golden-plover	AMGP	0.16 (0.69)	1.24 (0.2)	2.90 (0.09)	-	-	-
Killdeer	KILL	0.49 (0.48)	2.30 (0.13)	0.85 (0.36)	-	-	-
Mourning Dove	MODO	**4.08 (0.04)**	0.59 (0.44)	0.42 (0.52)	cover	-	-
American Pipit	AMPI	1.67 (0.20)	0.63 (0.43)	2.21 (0.14)	-	-	-
American Robin	AMRO	0.69 (0.41)	2.47 (0.12)	1.53 (0.22)	-	-	-
Barn Swallow	BARS	0.07 (0.78)	**6.86 (< 0.01)**	1.39 (0.24)	-	corn	-
Brown-headed cowbird	BHCO	0.01 (0.92)	0.09 (0.77)	**6.55 (0.01)**	-	-	soybean + cover crop
Common Grackle	COGR	0.08 (0.77)	0.63 (0.43)	0.62 (0.43)	-	-	-
Dickcissel	DICK	1.65 (0.20)	1.15 (0.28)	0.68 (0.41)	-	-	-
Eastern Meadowlark	EAME	**8.02 (< 0.01)**	1.96 (0.16)	0.01 (0.93)	cover	-	-
European Starling	EUST	0.12 (0.73)	0.88 (0.35)	0.25 (0.62)	-	-	-
Grasshopper Sparrow	GRSP	**7.63 (< 0.01)**	**4.88 (0.03)**	0.02 (0.88)	cover	corn	-
Horned Lark	HOLA	**5.83 (0.02)**	**37.46 (< 0.01)**	**11.18 (< 0.01)**	no cover	soybean	soybean only
Lapland Longspur	LALP	1.12 (0.29)	0.47 (0.49)	0.06 (0.81)	-	-	-
Red-winged Blackbird	RWBL	**38.02 (< 0.01)**	**20.59 (< 0.01)**	**5.34 (0.02)**	cover	corn	corn + cover crop
Savannah Sparrow	SAVS	**3.61 (0.06)**	**7.26 (< 0.01)**	1.81 (0.18)	cover	corn	-
Smith's Longspur	SMLO	1.77 (0.18)	**7.82 (< 0.01)**	0.12 (0.72)	-	corn	-
Song Sparrow	SOSP	0.09 (0.76)	**7.01 (< 0.01)**	0.66 (0.42)	-	corn	-
Vesper Sparrow	VESP	**3.29 (0.07)**	**20.79 (< 0.01)**	0.62 (0.43)	cover	corn	-

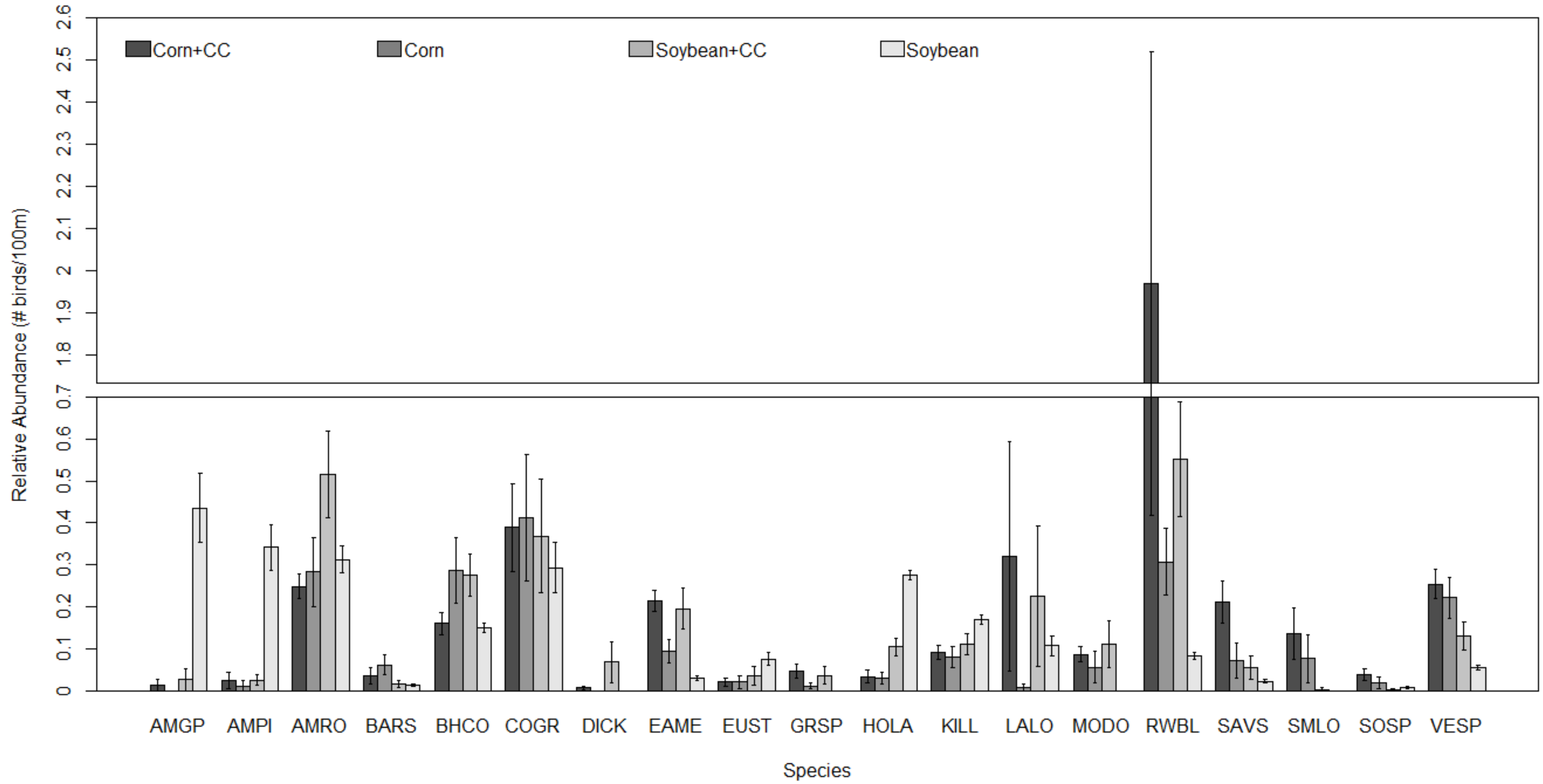

Figure 1. Species relative abundances (# of birds/100 m) by field type (Corn+CC = Corn + Cover Crop, Soybean+CC = Soybean + Cover Crop) with standard error for species with over 40 observations. Relative abundances were calculated per transect and averaged by field type. Refer to Table 3 for species codes. Transect surveys conducted in east-central Illinois, 2015-2016.

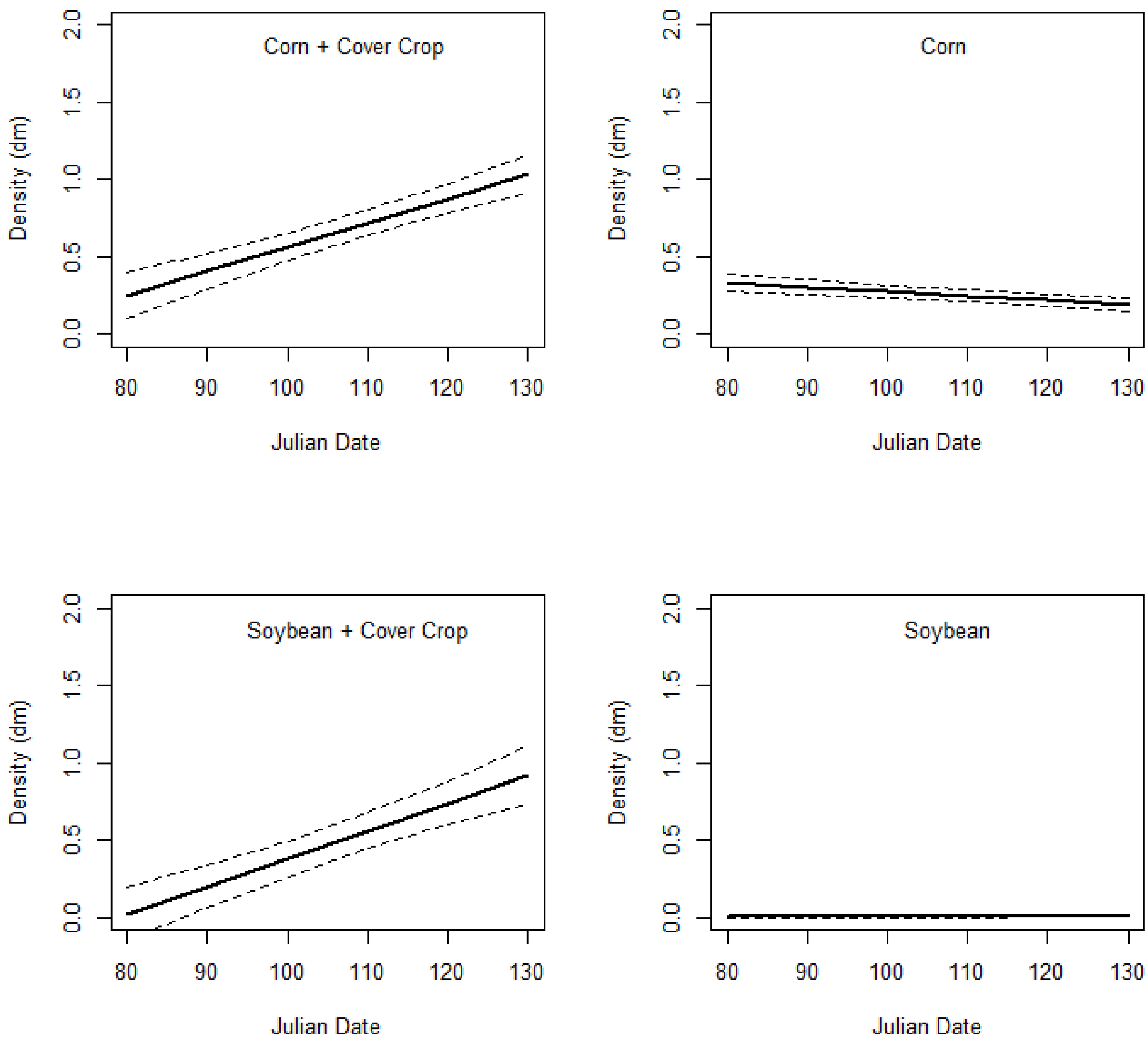

Figure 2. Vegetation density (measured in decimeters) across time based on predicted values of the model field type × date. Dashed lines indicate standard error of predicted values. Day 80=March 20th and 130=May 9th. Vegetation surveys were conducted on fields in east-central Illinois, 2015-2016.

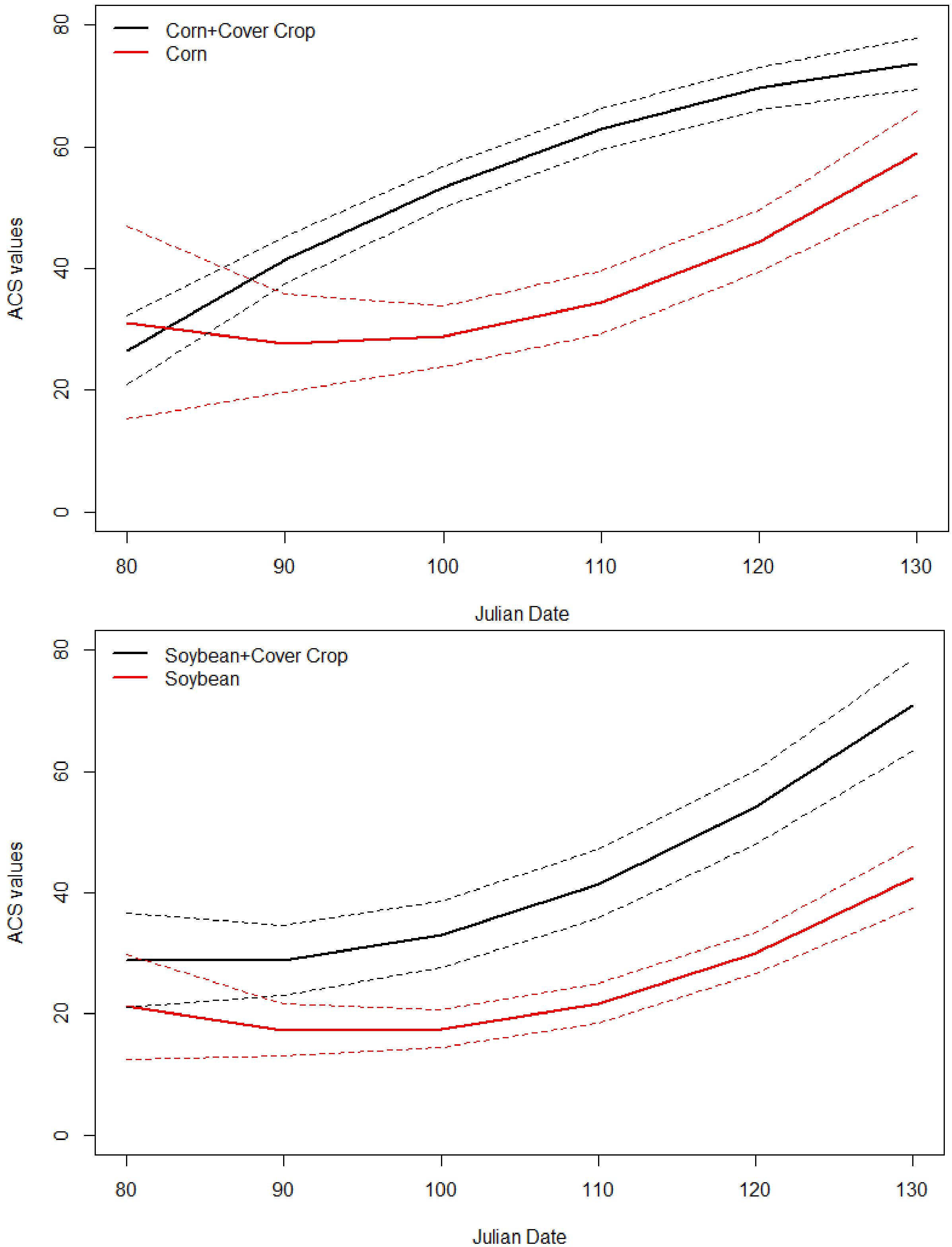

Figure 3. Avian Conservation Significance (ACS) values in (a) corn with cover crop and corn only, (b) soybean with cover crop and soybean only across time based on predicted values of the model date^2 + cover type + crop type. Dashed lines indicate standard error of predicted values. Day 80=March 20th and 130=May 9th. Bird surveys were conducted on fields in east-central Illinois, 2015-2016.

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CHAPTER 3: THE INFLUENCE OF DIFFERENT AGRICULTURAL PRACTICES ON THE BREEDING BIRDS IN THE MIDWEST

ABSTRACT

In the past century and a half, agriculture has become the single largest land use in the Midwest resulting in the loss of native habitat for breeding birds. The goal of this research was to understand how agricultural practices influence breeding bird abundance. Bird surveys were conducted during the breeding season on conventionally and organically managed fields in east central Illinois in 2015 and 2016. Agricultural practices can be classified as in-field, those located where the cash crop is grown, and edge-of-field, those located on the edges or within fields, but not where the cash crop is grown. To assess how agricultural practices in a predominately agricultural landscape influence bird species, I examined relative bird abundance across several in-field and edge-of-field practices. I also calculated the Avian Conservation Significance value (ACS) for each field to evaluate how practices were influencing birds of conservation concern. Total bird abundance and ACS values were most influenced by in-field practices, most notably crop type. Total bird abundance and ACS values were greatest on wheat fields, no-till fields, and on fields with a cover crop. Although total bird abundance was greatest on organically managed fields, ACS values were not significantly different between organically managed fields and those that were not organically managed. Although in-field practices were most important in explaining individual species abundances and ACS values, there was an additive effect when edge-of-field practices were included that demonstrated the need for increased acreage of edge-of-field practices. Further understanding how particular species, especially species of conservation concern, are influenced by in-field and edge-of-field practices

is vitally important in order to make management recommendations to land managers and farmers to help support bird populations.

INTRODUCTION

Worldwide large areas have been converted to agriculture over the past century, leading to population declines in many taxa (Mankin and Warner, 1999; Stuart *et al.*, 2004). Most notably in the United States and Europe, bird population declines have paralleled agricultural intensification with the greatest decline in grassland species (Warner, 1994; Herkert, 1995; Donald *et al.*, 2001; Donald *et al.*, 2006; Herzon *et al.*, 2008; Walk *et al.*, 2010). A part of agricultural intensification is the increased use of herbicides and pesticides (Osteen and Fernandez-Cornejo, 2013) that has led to less weed seeds and insects for foraging birds, which decreases abundance (Freemark and Boutin, 1995; Taylor *et al.*, 2006; Chiron *et al.*, 2014). Intensive agriculture has become predominant in developed countries and has resulted in extensive monoculture crop fields with little natural habitat remaining (Samson and Knopf, 1994). The habitat that does remain within and along the edges of fields is often not just the remnants of natural habitat, but agricultural practices that producers engage in due to broad agricultural policy (i.e., Farm Bill programs, such as Conservation Reserve Program (CRP)). While there has been a shift to intensive large-scale agriculture, the relatively large proportion of land in agriculture dictates that we understand how different agricultural practices promote or inhibit species in these regions.

Governments have developed policies over the last century to stabilize global food production systems, promote rural development, and protect the environment in which various governmental programs pay farmers to either not farm critical habitats or create new habitat patches (Council of the European Union, 2005; Graddy-Lovelace and Diamond, 2017). In the United States, one of the more popular and beneficial agriculture programs for birds is CRP (Johnson and Schawartz, 1993; Best, 2000; Burger, 2006); in Europe, the European Union funds the agri-environment schemes (AES) which is designed to protect and enhance the environment on farmlands (Heard *et al.*, 2001; Batary *et al.*, 2015). Programs in both countries have been beneficial in supporting populations of game and non-game species (Patterson and Best, 1996; Heard *et al.*, 2001; Bakker *et al.*, 2004; Nielson *et al.*, 2008; Riffell *et al.*, 2008; Grovenburg *et al.*, 2012; Bright *et al.*, 2015; Fischer and Wagner, 2016; Wiggers *et al.*, 2016). For example, even though only a small percentage of all agricultural lands in the United States are enrolled in CRP (USDA FSA, 2013; USDA NASS, 2012), the program is beneficial to birds.

The agricultural practices a landowner implements have an impact on the bird community in that field (Bryan and Best, 1991; Lokemoen and Beiser, 1997) and can generally be classified as in-field or edge-of-field. In-field practices occur on areas where crops are being produced during the growing season, while edge-of-field practices may be located within or around fields, though the crop is not grown on these areas. The species present in fields are driven by not only in-field practices, such as crop type, type of tillage regime, organic management, and use of cover crops (Flickinger and Pendleton, 1994; Quinn *et al.*, 2012), but also edge-of-field practices, such as fencerows, CRP, grassed waterways and buffer strips (Bakker *et al.*, 2004; Conover *et al.*, 2009; Wretenberg *et al.*, 2010). Fields that are managed organically use non-genetically modified organisms, green manure as fertilizer, and utilize a three-crop rotation. Given that land managers have certain agronomic and economic goals in mind when managing their working land and thus influencing the in-field practices used, it is possible there are greater opportunities for conservation with the edge-of-field practices rather than in-field agricultural practices.

In addition to in-field and edge-of-field practices, the surrounding landscape may influence the abundance of species in an agricultural field (Batary *et al.*, 2010; Fischer *et al.*, 2011; Morelli, 2013; Chiron *et al.*, 2014)), but not all species respond to the amount of surrounding landscape in a similar manner due to species' habitat preferences (Concepcion and Diaz, 2011; Fischer *et al.*, 2011; Chiron *et al.*, 2014). Understanding the role of landscape could help identify potentially important areas for bird populations and help certain in-field and edge-of-field practices be more beneficial and effectively implemented. Because the Midwest is predominately in row crop agriculture, it is critical to understand how the surrounding land use around fields influences avian species.

This study focuses on relative bird abundance during the breeding season in working agricultural fields and to understand this I looked at in-field practices and edge-of-field practices to determine which of these factors led to greater abundance of breeding birds. I used a two-tiered approach, first evaluating in-field practices then edge-of-field practices. I also used the Partners in Flight (PIF) conservation concern scores (Carter et al., 2000; PIF, 2012) to evaluate the influence of in-field and edge-of-field practices on the relative conservation value of the bird community in these fields. I then discuss the importance of a few key in-field and edge-of-field practices in supporting bird abundance in an agricultural landscape. I studied bird species during the breeding season with the expectation that understanding how in-field and edge-of-field practices influence these species will improve our ability to provide recommendations to farmers and land managers on what practices will improve bird populations.

METHODS

Fieldwork was conducted on corn, soybean, and winter wheat fields located in Champaign, McLean, Livingston, and Logan counties in central Illinois in 2015 and 2016. Fields were identified with the help of local Natural Resource and Conservation Service offices, Soil and Water Conservation District offices, and several Nature Conservancy personnel and selected to represent a variety of agricultural practices. Fields were managed either conventionally or organically and all organic farms were certified through the company Ecocert ICO, whom certifies that a farm meets the requirements for the USDA organic label (Ecocert, 2017).

Agricultural Practices

Agricultural practices were broken up into two categories: in-field, practices where the cash crop, which is a crop grown for commercial purposes, is located during the growing season, and edge-of-field, practices where the cash crop is not grown, but can be located within the field or directly adjacent to the field, such as a grassed waterway. All in-field practices are categorical variables and edge-of-field practices were the percentage of area that was in the given edge-of-field practice compared to the rest of the field (**Table 4)**. Practices falling into the no-till category were no-till and strip till, which only disturbs soil where the seed row is located. The tillage category included both the use of a chisel plow and vertical tillage; no moldboard plowing occurred on any field in this study. Organic fields utilize non-synthetic fertilizers, non-GMO seed, cover crops, and cultivation on a 3 crop rotation. Fields were categorized as using a cover crop if a cover crop was utilized after post-harvest up to the growing season of the current cash crop. Edge-of-field practices were broken into the percentages of the following: woody linear, herbaceous mowed, CRP, and water. Woody linear includes habitat from fence lines to hedgerows; whereas herbaceous mowed includes habitat from grassed waterways to roadside ditches that do not have any woody plants and are periodically mowed. CRP refers to habitat under a specific program CP-33, habitat buffers for upland birds (USDA FSA, 2017). Although CRP could be classified under the herbaceous mowed category, it is of particular interest and thus separated out. Landscape was calculated as the percentage of land in cash crop production within a 1.5 km buffer surrounding a given field perimeter. The landscape variable excludes land already accounted for in the other edge-of-field practices listed in **Table 1**. For example, a fencerow that is on average 5 meters wide is considered an edge-of-field practice because farmers have the ability to remove it if they want to, whereas larger forested areas greater than 3 hectares were not considered an edge-of-field practice, but part of the surrounding landscape. Field size (hectares) and percentage of edge-of-field practices were calculated based off of 2015 Orthophotographs (USDA 2015). Nearly all fields were in an annual corn-soybean rotation.

Bird Surveys

Bird point counts were conducted from late May to early July. Survey locations were placed at the perimeter of a field primarily in a roadside ditch at least 250 m from the field edge on either side. If fields were larger than 14 ha and field perimeters were accessible by road, they received 2 point counts for each visit and survey locations along the perimeter were placed at least 250 m apart from each other. Fields were visited on average 4 times (Range = 1, 9) with at least one week in between observations and observers alternated fields and order of fields surveyed to control for observer or time bias. Visual and auditory detections were used to detect birds within a 5-minute time period with distance and angle from observer recorded after a oneminute settling period. Point counts were conducted from sunrise to no later than 900, when wind was less than 24 km/hr. and no precipitation was present.

Results of analyses on species relative abundances are described by habitat preferences and categorized into six categories using Poole et al. (1992-2002) for non-grassland species and Vickery et al. (1999) for grassland species. Categories are as follows: generalists (all habitats), wetland, tundra, shrub, forest and grassland. Two categories of grassland species were used as defined in Vickery et al. (1999): obligate, where species are exclusively adapted and dependent on grassland habitats, and facultative, where species use grasslands as one of several habitats.

Statistical Analyses

Relative bird abundance was calculated by dividing the total number of birds per field by the total number of point counts conducted. For species with over 40 individuals detected throughout the survey, linear mixed models were created to test the influence of the fixed effects of in-field and edge-of-field practices on relative abundance. Field was included as a random variable to account for non-independence between fields because some fields were surveyed in both years and other fields were surveyed only one of the years. Edge-of-field practices were normalized between the values 0 to 1 for direct comparison to in-field practices. Models were evaluated using Akaike’s Information Criterion (AIC) for model selection in the AICcmodavg package in R 1.0.136 (Dochtermann and Jenkins, 2011; Mazerolle, 2016). Two sets of candidate models were created, the first set included the fixed main effects of in-field practices only: corn, wheat, soybean, cover crop, tillage, and organic. The second set of models included edge-of-field practices: herbaceous mowed, woody linear, CRP, water, and landscape. The variable/s in the top model from the in-field practices model set was included as an additive fixed effect to several models in the edge-of-field practices model set and also as a main effect to use as a null model (**Table 5**).

To determine what practices had the most influence on the conservation value of the bird community in these fields, the Avian Conservation Significance (ACS) value (Jessop et al., 2015; Norris et al., 2009; Twedt, 2005; Twedt and Somershoe, 2009; VanBeek et al., 2014), that incorporates PIF conservation scores (Carter et al., 2000; PIF, 2012), were calculated for all species. PIF scores were used from the bird conservation region (BCR) 22, the eastern tallgrass prairie, the location of the study. PIF concern scores reflect population trends, species vulnerability across their entire life cycle and geographic range, and indicates their need for management; scores range from 7 to 35. To calculate ACS, the natural log is taken of species relative abundance; thus to avoid negative numbers due to some species abundances being less than 1, species abundances were multiplied by ten . The same linear mixed models were created to test ACS values and the same in-field and edge-of-field candidate model sets were used to evaluate agricultural practices' influence on the conservation value of the bird community, except that corn, soybean, and wheat were grouped into one category of crop type. Assumption of homogeneity was assessed among the variables tillage, crop, organic, and cover crop using the leveneTest in package car (Fox and Weisberg, 2011) in R and a cut off value of 0.05. The variable tillage violated the assumption of homogeneity therefore a statement to control for heterogeneous variation was included in models with that particular variable. Residuals of models were visually inspected using qqPlot from the package car (Fox and Weisberg, 2011) and histograms and the models met the assumptions of a normal distribution. Traditional diversity indices were not calculated in this paper because they lack the ability to account for differences in species population dynamics (Sauer et al., 2013) and conservation status.

RESULTS

A total of 8,546 individuals of 48 species were detected, with thirteen species accounting for 90.7% of all observations. The most common species detected during the surveys were Red-winged Blackbird (*Agelaius phoeniceus*, 33.2%), Common Grackle (*Quiscalus quiscula*, 13.3%), and Dickcissel (*Spiza americana*, 12.7%; **Appendix E**). Of the species that had over 40 observations, there were a total of nine temperate breeding grassland species (five facultative grassland species and four obligate grassland species), eight generalist species, and two shrubland species (Poole et al., 1992-2002; Vickery et al., 1999). In-field practices were the most important set of practices on overall bird abundance when all in-field practices were compared to all edge-of-field practices (**Table 6**). Total bird abundance was greatest in wheat (20.65 # of birds/point count, 95% CI = 16.61, 24.70, n=18) and soybean fields (13.91 # of birds/point count, 95% CI = 12.37, 15.45, n=70) compared to corn fields (11.35 # of birds/point count, 95% CI = 10.12, 12.57, n=70; $F_{2,56}$ = 17.80, $P < 0.01$). Total bird abundance was greater on fields that utilized a cover crop (15.54 # of birds/point count, 95% CI = 13.72, 17.36, n=74) than fields that did not have a cover crop (11.79 # of birds/point count, 95% CI = 10.71, 12.86, n=84; t_{156} = 3.63, P <0.01), and abundance was greater on fields that were no-till (14.95 # of birds/point count, 95% CI = 13.55, 16.36, n=84) versus those that were tilled (11.94 # of birds/point count, 95% CI = 10.40, 13.49, n=74; t_{156})= -2.87, $P < 0.01$). Fields that were managed organically (16.31 # of birds/point count, 95% CI = 13.86, 18.75, n=52) hosted greater bird abundance than fields managed conventionally (12.19 # of birds/point count, 95% CI = 11.24, 13.14, n=106; t_{156} = 3.77, $P < 0.01$).

In-field practices were the most important set of practices for 9 out of the 19 species tested, when all in-field practices were compared to all edge-of-field practices. The in-field practice crop type was the most important variable for explaining species relative abundances for 9 out of the 19 species tested, followed by use of a cover crop that explained bird relative abundances for six species out of the 19 tested. Soybean was positively correlated with two obligate grassland species, one facultative grassland species, and one generalist species, but negatively correlated with one generalist species. Wheat was positively correlated with one obligate grassland species, one generalist species, and negatively correlated with one facultative grassland species. The use of cover crops was positively correlated with one facultative and one obligate grassland species but negatively correlated with one shrubland, one generalist, and one obligate and one facultative grassland species. The next most common in-field practice to explain bird species relative abundances was organic management that was positively correlated with three generalist species, but negative for one obligate and one facultative grasslands species. When comparing all in-field practices versus all edge-of-field practices, edge-of-field practices were only important for 3 out of the 19 species, with the percentage of CRP appearing the most frequently. The percentage of CRP on a field explained five bird species relative abundances; CRP was positively correlated with two obligate grassland species, one facultative grassland species, and one shrubland species, but negatively correlated with one facultative grassland species. Four of the 19 species had woody linear habitat come up as the most important edge-of-field practice with positive correlations and these birds were also the shrubland and facultative grassland birds. Another four species had landscape in the top model for edge-of-field practices and landscape was positively correlated with two generalist species, but negatively correlated with one generalist and one facultative grassland species (**Table 7**).

In-field practices had the most influence on ACS values when comparing all in-field practices versus all edge-of-field practices in an AIC model set and the main variable driving in-field practices' influence on ACS scores was crop type, followed by no-till and cover crops (**Table 8**). ACS values were greater in wheat (11.59, 95% CI = 9.93, 13.25, n=18) and soybean fields (10.94, 95% CI = 10.00, 11.88, n=70) compared to corn fields (9.81, 95% CI = 8.89, 10.73, n=70; $F_{2,56}$ = 3.62, P = 0.03). ACS values were significantly greater in no-till fields (11.23, 95% CI = 10.31, 12.14, n=84) compared to tilled fields (9.71, 95% CI = 8.94, 10.47, n=74; t_{156} = -2.50, P = 0.01). Fields that used a cover crop (11.18, 95% CI = 10.22, 12.15, n=74) hosted birds with higher PIF concern scores than fields that did not utilize a cover crop (9.92, 95% CI = 9.16, 10.69, n=84; t_{156} = 2.06, P = 0.04), however values did not differ between fields that were organically managed (10.54, 95% CI = 9.51, 11.57, n=52) versus those that were conventionally managed (10.50, 95% CI = 9.74, 11.27, n=106; t_{156} = 0.05, P=0.96). The top model predicting ACS values for in-field practices included crop type, tillage type, and cover crop usage. When the top model for in-field practices was incorporated into the edge-of-field practices model set, the top model predicting ACS values included crop type, cover crop, tillage, percent herbaceous mowed and percent woody linear (**Table 9, Figure 4**). Although ACS values increased as the percentage of herbaceous mowed increased, the increase was smaller than that for percent woody linear. The top species driving the ACS values was the Dickcissel, followed by the Red-winged Blackbird and the Eastern Meadowlark (**Appendix F**).

DISCUSSION

In-field practices were most important in explaining avian relative abundances, especially grassland species and there could be several reasons for this. The area in in-field practices is larger than edge-of-field and certain practices such as crop type, covers crops, and no-till could lead to greater cover within the field that would provide opportunities for nesting (Rodenhouse and Best, 1983; Flickinger and Pendleton, 1994; Lokemoen and Beiser, 1997; VanBeek et al., 2014) and potentially provide more forage items (Rodenhouse and Best, 1994; Clark et al., 2006; Dubie et al., 2011).

Fields that provide early green vegetation are attractive to migrating birds and wheat and cover crop fields provide such vegetation before soybean and corn are planted. They are perhaps the most important in-field practices because they attract migrating birds to a field. Declines in small grain fields, such as winter wheat across the Midwest have been cited as a contributing factor in grassland species population declines (Warner 1994; Walk et al., 2010). Cover crops were in the top model for more grassland species than wheat possibly due to the small number of wheat fields (**Table 4**), but wheat fields appeared very important to one particular obligate grassland species and one generalist (Dickcissel and Red-winged Blackbird). Cover crops were important in explaining several grassland species relative abundances possibly for two reasons; the early green growth was attractive and the use of cover crops creates a mulch on the soil surface that promotes greater abundances of certain insects (Hartwig and Ammon, 2002; Tillman et al., 2004; Wang et al., 2011; Bryant et al., 2013). Later in the season, soybean fields provide more suitable habitat than corn fields because they have considerably shorter vegetation that birds are more likely to use as demonstrated by positive correlations for three grassland species (Killdeer, *Charadrius vociferous*; Horned Lark, *Eremophila alpestris*; Vesper Sparrow, *Pooecetes gramineus*; Dechant et al., 2000; Dinkins et al., 2000; Walk *et al*., 2010). Interestingly, organically managed fields hosted greater relative abundance of birds than conventionally managed fields, but this was driven by three generalist species (European Starling, *Sturnus vulgaris;* Mourning Dove, *Zenaida macroura;* House Sparrow, *Passer domesticus*). I suspect these birds were primarily foraging in these fields due to frequent soil disturbance from weekly to bi-weekly cultivation used to control weeds and because organically managed fields have been shown to increase insect abundance (Beecher et al., 2002; Bengtsson et al., 2005; Girard et al., 2014).

Overall, edge-of-field practices were likely less important than in-field practices at explaining species relative abundance for several reasons. First, surveys were conducted within fields and did not directly survey edge-of-field habitats and the area edge-of-field practices occupied was relatively small compared to in-field practices. It is also possible birds in the edge-of-field practices had no interest in coming into fields or territorial birds within the fields excluded other species. The percentage of CRP and woody linear surrounding fields were the two most important edge-of-field practices that explained grassland and shrubland species relative abundances, but on average only made up 0.48 ha (1.93 %) and 0.34 ha (1.20 %) respectively of fields (Best, 1983; Best et al., 1995; Best et al., 1997). Although herbaceous mowed appeared in the top model for ACS values and on average was approximately 3× greater in area (1.37 ha) than woody linear and CRP, it was not as important in explaining species densities. Although edge-of-field practices will bring in a few more species, in-field practices were primarily driving relative abundances with no significant impacts from edge-of-field practices. Because the landscapes around the fields in this study region did not differ much, landscape in this analysis did not have a large impact on species relative abundances.

The primary drivers influencing relative abundance are also influencing ACS values and are associated with residual ground cover. The conservation value of fields was primarily driven by in-field practices, with crop type being the most important. As stated previously, wheat and soybean fields provide more similar habitat to grasslands than corn fields, thus are more suitable for use by grassland species of greater conservation concern. It is also interesting to note that organically managed fields add little value to the conservation of important species. Additionally, ACS values were primarily driven by Dickcissels and Red-winged Blackbirds that are likely not breeding in these fields, but instead breeding in edge-of-field habitats (Bryan and Best, 1994; Conover et al., 2009; Conover et al., 2011) and foraging in these fields. Because these edge-of-field habitats are so small these birds need to use in-field habitats, hence fields with more structure and presumably foraging items (seeds and insects) are of higher quality. Although the amount of woody linear habitat in this study was small, it best explained ACS values and the conservation value of all crop types increase with increasing amount of woody linear habitat surrounding fields (**Figure 4**).

In-field agricultural practices are largely a by-product of agricultural policy and economics and therefore the good news is that policy can help bird populations in these fields. New approaches to agricultural production, such as no-till and cover crops are beneficial for birds; however, seeing more birds doesn't necessarily mean they are reproductively successful in these fields, thus the need for future nest density and success studies, especially in cover crop fields. There is an additive effect when combining certain edge-of-field practices with in-field practices (**Figure 4**) that results in more birds using these fields. If the goal was to increase Eastern Meadowlark abundance in fields, then increasing the number of fields that utilize cover crops would support a greater population of meadowlarks (**Figure 5**), whereas if the goal was to increase Ring-necked Pheasant (*Phasianus colchicus*) abundance, then increasing the amount of CRP would support a greater population of pheasants (**Figure 6**). There is no single approach that is likely to improve all bird species populations in agricultural fields; however the integration of cover crop and no-till approaches within fields and the use of CRP (grasslands habitat) and woody linear areas (shrublands) is likely to result in more robust bird communities in the agricultural landscape of the Midwest.

TABLES AND FIGURES

Table 4. Agricultural practices broken down into in-field and edge-of-field categories with descriptions and the number of fields in each practice (N). The mean size and range (hectares) for in-field practices are for the entire field using those practices, whereas the mean size and range for edge-of-field practices correspond to the amount of area in that particular practice, not the entire field it is associated with. The percent area of field is the range of percentage values that edge-of-field practices compose of a given field.

Practice	Practice description	N	Mean size (ha)	Range (ha)	Percent Area of Field (%)	Percent Area of Field Range (%)
In-field						
Corn		70	35.9	3.3-97.8		
Soybean		70	34.2	5.4-86.7		
Wheat	Winter wheat	18	28.7	5.2-63.4		
Tillage (Yes/No)	No = no-till or strip till (soil disturbance in seed row only)	67	35.6	5.2-86.7		
Organic (Yes/No)	Yes = use of non-synthetic fertilizers, non-GMO, oats buffer strips, 3 crop rotation	52	26.6	3.3-64.9		
Cover Crop (Yes/No)	Yes = use of any cover crop from post harvest of previous year to pre-plant of current year	74	27.9	3.3-64.9		
Edge-of-Field						
Woody Linear (%)	fence lines, hedgerows, windbreaks, shrublands, or any other patch of trees adjacent to field	67	0.3	0.0-3.3	1.2	0.0-13.3
Herbaceous Mowed (%)	grassed waterways, filter strips, buffer strips, road side ditches	153	1.4	0.0-8.0	4.2	0.0-16.9
CRP (%)	USDA Conservation Reserve Program (CRP): CP33	35	0.5	0.0-9.7	1.9	0.0-30.4
Water (%)	wetlands, drainage ditches, creeks	41	0.3	0.0-6.3	0.7	0.0-11.6
Landscape (%)	Percentage of area in cash crop production within 1.5km buffer around field perimeter	158		64.0-96.0		
Total Fields		158	34.3			

Table 5. Example two-tiered AIC candidate model sets using the Dickcissel (*Spiza americana*) as an example for (a) in-field agricultural practices fixed main effects, and (b) edge-of-field plus in-field agricultural practices fixed main effects. The variable/s in the top model from (a) were included in several models for candidate set (b) to determine what variables best explained species relative abundances. Herbmow = herbaceous mowed, Woodyl = woody linear.

(a)

Model	K	AIC_c	Δ	w_i
Year + Wheat	5	550.12	0.00	0.54
Year + Wheat + Cover Crop	6	550.45	0.34	0.46
Year + Cover Crop + Tillage + Organic	7	578.39	28.27	0.00
Year + Tillage + CoverCrop	6	581.27	31.15	0.00
Year + Soybean + Tillage	6	592.26	42.14	0.00
Year + Tillage	5	593.59	43.48	0.00
Year + Corn + Tillage	6	593.85	43.74	0.00
Year + Corn + Cover Crop	6	598.26	48.14	0.00
Year + Soybean + Cover Crop	6	599.19	49.08	0.00
Year + Cover Crop	5	599.90	49.79	0.00
Year + Organic + Cover Crop	6	601.96	51.85	0.00
Year + Corn + Organic	6	602.35	52.23	0.00
Year + Organic	5	605.04	54.92	0.00
Year + Soybean + Organic	6	605.18	55.07	0.00
Year + Corn	5	607.21	57.09	0.00
Year + Soybean	5	610.14	60.03	0.00
Year	4	611.09	60.98	0.00
Null	3	640.58	90.46	0.00

(b)

Model	K	AIC_c	Δ	w_i
Year + Wheat + % Herbmow	6	541.08	0.00	0.95
Year + Wheat + % Herbwood	6	548.55	7.47	0.02
Year + Wheat + % CRP	6	549.58	8.50	0.01
Year + Wheat	5	550.12	9.03	0.01
Year + Wheat + % Water	6	551.82	10.74	0.00
Year + Wheat + Landscape	6	552.02	10.94	0.00
Year + % Herbmow	5	606.76	65.68	0.00
Year + % Herbwood + % Herbmow	6	606.82	65.74	0.00
Year + % Herbmow + % CRP	6	607.04	65.95	0.00
Year + % Herbwood	5	610.98	69.89	0.00
Year + % Herbwood + % Herbmow + % CRP + Landscape + % Water	9	610.99	69.91	0.00
Year + % CRP	5	612.26	71.18	0.00
Year + Landscape	5	612.44	71.36	0.00
Year + % Herbwood + % CRP	6	613.08	72.00	0.00
Year + % Water	5	613.14	72.06	0.00
Year + Landscape + % CRP	6	613.86	72.77	0.00
Null	3	640.58	99.49	0.00

Table 6. AIC model set comparing all in-field practices and all edge-of-field practices influence on overall avian abundance. All species were included for overall bird abundance evaluation. Surveys were conducted on fields throughout central Illinois in 2015 and 2016. Herbmow = herbaceous mowed, Woodyl = woody linear.

Model	n	K	AIC_c	Δ	w_i
Year + Crop Type + Cover Crop + Tillage + Organic	158	9	992.09	0.00	1.00
Year + % Herb mowed + % Woodyl + % CRP + Landscape + % Water	158	9	1037.05	44.97	0.00
Null	158	3	1055.53	63.44	0.00

Table 7. Relative influence of in-field and edge-of-field practices on species relative abundances taken from the top model using the 2-tiered AIC model set approach. Only species with over 40 observations were included in analysis. A single +/- means beta value from top model was < |2| and ++/-- means beta value from top model was > |2|. Surveys were conducted on fields throughout central Illinois in 2015 and 2016.

	In-Field Practices						Edge-of-Field Practices				
Specie	**Corn**	**Soybean**	**Wheat**	**No-Till**	**Organic**	**Cover Crop**	**% Herb mowed**	**% Woodyl**	**% CRP**	**% Water**	**Landscape**
Red-winged Blackbird (*Agelaius phoeniceus*)			+ +								
Common Grackle (*Quiscalus quiscula*)		+									+ +
Dickcissel (*Spiza americana*)			+ +				+ +				
European Starling (*Sturnus vulgaris*)	+				+					+ +	
American Robin (*Turdus migratorius*)											
Killdeer (*Charadrius vociferus*)		+				-			-		
Brown-headed Cowbird (*Molothrus ater*)			-							-	
Barn Swallow (*Hirundo rustica*)		-									
Eastern Meadowlark (*Sturnella magna*)					-	+	+				
Mourning Dove (*Zenaida macroura*)					+						+ +
Cliff Swallow (*Petrochelidon pyrrhonota*)						-				+	
Horned Lark (*Eremophila alpestris*)		+									
House Sparrow (*Passer domesticus*)					+						- -
Vesper Sparrow (*Pooecetes gramineus*)		+				-			+		
Common Yellowthroat (*Geothlypis trichas*)							-	+	+	+	- -
Ring-necked Pheasant (*Phasianus colchicus*)									+		
Song Sparrow (*Melospiza melodia*)						-		+			
Field Sparrow (*Spizella pusilla*)					-	+		+			
Indigo Bunting (*Passerina cyanea*)								+	+		

Table 8. AIC model set comparing all in-field practices and edge-of-field practices influence on the Avian Conservation Significance (ACS) value calculated for each field. All species were included for ACS evaluation. Surveys were conducted on fields throughout central Illinois in 2015 and 2016. Herbmow = herbaceous mowed, Woodyl = woody linear.

Model	n	K	AIC_c	Δ	w_i
Year + Crop Type + Cover Crop + Tillage + Organic	158	9	812.96	0.00	0.65
Year + % Herb mowed + % Woodyl + % CRP + Landscape + % Water	158	9	814.23	1.27	0.35
Null	158	3	880.55	67.59	0.00

Table 9. AIC model set for (a) in-field practices and (b) edge-of-field practices and their influence on the Avian Conservation Significance (ACS) values calculated for each field. All species were included for ACS evaluation. Surveys were conducted on fields throughout central Illinois in 2015 and 2016. Herbmow = herbaceous mowed, Woodyl = woody linear.

(a)

Model	n	K	AIC_c	Δ	w_i
Year + Crop + Cover Crop + Tillage	158	8	805.40	0.00	0.38
Year + Crop + Tillage	158	7	806.59	1.19	0.21
Year + Organic + Cover Crop + Crop + Tillage	158	9	807.34	1.94	0.14
Year + Tillage + Cover Crop	158	6	808.36	2.96	0.09
Year + Crop	158	6	808.90	3.50	0.07
Year + Crop + Cover Crop	158	7	809.40	4.00	0.05
Year + Crop + Organic	158	7	810.93	5.53	0.02
Year + Organic + Cover Crop	158	6	812.64	7.24	0.01
Year + Tillage + Organic	158	6	812.76	7.36	0.01
Year + Tillage	158	5	813.04	7.63	0.01
Year + Cover Crop	158	5	814.25	8.85	0.00
Year	158	4	815.96	10.56	0.00
Year + Organic	158	5	818.09	12.69	0.00
Null	158	3	880.55	75.15	0.00

(b)

Model	n	K	AIC_c	Δ	w_i
Year + Crop + Cover Crop + Tillage + % Herb mowed + % Woodyl	158	10	794.96	0.00	0.32
Year + Crop + Tillage + % Herb mowed + % Woodyl	158	9	795.52	0.57	0.24
Year + Crop + Cover Crop + Tillage + % Herb mowed + % CRP	158	10	796.88	1.93	0.12
Year + Crop + Cover Crop + Tillage + % Herb mowed + % Woodyl + % CRP + Landscape + % Water	158	13	797.26	2.30	0.10
Year + Crop + Tillage + % Herb mowed + % CRP	158	9	797.87	2.92	0.08
Year + Landscape + Crop + Tillage	158	8	799.30	4.34	0.04
Year + Crop + Tillage + Landscape	158	8	799.30	4.34	0.04
Year + Crop + Tillage + % Woodyl	158	8	800.22	5.26	0.02
Year + Crop + Tillage + % Herb mowed	158	8	801.66	6.70	0.01
Year + Crop + Tillage + % Woodyl + % CRP	158	9	801.98	7.02	0.01
Year + Crop + Cover Crop + Tillage + % Woodyl + % CRP	158	10	802.32	7.36	0.01
Year + Crop + Tillage + % CRP	158	8	804.68	9.73	0.00
Year + Crop + Tillage	158	7	806.59	11.64	0.00
Year + Cover Crop + Tillage	158	6	808.36	13.41	0.00
Year + Crop + Tillage + % Water	158	8	808.79	13.84	0.00
Year + Landscape	158	5	810.77	15.81	0.00
Null	158	3	880.55	85.59	0.00

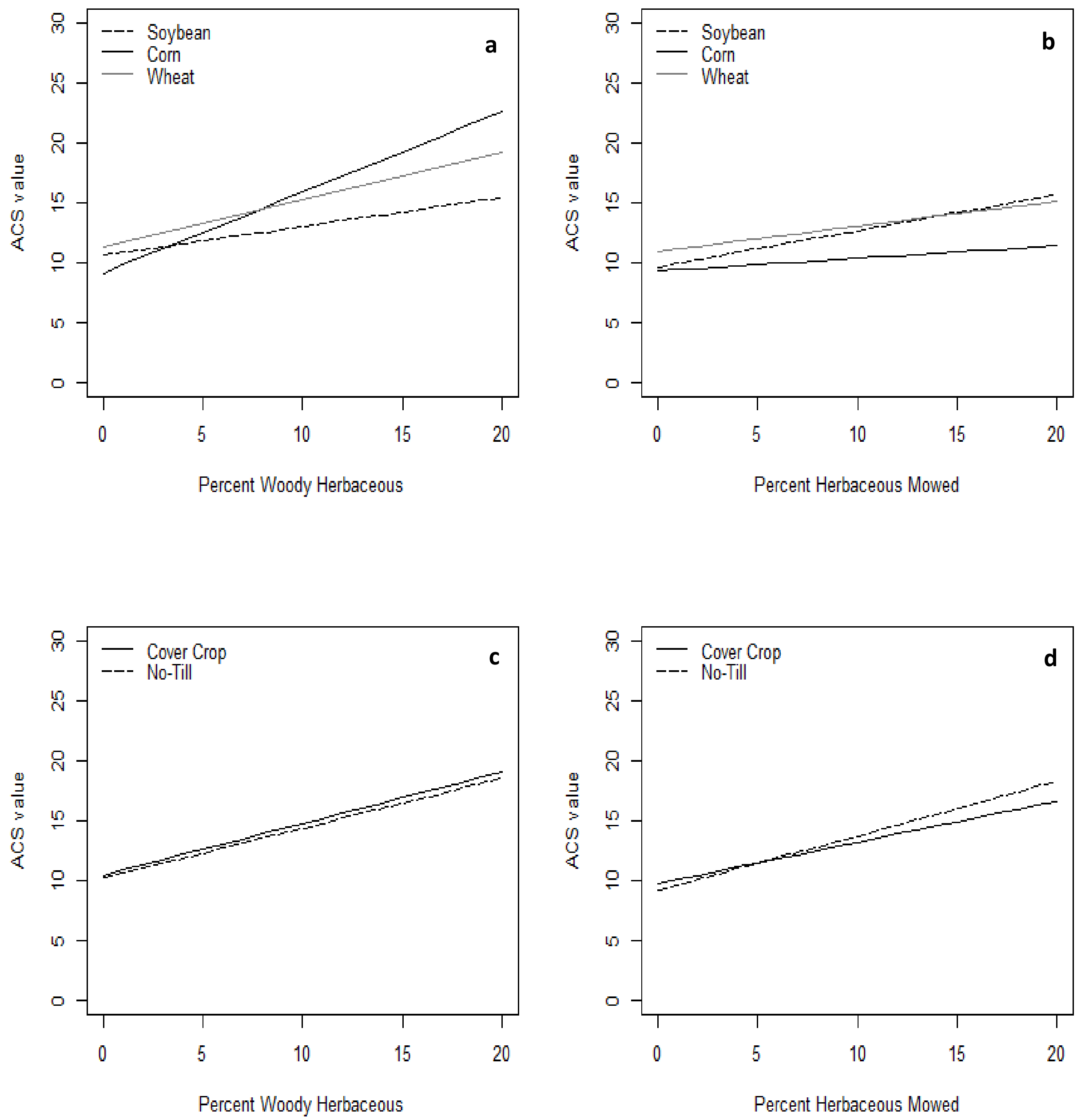

Figure 4. Predicted Avian Conservation Significance (ACS) values across increasing values of woody linear vegetation (fence lines, hedgerows) in (a) soybean, corn, and wheat; (c) all fields using cover crops and no-till; ACS values across increasing values of Herbaceous mowed vegetation (grassed waterways, filter and buffer strips) in (b) soybean, corn, and wheat; (d) all fields using cover crops and no-till. Values created using practices from the top AIC model explaining ACS values Predictions based off surveys conducted in central Illinois in 2015 and 2016.

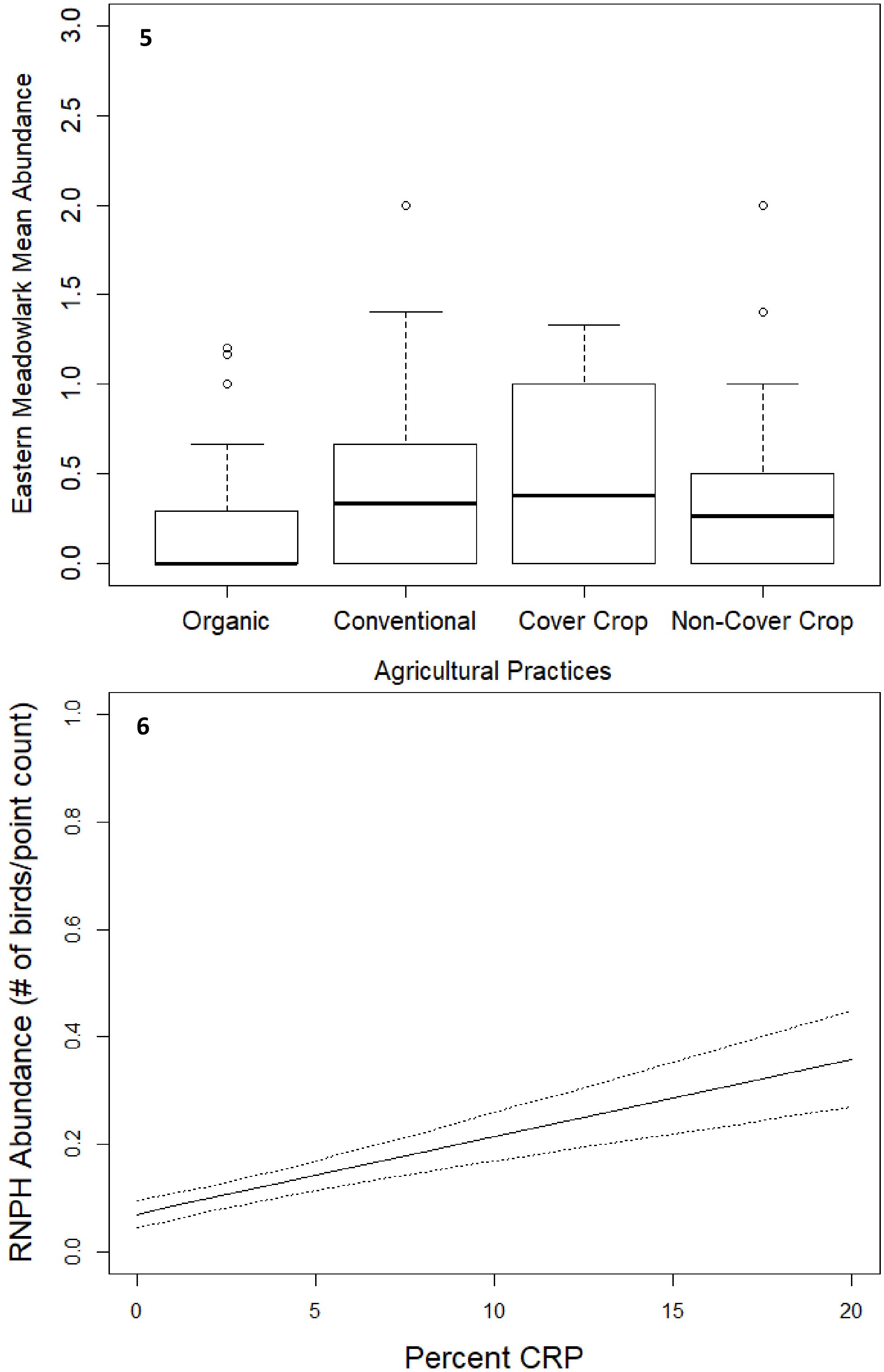

Figure 5 and 6. Mean Eastern Meadowlark (*Sturnella magna*) abundance on organic and conventional fields as well as in fields that utilize a cover crop (only on conventionally managed fields) and those that do not (**5**) and predicted Ring-necked Pheasant (*Phasianus colchicus*) abundance across increasing percent of CRP (**6**). Only conventionally managed fields using a cover crop were included for meadowlark abundance to isolate the true effect of cover crops because organically managed fields have frequent cultivation events removing any leftover residue and create frequent disturbances.

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CHAPTER 4

SUMMARY

As agriculture continues to be the dominate land use in the Midwest, it is imperative to understand how new agricultural practices influence species and how those practices, whether they be in-field or edge-of-field, influence species relative abundances. The primary purpose of this research was to identify which species and in what numbers were using a fairly new agricultural practice, cover crops, during their spring migration and then further to understand the dynamics between in-field practices, such as cover crops, and edge-of-field practices, such as fencerows, during their breeding season. The main finding from Chapter 2 was that grassland species were predominately using cover crop fields, in particular the Eastern Meadowlark (*Sturnella magna*), which is a species of high conservation concern. The conservation value of cover crops increased over time thus evidence for recommending later termination dates of the cover crop.

The main finding from Chapter 3 was that all in-field practices better explained overall bird abundance and ACS values than edge-of-field practices. However, individual species relative abundances were best explained by a combination of in-field and edge-of-field practices. The edge-of-field practice CRP explained the most individual species relative abundances, whereas crop type for in-field practices explained the most species relative abundances. Although edge-of-field practices did not have as much influence on species, I found evidence of an additive effect when adding edge-of-field practices with in-field practices on the conservation value of such fields. Another main finding was that organically managed fields were not important for species of conservation concern.

Overall, these results suggest that cover crops provide necessary temporary habitat for migratory and resident species during a stressful period in their life cycle, as well as influencing abundance of breeding birds. Farmers and land managers should consider later termination dates of cover crops in order to benefit later arriving species and use grass species such as cereal rye as the main cover crop. These results also provide further evidence of the importance of CRP and fencerows in the agricultural landscape for species to thrive. Species are influenced by various in-field and edge-of-field practices differently, but these practices can be managed to help support bird populations. Increasing the acreage of CRP on the landscape and leaving fencerows in provides critical habitat for farmland birds.

Appendix A. Avian species abundance (total individuals counted for all surveys) by field type. Percentage of total individuals detected, Partners in Flight (PIF) concern scores, and habitat description included. Data collected in 2015 and 2016 in agricultural fields located throughout Central Illinois. G=generalist, F=grassland facultative, Fo=forest, O=grassland obligate, S=Shrub, T=Tundra, W=wetland.

Species	**Corn + Cover Crop**	**Corn**	**Soybean + Cover Crop**	**Soybean**	**Total**	**% of Total**	**PIF Score**	**Habitat Description**
Red-winged Blackbird (*Agelaius phoeniceus*)	1333	73	250	31	1687	27.5	13	G
Common Grackle (*Quiscalus quiscula*)	300	97	124	116	637	10.4	10	G
American Robin (*Turdus migratorius*)	216	68	214	114	612	10.0	9	G
Lapland Longspur (*Calcarius lapponicus*)	342	3	95	41	481	7.8	9	T
Brown-headed Cowbird (*Molothrus ater*)	139	71	114	56	380	6.2	10	F
Vesper Sparrow (*Pooecetes gramineus*)	222	50	55	23	350	5.7	12	O
Eastern Meadowlark (*Sturnella magna*)	161	24	73	12	270	4.4	17	O
Horned Lark (*Eremophila alpestris*)	33	8	48	112	201	3.3	12	O
Killdeer (*Charadrius vociferus*)	71	20	51	64	206	3.4	12	F
Savannah Sparrow (*Passerculus sandwichensis*)	154	16	25	8	203	3.3	12	O
American Golden-plover (*Pluvialis dominica*)	18	0	12	161	191	3.1	16	T
American Pipit (*Anthus rubescens*)	18	3	10	135	166	2.7	10	T
Smith's Longspur (*Calcarius pictus*)	122	17	2	0	141	2.3	16	T
Mourning Dove (*Zenaida macroura*)	68	13	37	0	118	1.9	10	G
Grasshopper Sparrow (*Ammodramus savannarum*)	49	3	15	0	67	1.1	16	O
European Starling (*Sturnus vulgaris*)	19	4	15	35	73	1.2	10	G
Barn Swallow (*Hirundo rustica*)	29	15	8	5	57	0.9	13	G
Song Sparrow (*Melospiza melodia*)	32	5	2	4	43	0.7	10	S
Dickcissel (*Spiza americana*)	6	0	28	0	34	0.6	17	O
Bobolink (*Dolichonyx oryzivorus*)	4	0	19	0	23	0.4	16	O
Tree Swallow (*Tachycineta bicolor*)	7	0	14	1	22	0.4	8	G
House Sparrow (*Passer domesticus*)	10	0	9	0	19	0.3	13	G
Ring-necked Pheasant (*Phasianus colchicus*)	9	2	4	0	15	0.2	13	F

Appendix A (cont.)

Wild Turkey (*Meleagris gallopavo*)	13	0	0	0	13	0.2	11	Fo
American Crow (*Corvus brachyrhynchos*)	3	2	1	7	13	0.2	10	G
Chipping Sparrow (*Spizella passerina*)	2	0	3	2	7	0.1	9	G
Field Sparrow (*Spizella pusilla*)	6	0	3	0	9	0.1	17	F
Eastern Kingbird (*Tyrannus tyrannus*)	0	7	1	2	10	0.2	15	S
Palm Warbler (*Setophaga palmarum*)	5	3	2	0	10	0.2	13	T
Wilson's Snipe (*Galinago delicata*)	1	1	3	5	10	0.2	14	F
Canada Goose (*Branta canadensis*)	6	0	0	2	8	0.1	13	G
Northern Cardinal (*Cardinalis cardinalis*)	4	0	3	0	7	0.1	9	G
Western Meadowlark (*Sturnella neglecta*)	6	0	0	1	7	0.1	12	O
Spotted Sandpiper (*Actitis macularius*)	3	0	3	0	6	0.1	14	W
Upland Sandpiper (*Bartramia longicauda*)	0	5	0	1	6	0.1	17	O
Mallard (*Anas platyrhynchos*)	5	0	0	0	5	0.1	8	F
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	4	0	0	0	4	0.1	10	G
Swamp Sparrow (*Melospiza georgiana*)	1	0	2	0	3	0.0	10	W
Chimney Swift (*Chaetura pelagica*)	0	0	2	0	2	0.0	15	G
Least Sandpiper (*Calidris minutilla*)	0	2	0	0	2	0.0	12	T
Rock Pigeon (*Columba livia*)	2	0	0	0	2	0.0	11	G
Red-tailed Hawk (*Buteo jamaicensis*)	1	0	0	0	1	0.0	10	G
Turkey Vulture (*Cathartes aura*)	1	0	0	0	1	0.0	8	G
Blue-winged Teal (*Anas discors*)	2	0	0	0	2	0.0	10	F
Northern Harrier (*Circus cyaneus*)	1	1	0	0	2	0.0	13	O
American Kestrel (*Falco sparverius*)	0	1	0	0	1	0.0	13	F
Brown Thrasher (*Toxostoma rufum*)	1	0	0	0	1	0.0	16	S
Cliff Swallow (*Petrochelidon pyrrhonota*)	0	1	0	0	1	0.0	9	G
Cooper's Hawk (*Accipiter cooperii*)	1	0	0	0	1	0.0	11	G
Common Nighthawk (*Chordeiles minor*)	0	1	0	0	1	0.0	13	F
Northern Flicker (*Colaptes auratus*)	1	0	0	0	1	0.0	16	Fo
Sedge Wren (*Cistothorus platensis*)	0	0	1	0	1	0.0	12	O

Appendix B. Species relative abundances (# of birds/100 m) per field type with standard error for species with over 40 observations. Highest values for each species are bolded and values in parentheses are standard error. Transect surveys conducted in east-central Illinois, 2015-2016.

		Relative Abundance			
Species	**AlphaCode**	**Corn + Cover Crop (se)**	**Corn (se)**	**Soybean + Cover Crop (se)**	**Soybean (se)**
American Golden-plover	AMGP	0.014 (0.014)	-	0.027 (0.027)	**0.435 (0.082)**
American Pipit	AMPI	0.026 (0.019)	0.013 (0.013)	0.026 (0.013)	**0.342 (0.054)**
American Robin	AMRO	0.249 (0.030)	0.283 (0.082)	**0.515 (0.103)**	0.313 (0.032)
Barn Swallow	BARS	0.037 (0.010)	**0.063 (0.023)**	0.017 (0.008)	0.014 (0.002)
Brown-headed cowbird	BHCO	0.161 (0.027)	**0.288 (0.078)**	0.276 (0.051)	0.151 (0.011)
Common Grackle	COGR	0.389 (0.104)	**0.413 (0.150)**	0.369 (0.136)	0.294 (0.059)
Dickcissel	DICK	0.008 (0.004)	-	**0.069 (0.049)**	-
Eastern Meadowlark	EAME	**0.216 (0.025)**	0.095 (0.027)	0.196 (0.049)	0.031 (0.005)
European Starling	EUST	0.022 (0.010)	0.022 (0.015)	0.037 (0.022)	**0.077 (0.014)**
Grasshopper Sparrow	GRSP	**0.047 (0.017)**	0.012 (0.007)	0.038 (0.022)	-
Horned Lark	HOLA	0.035 (0.016)	0.031 (0.013)	0.105 (0.020)	**0.277 (0.011)**
Killdeer	KILL	0.093 (0.017)	0.081 (0.024)	0.113 (0.025)	**0.170 (0.010)**
Lapland Longspur	LALO	**0.320 (0.272)**	0.009 (0.009)	0.226 (0.167)	0.108 (0.023)
Mourning Dove	MODO	0.088 (0.018)	0.057 (0.037)	**0.111 (0.056)**	-
Red-winged Blackbird	RWBL	**1.970 (0.551)**	0.308 (0.078)	0.551 (0.137)	0.084 (0.009)
Savannah Sparrow	SAVS	**0.212 (0.050)**	0.073(0.042)	0.057 (0.028)	0.023 (0.004)
Smith's Longspur	SMLO	**0.136 (0.061)**	0.078 (0.057)	0.004 (0.004)	-
Song Sparrow	SOSP	**0.040 (0.014)**	0.020 (0.014)	0.004 (0.003)	0.008 (0.002)
Vesper Sparrow	VESP	**0.254 (0.035)**	0.222 (0.048)	0.131 (0.034)	0.057 (0.005)

Appendix C. Average species relative abundances (# birds/100 m) in grass cover crops (cereal rye, winter wheat, annual rye grass), cocktail mix/other (mix of legume, grass, and/or non-legume broadleaf, or single non-grass cover crop), and non-cover crop fields for species with over 40 observations. Highest values for each species are bolded and values in parentheses are standard error. Sample size = n. Transect surveys conducted in east-central Illinois, 2015-2016.

		Relative Abundance		
Species	**Scientific Name**	**Grass (n = 34)**	**Cocktail/Other (n = 10)**	**No cover crop (n = 31)**
American Golden-plover	*Pluvialis dominica*	0.024 (0.017)	-	**0.253 (0.172)**
American Pipit	*Anthus rubescens*	0.023 (0.017)	0.040 (0.012)	**0.204 (0.114)**
American Robin	*Turdus migratorius*	0.311 (0.043)	**0.465 (0.116)**	0.294 (0.074)
Barn Swallow	*Hirundo rustica*	**0.037 (0.008)**	0.010 (0.008)	0.033 (0.010)
Brown-headed cowbird	*Molothrus ater*	0.195 (0.028)	**0.233 (0.061)**	0.202 (0.040)
Common Grackle	*Quiscalus quiscula*	**0.406 (0.097)**	0.321 (0.152)	0.334 (0.138)
Dickcissel	*Spiza americana*	**0.034 (0.022)**	0.015 (012)	-
Eastern Meadowlark	*Sturnella magna*	**0.224 (0.030)**	0.142 (0.030)	0.068 (0.015)
European Starling	*Sturnus vulgaris*	0.026 (0.012)	0.032 (0.020)	**0.053 (0.030)**
Grasshopper Sparrow	*Ammodramus savannarum*	**0.054 (0.017)**	0.011 (0.007)	0.005 (0.003)
Horned Lark	*Eremophila alpestris*	0.055 (0.015)	0.080 (0.026)	**0.174 (0.027)**
Killdeer	*Charadrius vociferus*	0.073 (0.013)	**0.176 (0.040)**	0.138 (0.023)
Lapland Longspur	*Calcarius lapponicus*	0.271 (0.223)	**0.355 (0.278)**	0.066 (0.050)
Mourning Dove	*Zenaida macroura*	**0.113 (0.028)**	0.044 (0.016)	0.023 (0.015)
Red-winged Blackbird	*Agelaius phoeniceus*	**1.614 (0.454)**	0.970 (0.278)	0.213 (0.038)
Savannah Sparrow	*Passerculus sandwichensis*	**0.174 (0.042)**	0.110 (0.049)	0.043 (0.019)
Smith's Longspur	*Calcarius pictus*	**0.116 (0.050)**	0.006 (0.007)	0.031 (0.023)
Song Sparrow	*Melospiza melodia*	**0.032 (0.012)**	0.011 (0.006)	0.014 (0.006)
Vesper Sparrow	*Pooecetes gramineus*	**0.232 (0.030)**	0.145 (0.052)	0.124 (0.023)

Appendix D. Species relative impact on ACS scores in cover crop and non-cover crop fields. The relative impact was calculated by summing species ACS scores per visit then divided by the total number of visits to cover crop and non-cover crop fields. Species arranged by total abundance in surveys with the most abundant listed first and the highest value bolded for cover crop and non-cover crop categories. Transect surveys conducted in east-central Illinois, 2015-2016.

Species	**Scientific Name**	**PIF Score**	**Cover crop**	**Non-Cover crop**
Red-winged Blackbird	*Agelaius phoeniceus*	13	7.56	1.31
Common Grackle	*Quiscalus quiscula*	10	1.32	0.50
American Robin	*Turdus migratorius*	9	1.33	0.53
Lapland Longspur	*Calcarius lapponicus*	9	0.26	0.07
Brown-headed cowbird	*Molothrus ater*	10	1.27	0.65
Vesper Sparrow	*Pooecetes gramineus*	12	2.62	0.95
Eastern Meadowlark	*Sturnella magna*	17	**8.62**	**1.45**
Horned Lark	*Eremophila alpestris*	12	0.90	1.33
Killdeer	*Charadrius vociferus*	12	1.57	1.06
Savannah Sparrow	*Passerculus sandwich*	12	1.38	0.25
American Golden-plover	*Pluvialis dominica*	16	0.30	0.63
American Pipit	*Anthus rubescens*	10	0.14	0.19
Smith's Longspur	*Calcarius pictus*	16	1.16	0.28
Mourning Dove	*Zenaida macroura*	10	0.65	0.07
Grasshopper Sparrow	*Ammodramus savanna*	16	1.44	0.13
European Starling	*Sturnus vulgaris*	10	0.18	0.12
Barn Swallow	*Hirundo rustica*	13	0.70	0.40
Song Sparrow	*Melospiza melodia*	10	0.21	0.06
Dickcissel	*Spiza americana*	17	0.69	-

Appendix E. Avian species abundance (total individuals counted for all surveys), percentage of individual species observations of all species observations, Partners in Flight (PIF) concern scores, and habitat descriptions. Data was collected in 2015 and 2016 on fields located throughout central Illinois. G=generalist, F=grassland facultative, Fo=forest, O=grassland obligate, S=shrub, W=wetland.

Species	**Species Count**	**% of Total**	**PIF Score**	**Habitat Description**
Red-winged Blackbird (*Agelaius phoeniceus*)	2837	33.20	13	G
Common Grackle (*Quiscalus quiscula*)	1137	13.30	10	G
Dickcissel (*Spiza americana*)	1088	12.73	17	O
European Starling (*Sturnus vulgaris*)	416	4.87	10	G
American Robin (*Turdus migratorius*)	402	4.70	9	G
Killdeer (*Charadrius vociferus*)	348	4.07	12	F
Brown-headed Cowbird (*Molothrus ater*)	337	3.94	10	F
Barn Swallow (*Hirundo rustica*)	239	2.80	13	G
Eastern Meadowlark (*Sturnella magna*)	206	2.41	17	O
Mourning Dove (*Zenaida macroura*)	204	2.39	10	G
Cliff Swallow (*Petrochelidon pyrrhonota*)	189	2.21	9	G
Horned Lark (*Eremophila alpestris*)	175	2.05	12	O
House Sparrow (*Passer domesticus*)	172	2.01	13	G
Vesper Sparrow (*Pooecetes gramineus*)	146	1.71	12	O
Common Yellowthroat (*Geothlypis trichas*)	130	1.52	13	F
Ring-necked Pheasant (*Phasianus colchicus*)	53	0.62	13	F
Song Sparrow (*Melospiza melodia*)	51	0.60	10	S
Field Sparrow (*Spizella pusilla*)	47	0.55	17	F
Indigo Bunting (*Passerina cyanea*)	40	0.47	10	S
Rock Pigeon (*Columba livia*)	35	0.41	11	G
American goldfinch (*Spinus tristis*)	34	0.40	13	S
Grasshopper Sparrow (*Ammodramus savannarum*)	32	0.37	16	O
American Crow (*Corvus brachyrhynchos*)	24	0.28	10	G
Chipping Sparrow (*Spizella passerina*)	24	0.28	9	G
Upland Sandpiper (*Bartramia longicauda*)	19	0.22	17	O
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	17	0.20	10	G
American Kestrel (*Falco sparverius*)	17	0.20	13	F
Northern Bobwhite (*Colinus virginianus*)	13	0.15	16	F
Western Meadowlark (*Sturnella neglecta*)	12	0.14	12	O
Mallard (*Anas platyrhynchos*)	12	0.14	8	F
Eastern Kingbird (*Tyrannus tyrannus*)	11	0.13	15	S
Northern Cardinal (*Cardinalis cardinalis*)	11	0.13	9	G
House Wren (*Troglodytes aedon*)	10	0.12	9	Fo
Red-tailed Hawk (*Buteo jamaicensis*)	9	0.11	10	G
Great Blue Heron (*Ardea herodias*)	9	0.11	11	W
Savannah Sparrow (*Passerculus sandwichensis*)	8	0.09	12	O
Tree Swallow (*Tachycineta bicolor*)	6	0.07	8	G

Appendix E (cont.)

Gray Catbird (*Dumetella carolinensis*)	5	0.06	10	S
Chimney Swift (*Chaetura pelagica*)	5	0.06	15	G
Brown Thrasher (*Toxostoma rufum*)	3	0.04	16	S
Black capped chickadee (*Poecile atricapillus*)	3	0.04	11	Fo
Wood duck (*Aix sponsa*)	3	0.04	12	W
Wild Turkey (*Meleagris gallopavo*)	2	0.02	11	Fo
Spotted Sandpiper (*Actitis macularius*)	1	0.01	14	W
Northern Harrier (*Circus cyaneus*)	1	0.01	13	O
Cedar Waxwing (*Bombycilla cedrorum*)	1	0.01	9	S
Ruby Throated Hummingbird (*Archilochus colubris*)	1	0.01	11	Fo
Belted Kingfisher (*Megaceryle alcyon*)	1	0.01	14	W

Appendix F. Relative influence of species on the Avian Conservation Significance (ACS) values. All species were included for ACS values, but only the species with more than 40 observations are included in this table to explore their influence on ACS values. The species with the highest relative influence is bolded in the All Fields column. Data was collected in 2015 and 2016 on fields located throughout central Illinois.

Species	PIF Score	All Fields
Red-winged Blackbird (*Agelaius phoeniceus*)	13	1.92
Common Grackle (*Quiscalus quiscula*)	10	0.51
Dickcissel (*Spiza americana*)	17	**2.82**
European Starling (*Sturnus vulgaris*)	10	0.21
American Robin (*Turdus migratorius*)	9	0.21
Killdeer (*Charadrius vociferus*)	12	0.49
Brown-headed Cowbird (*Molothrus ater*)	10	0.28
Barn Swallow (*Hirundo rustica*)	13	0.48
Eastern Meadowlark (*Sturnella magna*)	17	1.10
Mourning Dove (*Zenaida macroura*)	10	0.15
Cliff Swallow (*Petrochelidon pyrrhonota*)	9	0.07
Horned Lark (*Eremophila alpestris*)	12	0.28
House Sparrow (*Passer domesticus*)	13	0.20
Vesper Sparrow (*Pooecetes gramineus*)	12	0.28
Common Yellowthroat (*Geothlypis trichas*)	13	0.26
Ring-necked Pheasant (*Phasianus colchicus*)	13	0.15
Song Sparrow (*Melospiza melodia*)	10	0.06
Field Sparrow (*Spizella pusilla*)	17	0.27
Indigo Bunting (*Passerina cyanea*)	10	0.04