2013

Bird use of heterogeneous native prairie biofuel production plots

Jarrett D. Pfrimmer
University of Northern Iowa

BIRD USE OF HETEROGENEOUS NATIVE PRAIRIE BIOFUEL PRODUCTION PLOTS

An Abstract of a Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Master of Science

Jarrett D. Pfrimmer

University of Northern Iowa

May 2013

ABSTRACT

Changing land use practices and agricultural intensification have driven the loss of >90% of native grassland habitats in the Midwestern U.S.A. Consequently, grassland birds have declined more drastically than any other North American guild. Current biofuel production systems in the Midwest rely on high input monoculture crops that provide little habitat value to most grassland birds. The Tallgrass Prairie Center at the University of Northern Iowa is exploring the feasibility of growing and harvesting diverse mixes of native prairie vegetation for use as a sustainable biofuel in a manner that also provides high quality bird habitat.

In 2009, 48 research plots on three soil types were seeded with one of four treatments of native prairie vegetation: 1) switchgrass monoculture, 2) a 5-species grass mix, 3) a 16-species biomass mix, or 4) a 32-species prairie mix. In subsequent years, I conducted visual surveys of breeding birds and monitored bird nesting attempts in the biomass production plots. I hypothesized that more diverse plant communities would support more abundant and diverse bird communities with higher nest densities and nest success rates.

Results indicated that bird species richness and abundance were significantly greater in the biomass and prairie mixes compared to the low diversity grass plots; however, there were no differences between the biomass and prairie mix plots nor between the switchgrass and grass mix plots. Three grassland birds classified as "species of greatest conservation need" in Iowa successfully nested in the biomass production plots during my study, but nest density did not vary significantly among treatments or soil types. My

results suggested that establishment and management of diverse native prairie vegetation for biomass production on marginal lands could have positive impacts on the maintenance of bird populations in agricultural landscapes.

BIRD USE OF HETEROGENEOUS NATIVE PRAIRIE
BIOFUEL PRODUCTION PLOTS

A Thesis

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Master of Science

Jarrett D. Pfrimmer

University of Northern Iowa

May 2013

This Study by: Jarrett D. Pfrimmer
Entitled: Bird Use of Heterogeneous Native Prairie Biofuel Production Plots

has been approved as meeting the thesis requirement for the

Degree of Master of Science

Date	Dr. Mark C. Myers, Chair, Thesis Committee
Date	Dr. Daryl D. Smith, Thesis Committee Member
Date	Dr. Peter B. Berendzen, Thesis Committee Member
Date	Dr. Michael J. Licari, Dean, Graduate College

ACKNOWLEDGEMENTS

I owe a debt of gratitude to many people who provided support and encouragement throughout the entire process. Funding was provided by the Iowa Power Fund, the Myrle Burk Scholarship in Ornithology, and the Graduate College and Department of Biology at the University of Northern Iowa. A special thanks to my advisor, Dr. Mark Myers, for the constant encouragement and guidance through my Master of Science education and thesis research. I would like to show my appreciation and gratitude to Dr. Daryl Smith and Dr. Pete Berendzen for taking time out of their schedules and serving as committee members for my thesis research. My research would not have been possible without the support of the entire staff of the Tallgrass Prairie Center at the University of Northern Iowa. I also want to thank Dr. Mark Myers, Ben Hoksch, Drew Miller, and Nick Tebockhorst for the countless hours of data collection in the field. Special recognition must be given to Jim Mason for his support and generosity for providing 2010 breeding bird survey data and existing figures. Most importantly, I would like to thank my family and friends for their support through my thesis research. Without all of these people, this project would not have been possible.

TABLE OF CONTENTS

PAGE

LIST OF TABLES vi

LIST OF FIGURES viii

CHAPTER 1 INTRODUCTION 1

CHAPTER 2 METHODS 5

Study Area 5

Site Establishment and Management 7

Vegetation Characteristics 8

Avian Surveys 9

Nest Surveys and Monitoring 10

Data Analysis 11

CHAPTER 3 RESULTS 15

Vegetation Characteristics 15

Breeding Bird Abundance, Richness, and Diversity 23

Breeding Bird Community Composition 34

Nesting 44

CHAPTER 4 DISCUSSION 49

Breeding Bird Response to Biofuel Management 50

Nesting 54

Implications and Recommendations 57

PAGE

REFERENCES 60

APPENDIX ADDITIONAL INFORMATION 66

LIST OF TABLES

TABLE PAGE

1 Management activities by year on all 48 treatment plots representing four perennial biofuel feedstocks across three soil types 8

2 Vegetation characteristics in four perennial biofuel feedstocks by year. For each vegetation characteristic, means ($\bar{x}$) are listed across the top row with the standard error (SE) directly below. 17

3 Principle components analysis of vegetation structural characteristics from 2010-2012 in four perennial biofuel feedstocks. Factor loadings in bold indicate variables most strongly correlated with each axis...................................18

4 PERMANOVA comparing bird abundance, species richness, and Shannon's diversity index in four perennial biofuel feedstocks on three soil types during the 2010-2012 breeding seasons...24

5 Bird species abundance in four perennial biofuel feedstocks (S = switchgrass, G = grass mix, B = biomass mix, and P = prairie mix) by year. Asterisks indicate species observed nesting in the research plots 25

6 Bird species abundance in perennial biofuel feedstocks by soil type (S = sandy loam, L = loam, C = clay loam) by year...28

7 PERMANOVA comparing bird community composition in four perennial biofuel feedstocks on three soil types over time. 36

8 PERMANOVA pair-wise comparisons of bird community dissimilarity among four perennial biofuel feedstocks (S = swicthgrass, G = grass mix, B = biomass mix, and P = prairie mix on three soil types from 2010-2012. 37

9 Bird community composition by functional group and mean Partners in Flight Regional Combined Scores of birds observed in perennial biofuel feedstocks from 2010 to 2012...44

10 Mayfield daily survival probabilities and nest success rates for Dickcissel in perennial biofuel feedstocks by year...46

11 Mayfield daily survival probabilities and nest success rates for Lark Sparrow in perennial biofuel feedstocks by year. Mayfield values were not calculated in 2012 because no nest successfully fledged young............................47

12 Chi-square analysis of 2011-2012 Dickcissel and Lark Sparrow nest site selection by treatment, soil type, and percent forb cover in four perennial biofuel feedstocks across three soil types. 48

TABLE PAGE

A1 Species composition and seeding rates for four perennial biofuel feedstocks All feedstocks were seeded with Iowa source identified seed (Prairie Moon Nursery; Winona, MN U.S.A.) in Black Hawk County, Iowa, U.S.A. 67

A2 Bird abundance in perennial biofuel feedstocks by year, Partners in Flight (PIF) Regional Concern Scores (RCS), and bird species habitat guild classifications..68

LIST OF FIGURES

FIGURE PAGE

1 Map of research site at the Cedar River Natural Resource Area in Black Hawk County, Iowa, U.S.A. (N42 23'04.26 W 92 13'47.81). Each of the four perennial biofuel feedstocks was replicated four times on each of three soil types 6

2 Principle component analysis of vegetation structure in four perennial biofuel feedstocks by a) year (2010-2012) and b) treatment. Axis 1 (PC1) was negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes…..........19

3a Principle component analysis of 2010 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes 20

3b Principle component analysis of 2011 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes 21

3c Principle component analysis of 2012 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes 22

FIGURE		PAGE
4	Mean bird abundance in four perennial biofuel feedstocks by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird abundance declined significantly each year	31
5	Mean bird species a) richness and b) diversity in four perennial biofuel feedstocks by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird species richness and diversity declined significantly each year	32
6	Mean bird a) species richness and b) community diversity in four perennial biofuel feedstocks across three soil types by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird species richness and diversity declined significantly each year	33
7	NMDS depicting variation in breeding bird community composition among four perennial biofuel feedstocks by year. Each point represents the centroid of one treatment × soil group ($n = 4$) during the year indicated by the label	38
8a	NMDS of 2010 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.	39
8b	NMDS of 2011 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.	40
8c	NMDS of 2012 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.	41
9a	NMDS bubble plot of Sedge Wren abundance in four perennial biofuel feedstocks on three soil types during the 2010 breeding season. The first letter of the two-letter plot label refers to vegetation treatment: S = switchgrass, G = grass mix, B = biomass mix, p = prairie mix; the second refers to soil type: C = clay loam, L = loam, and S = sandy loam. A plot label with no bubble indicates that no Sedge Wrens were observed in the plot	42

FIGURE PAGE

9b NMDS bubble plot of Sedge Wren abundance in four perennial biofuel feedstocks on three soil types during the 2012 breeding season. The first letter of the two-letter plot label refers to vegetation treatment: S = switchgrass, G = grass mix, B = biomass mix, p = prairie mix; the second refers to soil type: C = clay loam, L = loam, and S = sandy loam. A plot label with no bubble indicates that no Sedge Wrens were observed in the plot. 43

CHAPTER 1

INTRODUCTION

The conversion of the native tallgrass prairie ecosystem to row crop agriculture in the Midwestern U.S.A. over the past 150 years has been described as one of the most rapid and comprehensive environmental alterations in human history (Smith 1998). In Iowa, 99.9% of original tallgrass prairie habitat has been destroyed (Samson and Knopf 1994) and today much of the state's landscape is dominated by fields of high input, low diversity (HILD) annual crops primarily comprised of corn (*Zea mays*) and soybeans (*Glycine max*). The expansion and intensification of agricultural production systems and subsequent loss of grassland habitat have driven significant biodiversity declines in the region (Warner 1994, Fletcher and Koford 2002, Murphy 2003, Wiens *et al.* 2011). In particular, Midwestern grassland birds have experienced widespread and dramatic population declines over the past four decades (Knopf 1994, Brennan and Kuvlesky 2005, Sauer *et al*. 2011) and have become dependent on intensively managed agricultural lands for breeding habitat (Askins *et al*. 2007).

Recently, historically high crop prices combined with federal policies promoting expanded corn ethanol and cellulosic biofuel production (EISA 2007, Sumner and Zulauf 2012) have driven further agricultural expansion and intensification in the Midwest. For example, approximately 5.7 million ha of U.S. grassland, wetland, and shrubland habitats were converted to corn and soybean production from 2008-2011, with most of the conversion occurring in the Midwest (Faber *et al*. 2012). From 2006 to 2011, grass-dominated land cover in the Western Corn Belt states (North and South Dakota, Nebraska, Minnesota, and Iowa) declined by 528,000 ha, with significant expansion of corn and soybean production onto marginal lands (Wright and Wimberly 2013). The expansion of HILD crop cultivation coupled with declines in Conservation Reserve Program acreage (Claassen *et al.* 2011, Wright and Wimberly 2013) have further intensified the threats of habitat loss and fragmentation to Midwestern grassland birds.

Projected future expansion of biofuel production in the Midwestern U.S. will greatly influence landscapes and affect biodiversity, including grassland birds (Robertson *et al*. 2012). The current (first-generation) model of biofuel production in Midwestern states relies heavily on producing liquid fuels from HILD annual food crops, primarily ethanol from corn, but also biodiesel from soybeans (Hill *et al*. 2006). However, second-generation lignocellulosic biofuels derived from native, perennial plant feedstocks may have the potential to yield greater net energy gains while simultaneously providing enhanced wildlife habitat and other ecosystem services (Tilman *et al*. 2006, Hill 2009, Fargione *et al*. 2010).

Recent research suggests that the establishment of low input high diversity (LIHD) perennial biofuel feedstocks in the Midwest could enhance avian diversity and create habitat for species of conservation concern. Field studies of bird communities in existing stands of biofuel crops (corn, switchgrass, and mixed grass-forb prairie plantings) have demonstrated that perennial feedstocks support greater avian species richness and abundance compared to corn (Robertson *et al*. 2011a, 2011b, 2012). However, the perennial feedstocks in these studies were selected from pre-existing fields (i.e., Conservation Reserve Program lands) with variable histories and site characteristics and were not actively managed for biomass production. In another study, Meehan *et al*. (2010) modeled alternative future bioenergy scenarios in the Upper Midwest and found that replacement of HILD crops with LIHD feedstocks on 8.3 million ha of marginal lands is expected to significantly increase bird species richness and aid in the recovery of species of conservation concern over 20% of the region. However, if HILD crop expansion continues into 9.5 million ha of marginal land currently containing LIHD habitats, bird species richness could decline between 7% and 65% across 20% of the region. Under both scenarios, significant portions of Iowa were included within the portion of the landscape likely to experience significant increases or decreases in avian richness (Meehan *et al*. 2010).

Research on bird community response to the conversion of HILD crops to perennial feedstocks specifically managed for biomass production at the field scale are urgently needed to better understand the potential consequences of expanded biofuel production on grassland birds (Fargione *et al*. 2009, Robertson *et al*. 2012). Here I present results of a study of breeding bird use of a heterogeneous prairie biomass production site over a four year management cycle from initial establishment through harvest. In 2009, 48 research plots were established on three soil types at a Black Hawk County, Iowa site with a 20 year history of annual HILD crop production and seeded with one, five, 16 or 32 species of native perennial prairie vegetation. From 2010 to 2012, I conducted surveys of vegetation structural characteristics and breeding bird use of the plots. The goal of my research was to determine the habitat value to grassland birds of perennial prairie plantings with varying levels of plant diversity established and managed specifically for biomass production. I sought to address the following research questions:

1) How do vegetation structural characteristics among four prairie biofuel crops on three soil types change over time and in response to management?
2) Does biomass feedstock diversity or soil type influence avian abundance, species richness, diversity, or community composition over time?
3) How do avian communities respond to management practices?
4) Do recently established perennial feedstocks provide habitat for species of conservation concern?
5) Do grassland birds nest in biomass production plots and at what rate do nests successfully fledge young?

CHAPTER 2

METHODS

Study Area

This study was conducted at a 40 ha site located in the Cedar River Natural Resource Area (CRNRA) in southeastern Black Hawk County, Iowa, U.S.A. (N42 23’04.26 W92 13’47.81; Figure 1). The research site contains seven open fields that were leased to a local farmer by the Black Hawk County Conservation Board and managed for corn and soybean production for approximately three decades prior to the study. In 2009, the Tallgrass Prairie Center at the University of Northern Iowa leased the area to initiate research investigating the use of native prairie vegetation as a biomass energy feedstock and 48 research plots ranging in size from 0.30 to 0.56 ha were established. Plots were seeded with one of four treatments of native prairie vegetation: 1) switchgrass monoculture, 2) grass mix (five species of warm-season grasses), 3) biomass mix (16 species of warm- and cool-season grasses, forbs, and legumes), or 4) prairie mix (32 species of warm- and cool-season grasses, forbs, legumes, and sedges) (Table A1). Henceforth, I refer to all treatments collectively as “biomass production plots”; switchgrass and grass mix collectively as “low diversity grass plots”; and biomass and prairie mixes collectively as “high diversity forb-rich plots.”

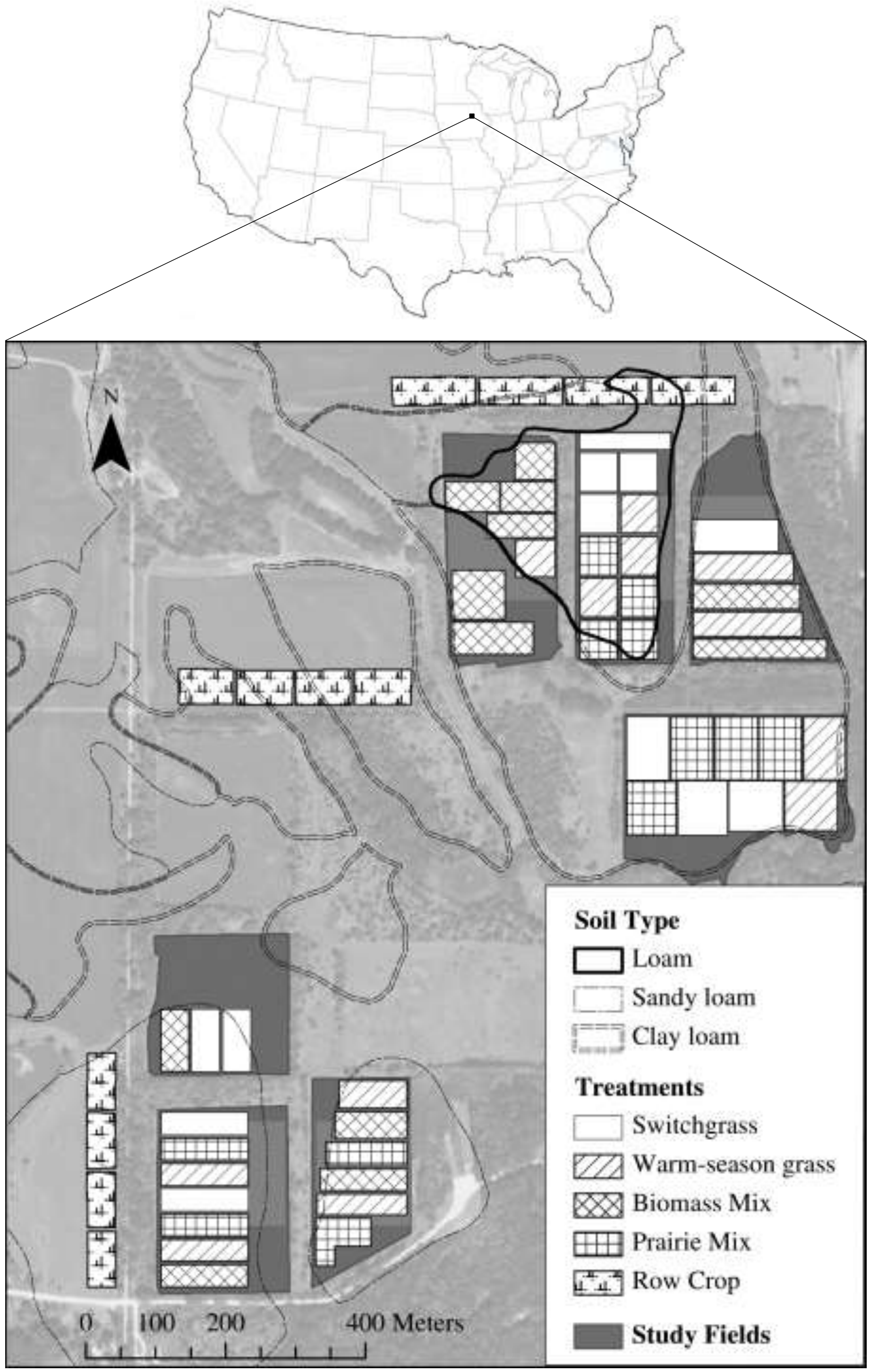

Figure 1. Map of research site at the Cedar River Natural Resource Area in Black Hawk County, Iowa, U.S.A. (N42 23’04.26 W 92 13’47.81). Each of the four perennial biofuel feedstocks was replicated four times on each of three soil types.

Each treatment was replicated in four plots on each of three soil types: Flagler sandy loam (no flooding, drainage class (DC) = excessively drained, corn suitability rating (CSR) = 50), Saude loam (no flooding, DC = well-drained, CSR = 63), and Spillville/Coland complex (some flooding, DC = poorly drained, CSR = 60); (Steckley 2006). Average CSR for Black Hawk County land used for row crop production in 2012 was 81 (Edwards 2012). Given its low CSRs and location in the Cedar River floodplain, my research site can be considered non-prime agricultural land.

Site Establishment and Management

In June 2008, all fields included in the research design were planted to Round-up® Ready soybeans. To control weeds, the area was sprayed with glyphosate prior to planting and again when the soybeans were growing. In October 2008 after soybeans were harvested, portions of fields not containing research plots were seeded to prairie mix with the forb seeding rates doubled (Appendix Table A1). In May 2009, plots were seeded from least diverse to most diverse mixes using a no-till native grass drill. A 2-4 m buffer strip of cool season vegetation (Dan Patch horse pasture mix, Des Moines Forage and Turf Seed Corp., Ankeny, Iowa) was seeded to form lanes around the periphery of each field and in the mowed lanes between plots. These lanes were mowed periodically during the growing season to keep grass height short. In July 2009, all plots were mowed at a height of 10 cm to reduce competition with annual weeds (Williams *et al*. 2007).

No other management activities took place except for lane mowing during the growing season until April 2011, when all 48 research plots were burned to stimulate plant growth and to control woody species establishment. In March 2012, aboveground biomass was harvested in all 48 plots using a flail mower and baled into 550 lb. rectangular bales and stored in stacks until they were pelletized for biofuel production (Table 1).

Table 1. Management activities by year on all 48 treatment plots representing four perennial biofuel feedstocks across three soil types.

Year	Technique Implemented
2008	Soybean cultivation
2009	Native prairie seeding; establishment mowing (July)
2010	No management
2011	Prescribed burn (April)
2012	Harvest (March)

Vegetation Characteristics

Vegetation composition and structure were surveyed in each research plot between 16 May and 2 June 2010-2012. A permanent 50 m transect was established in each plot and vegetation characteristics were measured in fifteen, 1 m^2 quadrats. Quadrats were randomly placed to the right or left of the transect at 3 m intervals. In each 1 m^2 quadrat, I measured litter depth (mm) at each corner of the sampling frame and heights (cm) of the tallest live and dead, grass and forb. Vegetation height-density (cm) was measured by recording visual obstruction readings (VOR) on a Robel pole placed in the center of the quadrat. Readings were taken from each of the four cardinal directions at 1 m in height and at a distance of 4 m from the pole (Robel *et al*. 1970). Ground cover and canopy coverage were measured in two 0.1 m^2 quadrats placed in the outside corners of the 1 m^2 frame. The Daubenmire cover class method (Daubenmire 1959) was used to estimate the percent bare ground, litter, and canopy coverage of standing dead vegetation and live grasses and forbs.

Avian Surveys

Visual surveys of breeding birds were conducted by walking (1 m per 5 sec) a transect that bisected each plot parallel to its longest dimension. All birds observed or heard using the habitat within the surveyed plot were counted. Birds flying overhead or using adjacent mowed lanes were not counted. All birds were identified visually with the aid of binoculars and using auditory cues to ensure correct identification. For each observation, I recorded the species, its location within plot, and whether the bird was alone, with another individual, or with multiple individuals. The behavior of each bird was recorded as: 1) entering plot, 2) flushed, 3) foraging, 4) perched, 5) perched singing male, 6) attending nest, or 7) attending young.

While the dimensions of my research plots were variable, all were sufficiently narrow that the entire area of each plot could be surveyed with a single pass along the centered transect, Diefenbach *et al.* (2003) demonstrated that detection probabilities of grassland birds were near 1.0 for transect half-widths of 25 m or less and that they began to drop significantly beyond 25 m. Seventy-nine percent of the transect half-widths in my study measured $\leq$ 27 m, so I am confident that I was able to detect birds using the research plots.

Surveys were conducted only in favorable weather conditions (Ralph *et al.* 1993) between 30 min after sunrise and 1100. No surveys were carried out in precipitation, fog, or when local wind speed exceeded 25 km/h. Weather data (temperature, wind speed, cloud cover, and humidity) were collected using a Kestrel® 3500 Pocket Weather® Meter.

Each research plot was surveyed seven times between May and July each year (two surveys in May, three in June, and two in July). It was not possible to survey all plots in a single day, so a restricted randomly selected subset of 8 to 20 plots were surveyed each day. To minimize bias associated with temporal or climatic variation, an equal number of plots of each treatment on each soil type was selected each day. Usually, one round of surveys (all 48 plots) was completed within 3-4 days. If adjacent plots were selected to be surveyed on the same day, the plots were surveyed simultaneously by two observers or the surveys were separated temporally (~30 min) to avoid counting birds flushed into adjacent plots.

Nest Surveys and Monitoring

Nest surveys were conducted weekly from 1 May to 30 July in 2011 and 2012 in all plots. Systematic nest searches were conducted by dragging a weighted nylon rope between two motorized vehicles at approximately 5 km/hr over the vegetation in each survey plot (Hughes *et al*. 1999, Renfrew *et al*. 2005, Kerns *et al*. 2010). When a bird flushed, I searched for a nest. Nests were also found opportunistically during breeding bird surveys. At each nest site, I recorded geographic coordinates, species and number of eggs/nestlings present, number of cowbird eggs/nestlings present, and plant species and functional group in which the nest was built if the nest was not on the ground. Nests were monitored every 3-4 days in order to maximize observation data (nest status, nest stage, success/failure, cause and timing of failure) and minimize nest disturbance (Johnson and Temple 1990, Winter 1999, Lusk *et al*. 2003).

Data Analysis

Variation in vegetation structural characteristics in the biomass production plots among years was assessed using Principle Components Analysis (PCA). Variables included in the PCA analysis included litter depth, litter depth coefficient of variation, VOR, VOR coefficient of variation, height of tallest live grass and forb, percent cover of bare ground and litter, and percent canopy coverage of grasses, forbs, and standing dead vegetation. Percent litter cover, percent standing dead cover, and VOR coefficient of variation were log transformed, and all variables were normalized prior to analysis.

For each year, I calculated average bird abundance, total species richness, and Shannon's diversity index for each plot. I converted bird counts to densities and then calculated the mean density of each species for each plot in each year using the seven surveys as subsamples. The mean densities were summed for all species to obtain total bird abundance for each plot during each year. Data were pooled from all seven surveys each year to calculate total species richness and Shannon's diversity index (H) for each plot. Since some response variables violated assumptions of normality, univariate permutational analysis of variance (PERMANOVA) was used based on a Euclidean distance matrix with treatment, soil type, and year as fixed factors and plot as a random factor nested in treatment and soil type to test for differences in abundance, species richness, and diversity among groups. I performed 9,999 permutations and applied a posteriori pair-wise comparison tests of significant terms where appropriate (Anderson 2001). Some models included interaction terms with large p-values (>0.50) and negative components of variation. In such cases, the term with the smallest mean square was pooled and the model re-fit. This process was repeated until all remaining terms had positive coefficients of variation (Anderson *et al.* 2008).

I used the Partners in Flight (PIF) species assessment database for the Eastern Tallgrass Prairie Region to calculate average Regional Combined Scores of birds using the biomass production plots during each year. These scores assess factors (i.e., population size, breeding distribution, non-breeding distribution, threats, and population trend) related to the vulnerability and regional conservation status for all North American bird species. In addition, I classified each species into one of four broad habitat guilds (obligate grassland, facultative grassland, woodland, or generalist) and evaluated community changes in the proportional representation of species in each habitat guild over time.

PERMANOVA was used to assess variation in bird community composition by treatment, soil type, and year. Using the untransformed bird abundance data with an additional dummy species with value 1 for all samples, I generated a Bray-Curtis dissimilarity matrix, conducted 9,999 permutations, and performed a posteriori pair-wise comparison test of significant main effects and/or interaction terms. For significant interaction terms where the number of unique permutations was small, I generated Monte Carlo p-values (Anderson *et al*. 2008). I employed non-metric multidimensional scaling (NMDS) to visualize patterns of variation in bird community composition by treatment, soil type, and year using the full data set (Clark and Gorley 2006). I also generated bubble plots to explore the contributions of particular species to differences in community structure among the treatment × soil type groups.

I calculated annual and pooled Mayfield daily survival probabilities and nest success rates (Mayfield 1975) for Dickcissel (*Spiza americana*) and Lark Sparrow (*Chondestes grammacus*) nests. Sample sizes were too low to calculate Mayfield daily survival probabilities and nest success rates by treatment or soil type; however I did calculate these for the pooled low diversity grass plots and diversity forb-rich plots. Pearson's Chi-square test was used to analyze nest site selection among treatments, soil types, and between low diversity grass plots and high diversity forb-rich plots. I used linear regression analysis to investigate the association between total bird abundance to the number of nests in each plot.

Statistical analyses were conducted using Systat 12 (SYSTAT Software Inc., Chicago, Illinois, U.S.A.) and Primer 6 (version 6.1.13) with PERMANOVA + (version 1.0.3; PRIMER-E Ltd., Plymouth PL1 3DH, UK) software. Graphs were constructed using Sigma Plot and Primer 6 (version 6.1.13).

CHAPTER 3

RESULTS

Vegetation Characteristics

Vegetation characteristics in biomass production plots (Table 2) varied site-wide among years (Figure 2a) and by treatment within years (Figure 2b, 3a-c). The first 3 PCA axes accounted for 74.1% of the variation in vegetation structure among plots (Table 3).

Temporal changes in vegetation structure resulted from annual variation in site management and from successional changes during establishment of native species at the site. Principle Component 1 (PC1) accounted for 38.6% of variation and was negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height (Figure 2a). Variation in vegetation structural characteristics along PC1 were driven by site management and clearly differentiated 2011 (spring burn) from 2010 (no management) and 2012 (spring harvest). Following a spring burn (2011), biomass production plots had greater bare ground coverage and heterogeneity in vegetation height-density and lower litter cover, vegetation height-density, and maximum grass height compared to years of no management or harvest (Figure 2a).

Principle Component 2 (PC2) accounted for 18.2% of variation and was positively associated with litter depth and standing dead vegetation cover. Variation in vegetation structural characteristics along PC2 also related to site management and differentiated vegetation characteristics in 2010 (no management) from years of prescribed burning (2011) or harvest (2012).

Principle Component 3 (PC3) accounted for 17.2% of variation and was negatively associated with grass cover and positively associated with forb cover and height. Variation in vegetation structural characteristics along PC3 appeared to be driven by successional changes associated with the establishment of species in the seed mixes and the reduction of volunteer forbs over time. Each year, grass cover increased and forb cover decreased in the low diversity grass plots and forb cover increased in the high diversity forb-rich plots. Vegetation structural characteristics in low diversity grass plots and high diversity forb-rich plots were most similar in 2010 and diverged over time (Figure 3a-c).

Table 2. Vegetation characteristics in four perennial biofuel feedstocks by year. For each vegetation characteristic, means ($\bar{x}$) are listed across the top row with the standard error (SE) directly below.

	2010				2011				2012			
	S	G	B	P	S	G	B	P	S	G	B	P
Litter	16.44	22.65	13.58	16.11	0.01	0.00	0.02	0.04	1.38	1.95	1.67	2.09
	3.19	5.22	2.17	2.36	0.00	0.00	0.01	0.02	0.17	0.21	0.12	0.22
Litter CV	0.86	0.81	0.87	0.87	0.67	0.50	0.57	0.71	0.49	0.57	0.58	0.61
	0.04	0.04	0.04	0.03	0.28	0.26	0.25	0.26	0.07	0.04	0.04	0.03
Robel	31.96	23.82	36.09	29.80	21.02	14.83	23.32	19.35	61.32	40.35	52.36	48.87
	4.08	2.63	4.05	3.22	2.66	1.96	3.26	2.91	2.11	0.04	2.39	2.25
Robel CV	0.26	0.33	0.29	0.31	0.27	0.36	0.35	0.40	0.10	0.16	0.15	0.16
	0.03	0.03	0.02	0.03	0.05	0.05	0.06	0.06	0.01	0.02	0.01	0.01
Grass Hgt	59.74	52.74	57.18	55.21	39.99	30.71	32.40	30.53	83.73	62.18	62.98	63.59
	3.56	2.77	2.48	2.53	1.69	1.16	1.63	1.40	2.17	1.73	1.82	1.36
Forb Hgt	51.83	42.63	68.62	66.68	26.74	21.79	38.10	37.43	36.67	27.01	66.26	64.71
	5.69	4.23	4.78	3.89	1.91	2.013	2.16	2.12	2.79	2.89	3.11	2.39
% Bare	34.13	27.12	31.65	32.75	93.67	95.10	94.40	93.44	13.95	14.93	15.63	18.18
	4.21	4.05	3.27	2.55	0.65	0.57	0.80	0.84	2.13	2.60	3.19	3.77
% Litter	63.24	69.93	66.54	65.95	6.42	4.88	5.71	6.37	83.08	81.97	81.04	76.85
	4.35	4.38	3.02	2.49	0.65	0.52	0.80	0.77	2.74	3.32	4.02	5.07
% St. Dead	21.69	10.49	10.75	10.31	2.78	2.67	2.50	2.54	3.11	3.38	2.64	2.87
	3.46	1.27	0.94	1.20	0.09	0.17	0.00	0.04	0.36	0.43	0.06	0.26
% Grass	32.76	46.40	31.32	34.74	49.98	43.26	30.15	33.92	53.12	65.12	34.93	41.69
	4.62	4.13	2.44	2.09	4.13	4.10	2.53	3.71	3.81	3.61	3.99	4.55
% Forb	28.56	22.67	42.02	35.61	16.31	10.79	42.59	38.69	12.07	5.62	56.05	49.13
	3.94	1.64	2.79	2.65	1.92	1.50	2.93	3.21	2.25	0.70	3.94	4.08
% plots w/ dead grass	100	100	100	100	8.33	0.00	0.00	0.00	83.33	66.67	66.67	100
% plots w/ dead forb	100	100	100	100	16.67	0.00	0.00	0.00	8.33	0.00	16.67	33.33

Table 3. Principle components analysis of vegetation structural characteristics from 2010-2012 in four perennial biofuel feedstocks. Factor loadings in bold indicate variables most strongly correlated with each axis.

Variable	PC1	PC2	PC3
Litter depth	0.187	**0.846**	0.050
Litter %	**0.864**	0.295	0.054
Litter CV	-0.124	0.421	0.089
Bare %	**-0.869**	-0.292	-0.061
VOR	**0.904**	-0.154	0.167
VOR CV	**-0.774**	0.264	0.095
Maximum grass height	**0.924**	0.135	-0.035
Maximum forb height	0.457	0.325	**0.741**
Grass %	0.433	-0.167	**-0.670**
Forb %	0.100	-0.069	**0.918**
Standing Dead %	0.151	**0.829**	0.015
Eigenvector	4.25	2.00	1.90
Variance explained (%)	38.6	18.2	17.3
Cumulative variance explained (%)	38.6	56.8	74.1

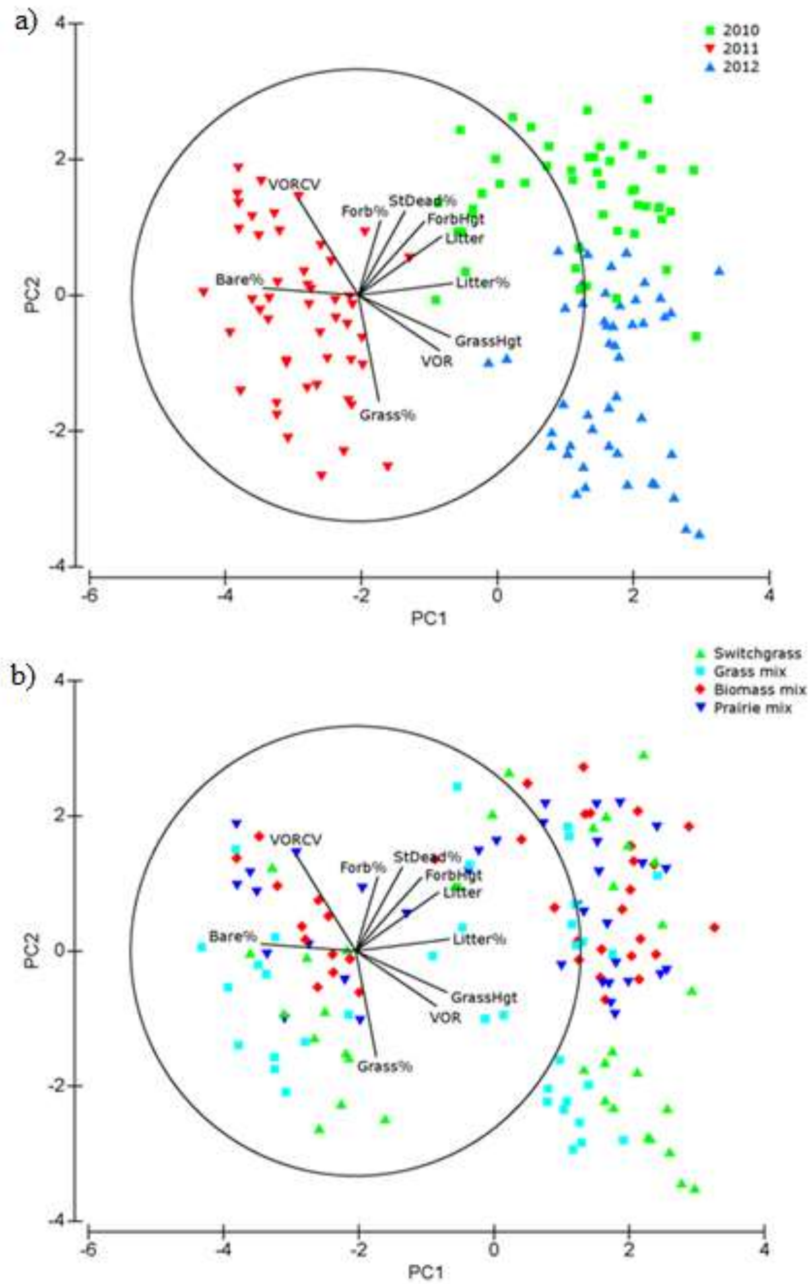

Figure 2. Principle component analysis of vegetation structure in four perennial biofuel feedstocks by a) year (2010-2012) and b) treatment. Axis 1 (PC1) was negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes.

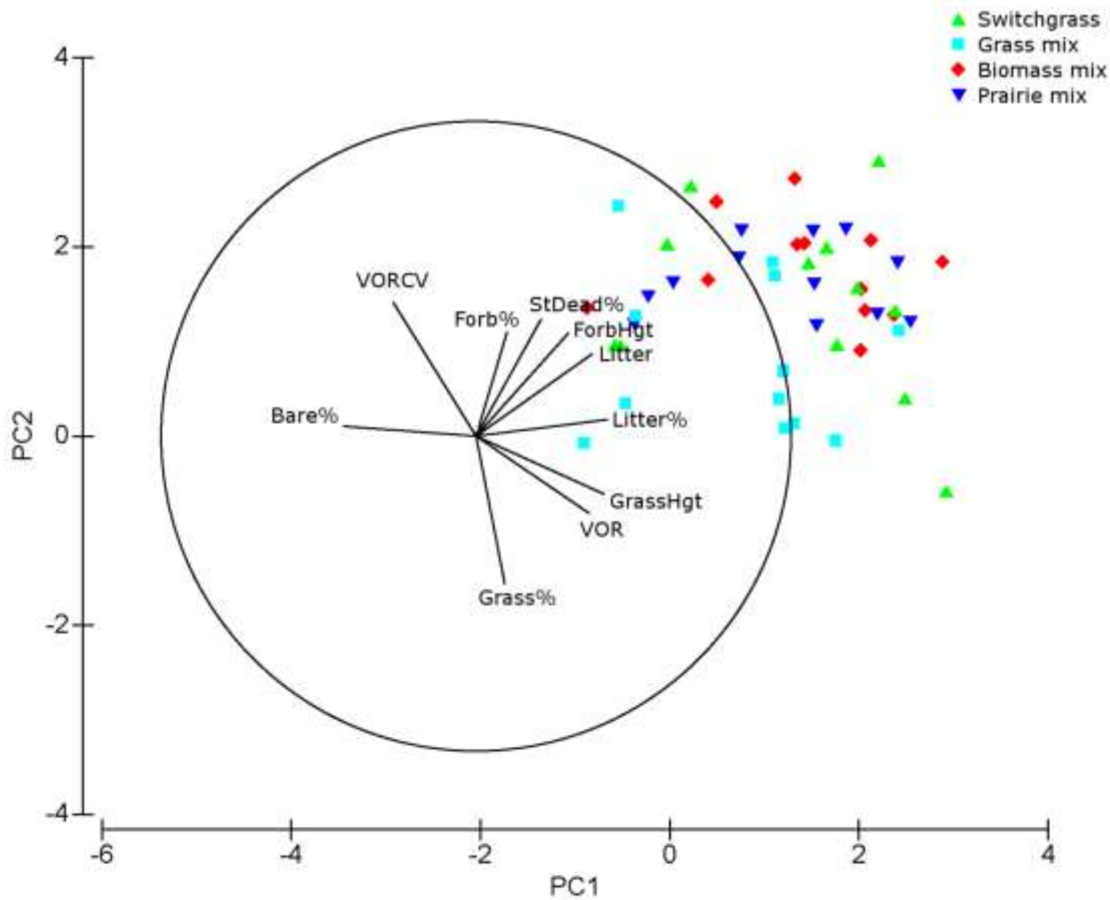

Figure 3a. Principle component analysis of 2010 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes.

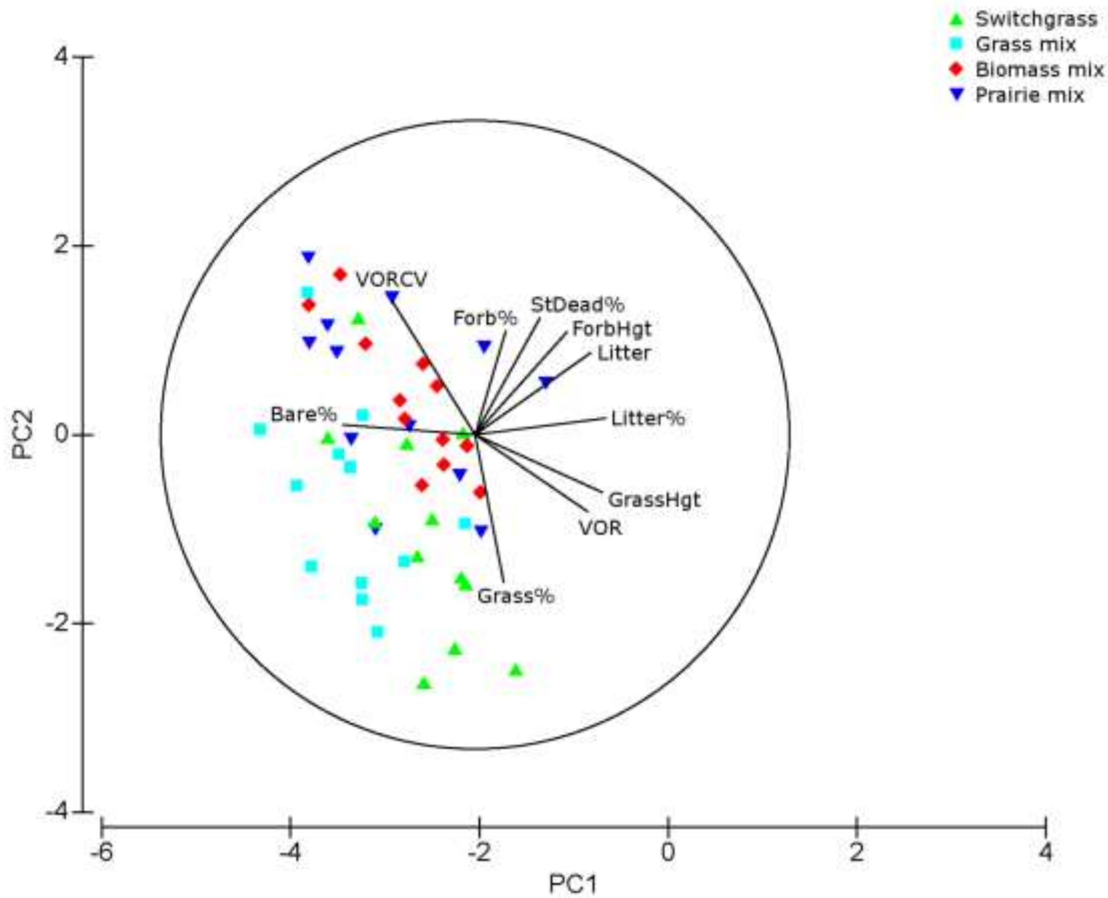

Figure 3b. Principle component analysis of 2011 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes.

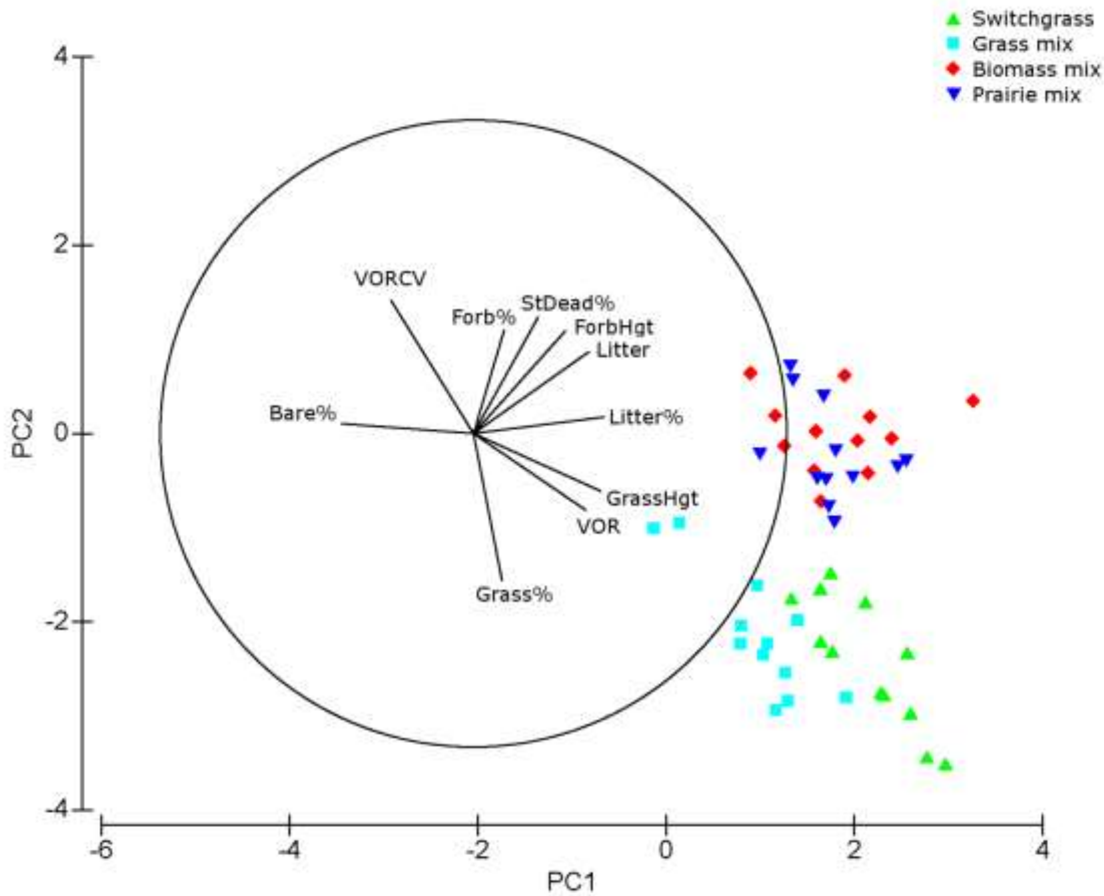

Figure 3c. Principle component analysis of 2012 vegetation structure in four perennial biofuel feedstocks by treatment. Axis 1 (PC1) was driven negatively associated with bare ground cover and VOR coefficient of variation and positively associated with litter cover, VOR, and grass height. Axis 2 (PC2) was positively associated with litter depth and standing dead vegetation cover. Axis 3 (PC3, not pictured) was negatively associated with grass cover and positively associated with forb cover and height. Vectors indicate multiple partial correlations of habitat variables to the PC axes.

Breeding Bird Abundance, Richness, and Diversity

I recorded 2076 bird observations representing 34 species. Bird abundance varied significantly by treatment and year (Table 4). In all years, bird abundance was significantly greater in the high diversity forb-rich plots compared to the low diversity grass plots (Table 5, Figure 4). However, there were no significant differences in bird abundance between biomass and prairie mix nor between switchgrass and grass mix in any year. Bird abundance was highest in 2010 and declined significantly each year thereafter.

Bird species richness and community diversity varied significantly by year, treatment, and soil type (Table 4-6). Species richness and diversity were greatest in 2010 and declined significantly each year (Figure 5a, b). In all years, species richness was significantly greater in the high diversity forb-rich plots compared to the low diversity grass plots and there were no significant differences in bird species richness between biomass and prairie mix nor between switchgrass and grass mix in any year (Figure 5a). The same general pattern applied to community diversity (Figure 5b), except that the difference between prairie mix and grass mix was not significant ($p=0.061$). Bird species richness (Figure 6a) and diversity (Figure 6b) were greater in plots on sandy loam and clay loam than on loam in all years.

Table 4. PERMANOVA comparing bird abundance, species richness, and Shannon's diversity index in four perennial biofuel feedstocks on three soil types during the 2010-2012 breeding seasons.

	df	Pseudo-F	p-value
Abundance			
Treatment	3	28.411	0.0001
Soil	2	1.1253	0.3405
Year	2	18.685	0.0001
Treatment x Soil	6	1.8985	0.1072
Soil x Year	4	3.072	0.0227
Plot (Treatment x Soil)	43	2.2323	0.0023
Treatment x Soil x Year	12	1.222	0.2888
Pooled	71		
Total	143		
Species Richness			
Treatment	3	15.647	0.0001
Soil	2	5.3253	0.0069
Year	2	30.908	0.0001
Treatment x Year	6	1.6053	0.1536
Pooled	130		
Total	143		
Shannon's Diversity Index			
Treatment	3	4.0561	0.0105
Soil	2	3.8703	0.0321
Year	2	22.958	0.0001
Treatment x Year	6	1.1317	0.3541
Soil x Year	4	1.133	0.3461
Pooled (1)	49	1.0099	0.4727
Pooled (2)	81		
Total	143		

Table 5. Bird species abundance in four perennial biofuel feedstocks (S = switchgrass, G = grass mix, B = biomass mix, and P = prairie mix) by year. Asterisks indicate species observed nesting in the research plots.

		2010					2011					2012				
		S	G	B	P	Total	S	G	B	P	Total	S	G	B	P	Total
Red-winged Blackbird	*Agelaius phoeniceus*	0	0	1	3	4	0	0	0	0	0	1	0	0	0	1
Grasshopper Sparrow	*Ammodramus savannarum* *	0	0	0	0	0	0	0	0	0	0	7	10	2	23	42
Ruby-throated Hummingbird	*Archilochus colubris*	0	0	1	3	4	0	0	0	0	0	0	0	0	1	1
Northern Cardinal	*Cardinalis cardinalis*	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
American Goldfinch	*Carduelis tristis* *	12	14	23	31	80	0	1	18	16	35	1	0	5	8	14
Lark Sparrow	*Chondestes grammacus* *	9	17	28	16	70	32	37	58	42	169	3	7	5	4	19
Sedge Wren	*Cistothorus platensis* *	41	27	1	12	81	0	0	0	0	0	0	23	0	1	24
Northern Flicker	*Colaptes auratus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Eastern Wood Peewee	*Contopus virens*	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Blue Jay	*Cyanocitta cristata*	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0
Gray Catbird	*Dumetella carolinensis*	0	1	1	0	2	1	0	0	0	1	1	0	0	0	1

(Table Continues)

		2010					2011					2012				
		S	G	B	P	Total	S	G	B	P	Total	S	G	B	P	Total
Sparrow spp.	*Emberizidae spp.*	1	1	0	0	2	0	0	1	1	2	0	0	1	0	1
Common Yellowthroat	*Geothlypis trichas* *	7	5	37	49	98	0	0	25	15	40	0	0	33	27	60
Baltimore Oriole	*Icterus galbula*	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Wild Turkey	*Meleagris gallopavo* *	5	0	0	0	5	1	0	0	0	1	0	0	0	0	0
Song Sparrow	*Melospiza melodia* *	23	20	43	37	123	6	4	12	7	29	3	0	6	4	13
Lincoln Sparrow	*Melospiza lincolnii*	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0
Brown-headed Cowbird	*Molothrus ater* *	10	5	6	8	29	1	8	1	4	14	1	0	0	0	1
Savannah Sparrow	*Passerculus sandwichensis*	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Indigo Bunting	*Passerina cyanea* *	6	10	24	28	68	8	2	16	12	38	2	0	12	3	17
Hairy Woodpecker	*Picoides villosus*	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Vesper Sparrow	*Pooecetes gramineus*	2	1	0	0	3	0	0	0	0	0	0	0	0	0	0
Eastern Phoebe	*Sayornis phoebe*	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0

(Table Continues)

		2010					2011					2012				
		S	G	B	P	Total	S	G	B	P	Total	S	G	B	P	Total
Eastern Bluebird	*Sialis sialis*	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
Dickcissel	*Spiza Americana* *	19	18	64	40	141	27	38	105	135	305	26	16	135	140	317
Chipping Sparrow	*Spizella passerine* *	7	11	28	11	57	3	7	12	15	37	0	1	11	1	13
Field Sparrow	*Spizella pusilla*	0	0	2	1	3	2	0	2	2	6	0	2	0	0	2
Eastern Meadowlark	*Sturnella magna*	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Brown Thrasher	*Toxostoma rufum*	0	1	4	0	5	6	0	1	0	7	1	0	3	0	4
House Wren	*Troglodytes aedon*	0	0	0	0	0	0	0	0	0	0	1	0	1	1	3
American Robin	*Turdus migratorius*	0	1	1	3	5	2	7	5	6	20	1	0	0	1	2
Eastern Kingbird	*Tyrannus tyrannus*	0	0	1	0	1	0	1	2	2	5	0	1	0	2	3
Mourning Dove	*Zenaida macroura*	3	15	3	9	30	0	0	0	0	0	0	0	0	0	0
White-Throated sparrow	*Zontrichia albicollis*	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0
Total abundance						819					718					539

Table 6. Bird species abundance in perennial biofuel feedstocks by soil type (S = sandy loam, L = loam, C = clay loam) by year.

		2010				2011							
		S	L	C	Total	S	L	C	Total	S	L	C	Total
Red-winged Blackbird	*Agelaius phoeniceus*	0	1	3	4	0	0	0	0	1	0	0	1
Grasshopper Sparrow	*Ammodramus savannarum*	0	0	0	0	0	0	0	0	19	0	23	42
Ruby-throated Hummingbird	*Archilochus colubris*	0	1	3	4	0	0	0	0	0	0	1	1
Northern Cardinal	*Cardinalis cardinalis*	1	0	0	1	0	0	0	0	0	0	0	0
American Goldfinch	*Carduelis tristis*	12	23	45	80	5	11	19	35	3	4	7	14
Lark Sparrow	*Chondestes grammacus*	46	17	7	70	87	46	36	169	17	1	1	19
Sedge Wren	*Cistothorus platensis*	0	42	39	81	0	0	0	0	0	13	11	24
Northern Flicker	*Colaptes auratus*	0	0	0	0	0	0	0	0	1	0	0	1
Eastern Wood Peewee	*Contopus virens*	0	0	0	0	1	0	0	1	0	0	0	0
Blue Jay	*Cyanocitta cristata*	1	0	0	1	1	0	0	1	0	0	0	0
Gray Catbird	*Dumetella carolinensis*	1	1	0	2	0	1	0	1	0	1	0	1

(Table Continues)

		2010				2011							
		S	L	C	Total	S	L	C	Total	S	L	C	Total
Sparrow spp.	*Emberizidae spp.*	2	0	0	2	2	0	0	2	1	0	0	1
Common Yellowthroat	*Geothlypis trichas*	0	22	76	98	8	8	24	40	1	9	50	60
Baltimore Oriole	*Icterus galbula*	1	0	0	1	0	0	0	0	0	0	0	0
Wild Turkey	*Meleagris gallopavo*	4	1	0	5	1	0	0	1	0	0	0	0
Song Sparrow	*Melospiza melodia*	22	36	65	123	1	5	23	29	5	4	4	0
Lincoln Sparrow	*Melospiza lincolnii*	0	0	0	0	0	0	2	2	0	0	0	13
Brown-headed Cowbird	*Molothrus ater*	24	2	3	29	7	3	4	14	0	1	0	1
Savannah Sparrow	*Passerculus sandwichensis*	0	1	0	1	0	0	0	0	0	0	0	17
Indigo Bunting	*Passerina cyanea*	18	9	41	68	4	9	25	38	3	3	11	0
Hairy Woodpecker	*Picoides villosus*	0	0	1	1	0	0	0	0	0	0	0	0
Vesper Sparrow	*Pooecetes gramineus*	0	1	2	3	0	0	0	0	0	0	0	0

(Table Continues)

		2010				2011							
		S	L	C	Total	S	L	C	Total	S	L	C	Total
Eastern Phoebe	*Sayornis phoebe*	0	0	0	0	1	0	1	2	0	0	0	0
Eastern Bluebird	*Sialis sialis*	0	0	0	0	2	0	0	2	0	0	0	0
Dickcissel	*Spiza americana*	26	71	44	141	68	94	143	305	77	73	167	317
Chipping Sparrow	*Spizella passerine*	31	13	13	57	11	13	13	37	4	6	3	13
Field Sparrow	*Spizella pusilla*	3	0	0	3	4	2	0	6	2	0	0	2
Eastern Meadowlark	*Sturnella magna*	0	0	0	0	1	0	0	1	0	0	0	0
Brown Thrasher	*Toxostoma rufum*	5	0	0	5	4	3	0	7	4	0	0	4
House Wren	*Troglodytes aedon*	0	0	0	0	0	0	0	0	1	1	1	3
American Robin	*Turdus migratorius*	5	0	0	5	15	0	5	20	2	0	0	2
Eastern Kingbird	*Tyrannus tyrannus*	0	1	0	1	3	2	0	5	3	0	0	3
Mourning Dove	*Zenaida macroura*	28	2	0	30	0	0	0	0	0	0	0	0
White-Throated sparrow	*Zontrichia albicollis*	3	0	0	3	0	0	0	0	0	0	0	0
Total abundance					819				718				539

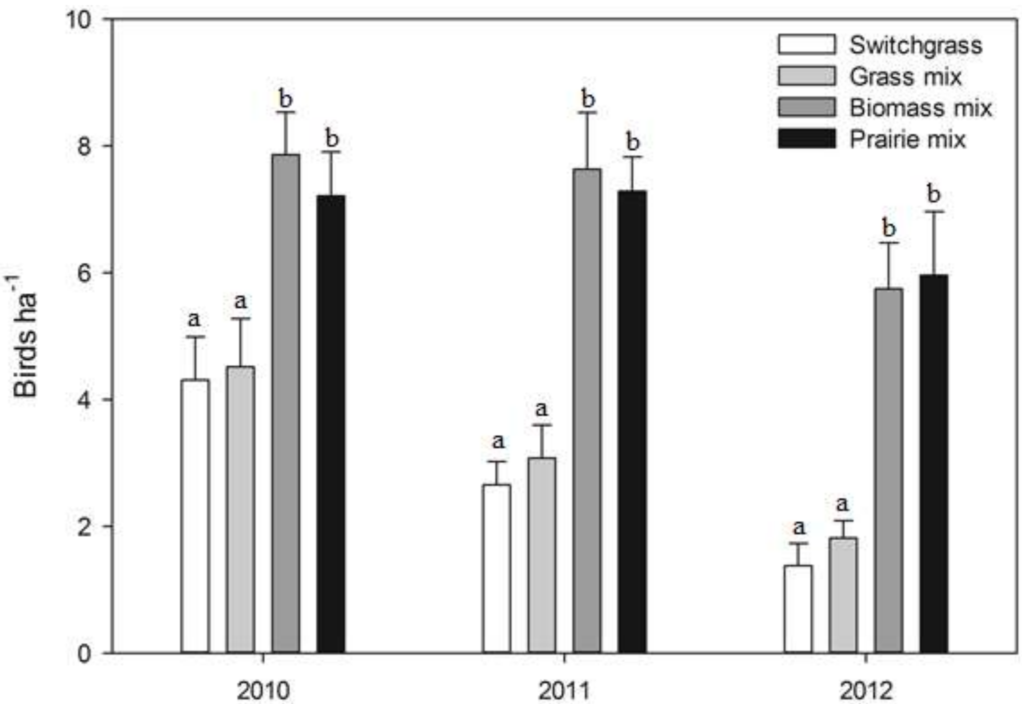

Figure 4. Mean bird abundance in four perennial biofuel feedstocks by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird abundance declined significantly each year.

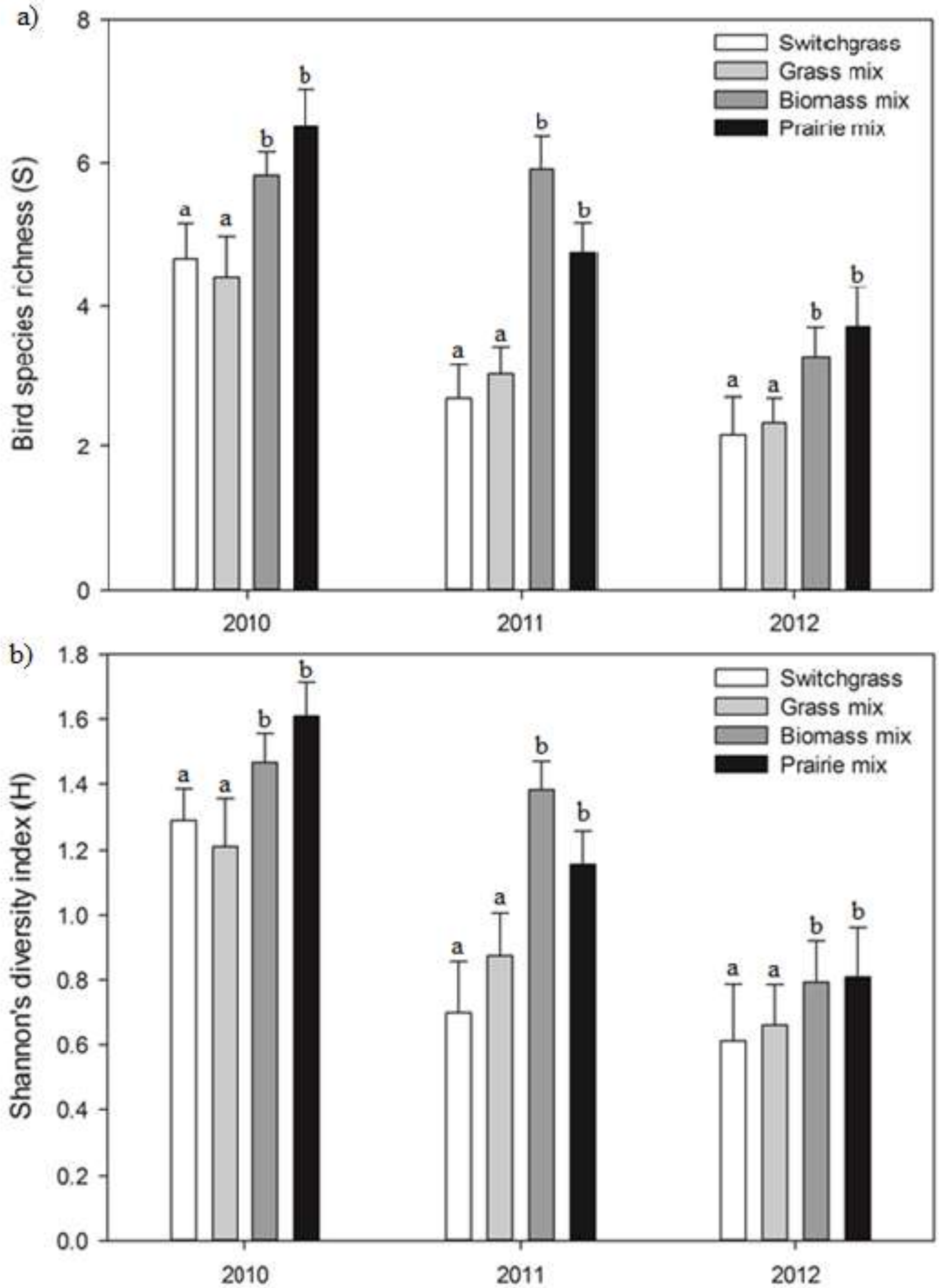

Figure 5. Mean bird species a) richness and b) diversity in four perennial biofuel feedstocks by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird species richness and diversity declined significantly each year.

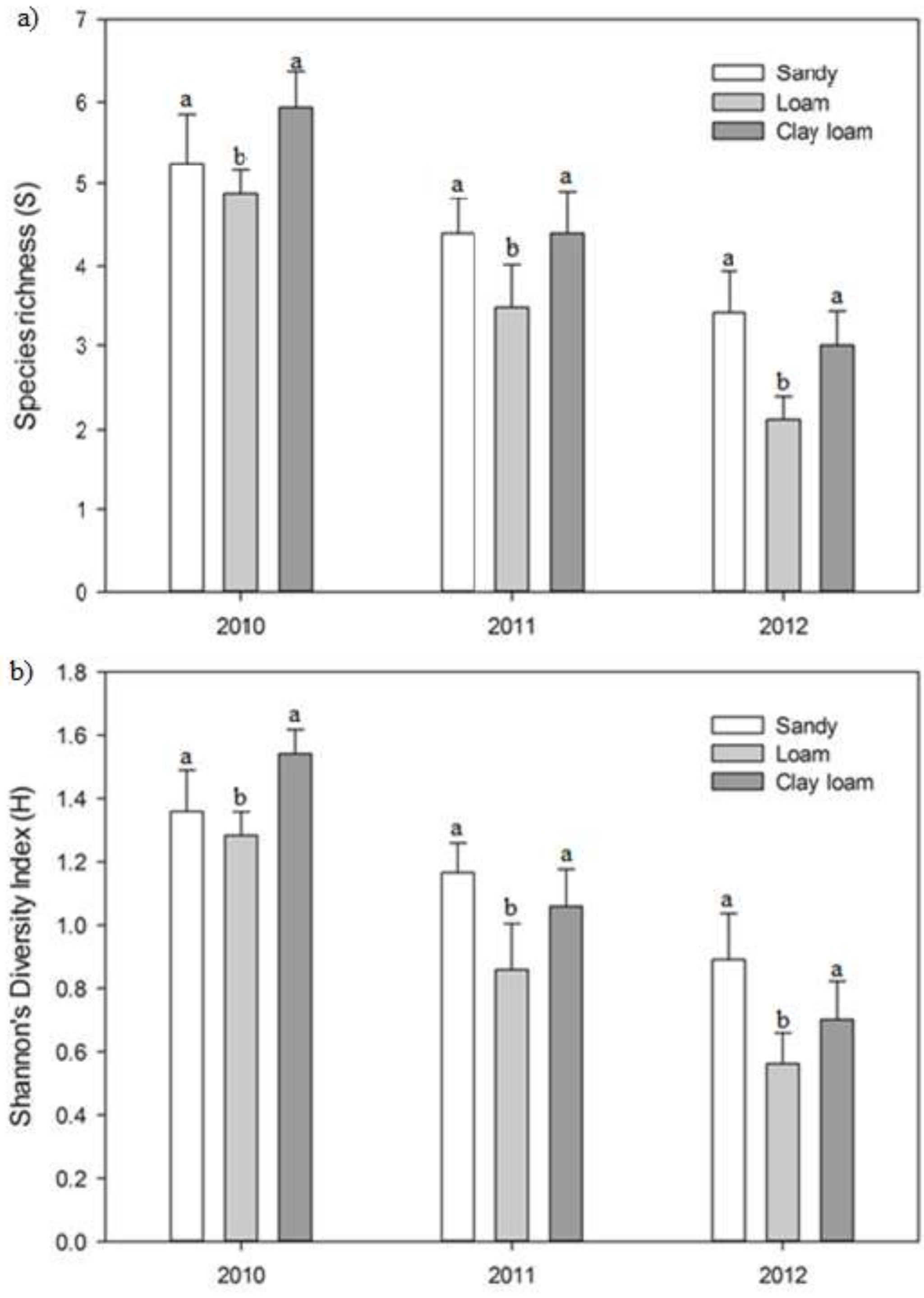

Figure 6. Mean bird a) species richness and b) community diversity in four perennial biofuel feedstocks across three soil types by year. Means labeled with different letters were significantly different ($p < 0.05$). Bird species richness and diversity declined significantly each year.

Breeding Bird Community Composition

Breeding bird community composition varied by treatment, soil type, and year with a significant three-way interaction (Table 7). The main effects of treatment and year explained the greatest amount of variation in bird community composition. The main effect of treatment can be visualized in the separation of the low diversity grass plots from the high diversity forb rich-plots along the horizontal NMDS axis 1 (Figure 7). The main effect of year can be visualized through the partial separation of 2010 from 2011-2012 along the vertical NMDS axis 2 (Figure 7). The interaction of treatment with year is evident in the increasing effect size (greater separation of high diversity forb-rich from low diversity grass groups along NMDS axis 1 over time (Figure 7). Comparisons of individual NMDS plots of bird community composition in all plots within each year (Figure 8a-c) also highlight that bird communities diverged over time, with progressively greater separation among the high diversity forb-rich plots and the low diversity grass plots, and consequently lower stress values, in the NMDS plots over time. American Goldfinch (*Carduelis tristis*), Common Yellowthroat (*Geothlypis trichas*), Dickcissel, and Indigo Bunting (*Passerina cyanea*) were proportionally more abundant in high diversity forb-rich plots, whereas Sedge Wren (*Cistothorus platensis*) was found almost exclusively in low diversity grass plots (Table 5).

Bird community composition varied over time as habitat characteristics changed due to plant establishment and site management. There was a general trend towards increased proportional representation of grassland obligate species in the bird community over time. Grassland obligate species, primarily Dickcissel, Grasshopper Sparrow (*Ammodramus savannarum*), and Sedge Wren, comprised 31% of bird observations in 2010, 45% in 2011, and 71% in 2010. Dickcissel in particular became increasingly dominant over time, accounting for 17% of bird observations in 2010, 42% in 2011, and 59% in 2012. Grasshopper Sparrow was absent from the site during early establishment (2010) and following a spring burn (2011); however, it was the third most abundant species after harvest in 2012. Sedge Wren was abundant in 2010 and 2012, but was completely absent in 2011 following a spring burn. In contrast, several generalist or facultative grassland species decreased in abundance over time, including American Goldfinch, Chipping Sparrow (*Spizella passerine*), Indigo Bunting, Mourning Dove (*Zenaida macroura*), and Song Sparrow (*Melospiza melodia*, Tables 5 and 9 and Appendix Table A2). Average PIF breeding season Regional Combined Scores for birds observed in the biomass production plots increased over time (11.9 in 2010, 13.1 in 2011, 15.2 in 2012; Table 9).

Soil type also affected bird community composition at the site. For example in 2010 and 2012, Sedge Wrens were commonly observed with approximately equal frequency in loam and clay loam plots; however, I never recorded a single Sedge Wren observation in plots on sandy loam. In contrast, Lark Sparrows were observed on all treatments on all soil types in 2010 and 2011; however, they were recorded disproportionately more on sandy loam (58% of observations; Table 6). In addition to these direct effects, there was a significant treatment × soil type × year interaction (Table 7). The treatment × soil type interaction was most pronounced in 2010, when there were no significant differences in bird community composition among plots of any treatment on sandy loam, but significant differences existed between the high diversity forb-rich plots and low diversity grass plots on the other soil types (Table 8). Despite this lag during early establishment, in subsequent years treatment effects on bird community composition on sandy loam were similar to those on the other soil types (Table 8). There was also some evidence of divergence in bird communities between switchgrass and grass mix plots on loam and clay loam over time, as illustrated by changes in the distribution of Sedge Wrens between 2010 and 2012. In both, years Sedge Wrens were found only on loam and clay loam soil types; however, in 2010 Sedge Wrens were most abundant in switchgrass and were observed in all four treatments (Figure 9a), whereas 96% of Sedge Wren observations were in grass mix plots in 2012 (Figure 9b).

Table 7. PERMANOVA comparing bird community composition in four perennial biofuel feedstocks on three soil types over time.

	df	Pseudo-F	p-value
Community Composition			
Treatment	3	12.799	0.0001
Soil	2	9.3909	0.0001
Year	2	21.138	0.0001
Treatment x Soil	6	1.8688	0.0048
Treatment x Year	6	3.1555	0.0001
Soil x Year	4	3.3768	0.0001
Plot (Treatment x Soil)	43	1.4559	0.0004
Treatment x Soil x Year	12	1.4208	0.0167
Residual	65		
Total	143		

Table 8. PERMANOVA pair-wise comparisons of bird community dissimilarity among four perennial biofuel feedstocks (S = swicthgrass, G = grass mix, B = biomass mix, and P = prairie mix on three soil types from 2010-2012.

	2010			2011			2012		
Sandy	Groups	t	p(mc)	Groups	t	p(mc)	Groups	t	p(mc)
loam	S, P	0.91075	0.5244	S, P	2.29	0.0117	S, P	2.2153	0.0145
	S, G	0.73512	0.7038	S, G	0.99428	0.4287	S, G	0.98276	0.4347
	S, B	0.96382	0.4314	S, B	1.4873	0.0971	S, B	1.8036	0.0415
	P, G	0.9957	0.4131	P, G	2.1636	0.0189	P, G	2.481	0.0062
	P, B	1.0274	0.3923	P, B	2.0154	0.0324	P, B	0.86716	0.5248
	G, B	1.0257	0.3792	G, B	1.4336	0.1377	G, B	2.2563	0.0105
Loam	Groups	t	p(mc)	Groups	t	p(mc)	Groups	t	p(mc)
	S, P	2.3038	0.01	S, P	2.3912	0.0079	S, P	2.6754	0.0085
	S, G	1.3863	0.1477	S, G	1.4706	0.1295	S, G	2.803	0.0054
	S, B	2.9019	0.0021	S, B	2.2205	0.0113	S, B	3.3771	0.0021
	P, G	1.9628	0.0364	P, G	1.6769	0.0847	P, G	3.1477	0.0038
	P, B	2.1926	0.0172	P, B	1.3902	0.143	P, B	0.86431	0.5052
	G, B	1.9631	0.0279	G, B	2.229	0.0251	G, B	4.0545	0.0006
Clay	Groups	t	p(mc)	Groups	t	p(mc)	Groups	t	p(mc)
loam	S, P	2.2309	0.0178	S, P	1.8727	0.0419	S, P	2.5435	0.0195
	S, G	1.1931	0.2672	S, G	0.94381	0.4486	S, G	1.3663	0.18
	S, B	2.3027	0.0127	S, B	1.6807	0.0811	S, B	2.5266	0.0102
	P, G	2.2796	0.0112	P, G	2.0379	0.0178	P, G	4.041	0.001
	P, B	1.1258	0.3054	P, B	0.37881	0.9431	P, B	1.0186	0.3894
	G, B	2.0002	0.0233	G, B	1.6334	0.0679	G, B	3.7755	0.0006

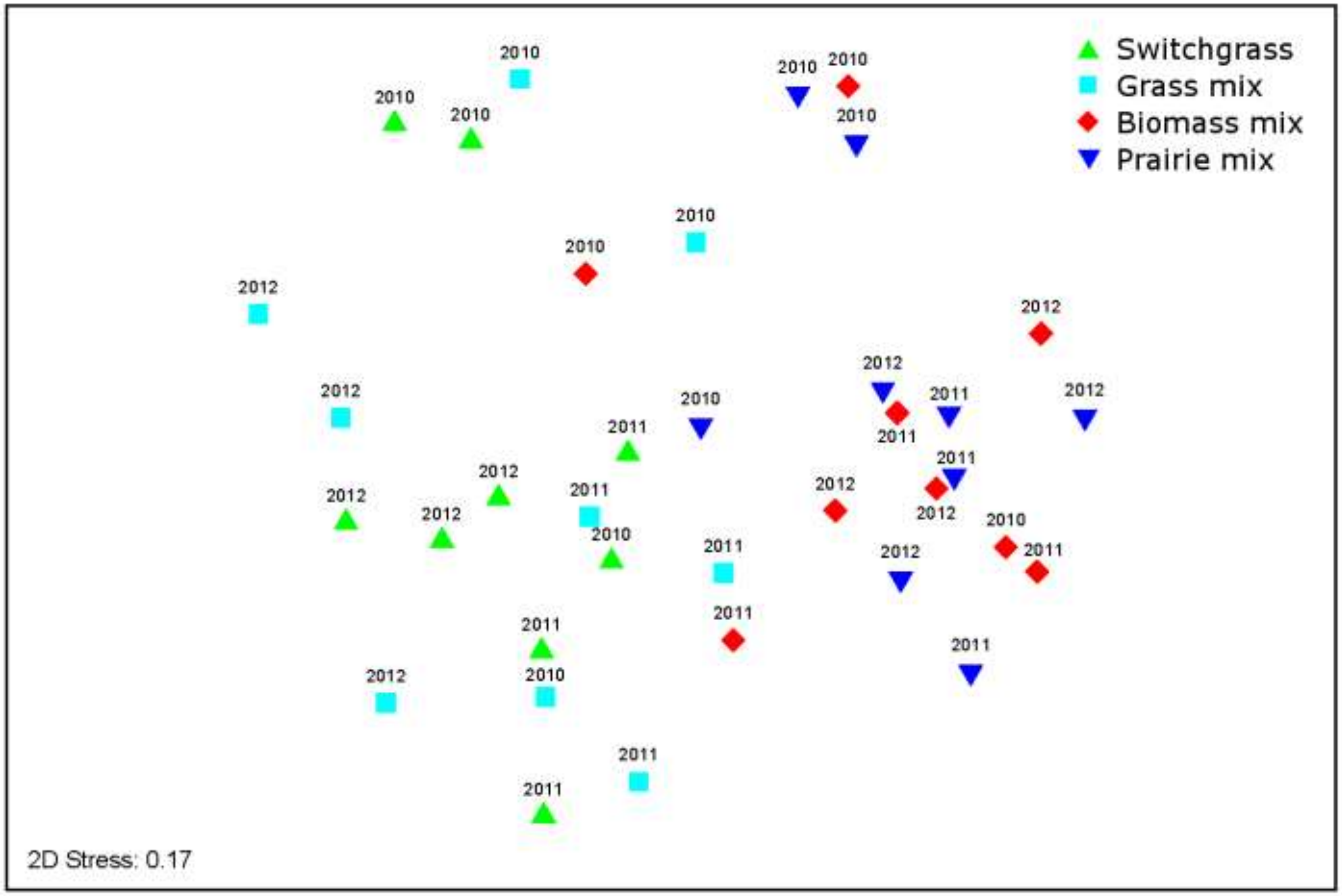

Figure 7. NMDS depicting variation in breeding bird community composition among four perennial biofuel feedstocks by year. Each point represents the centroid of one treatment × soil group (n = 4) during the year indicated by the label.

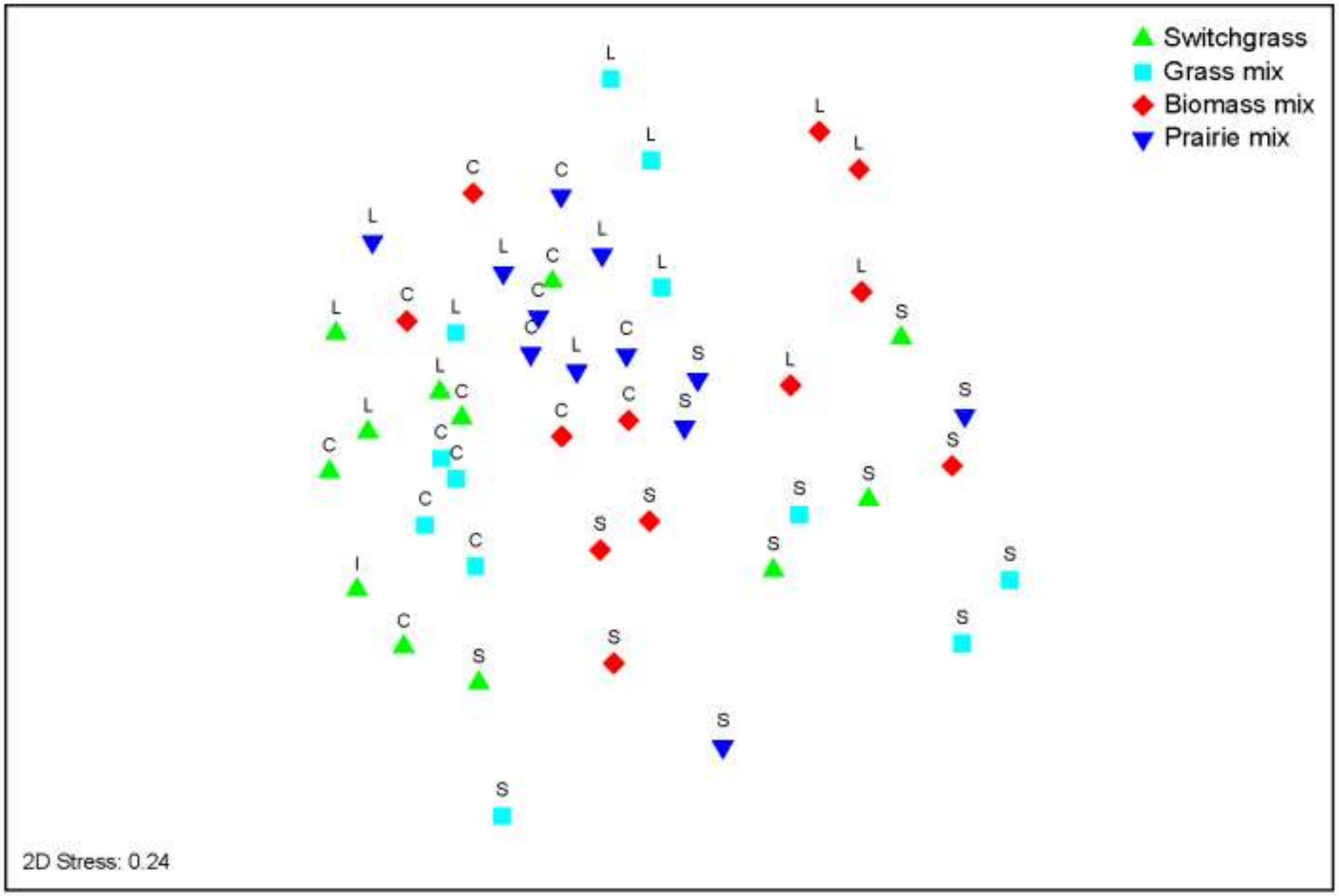

Figure 8a. NMDS of 2010 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.

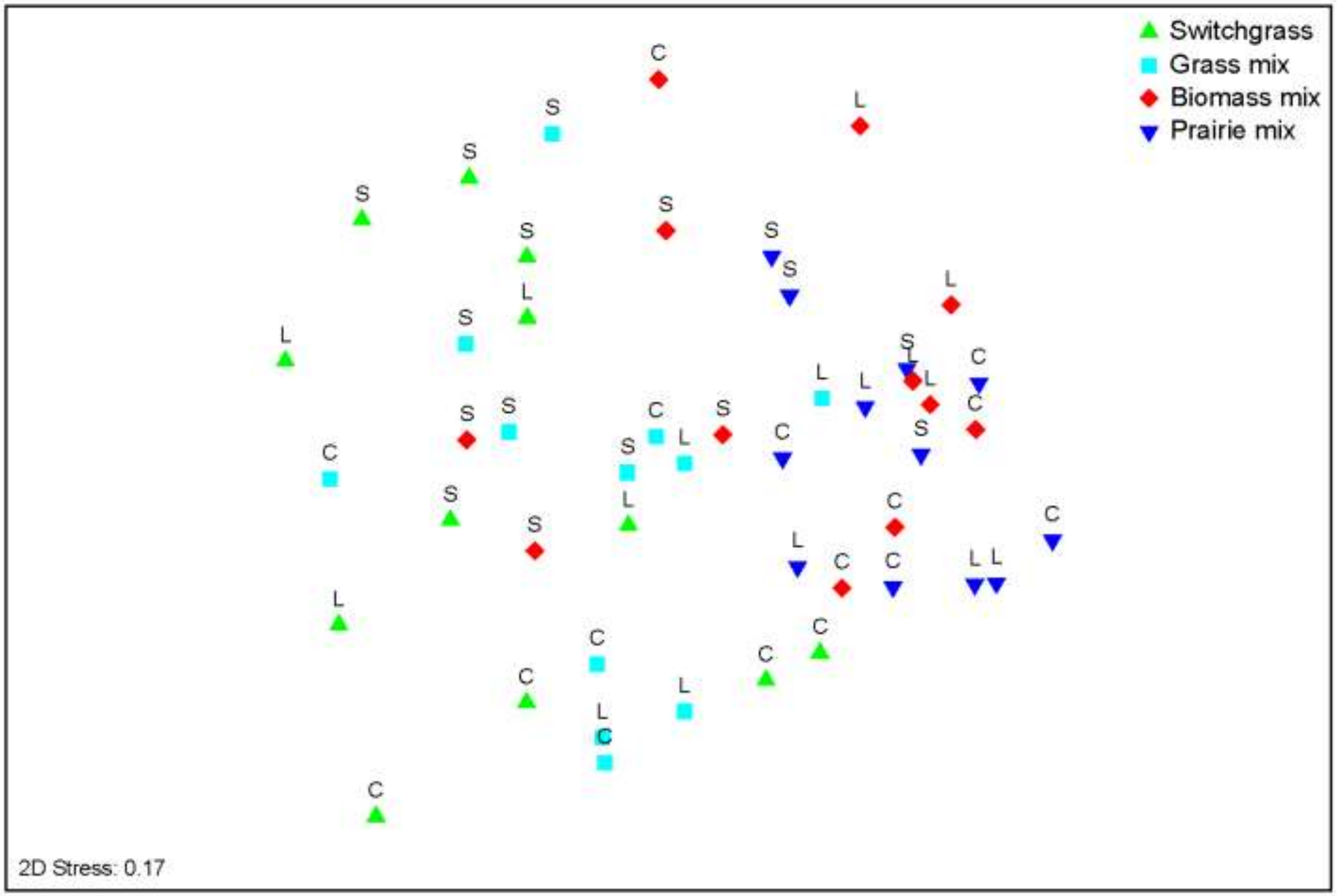

Figure 8b. NMDS of 2011 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.

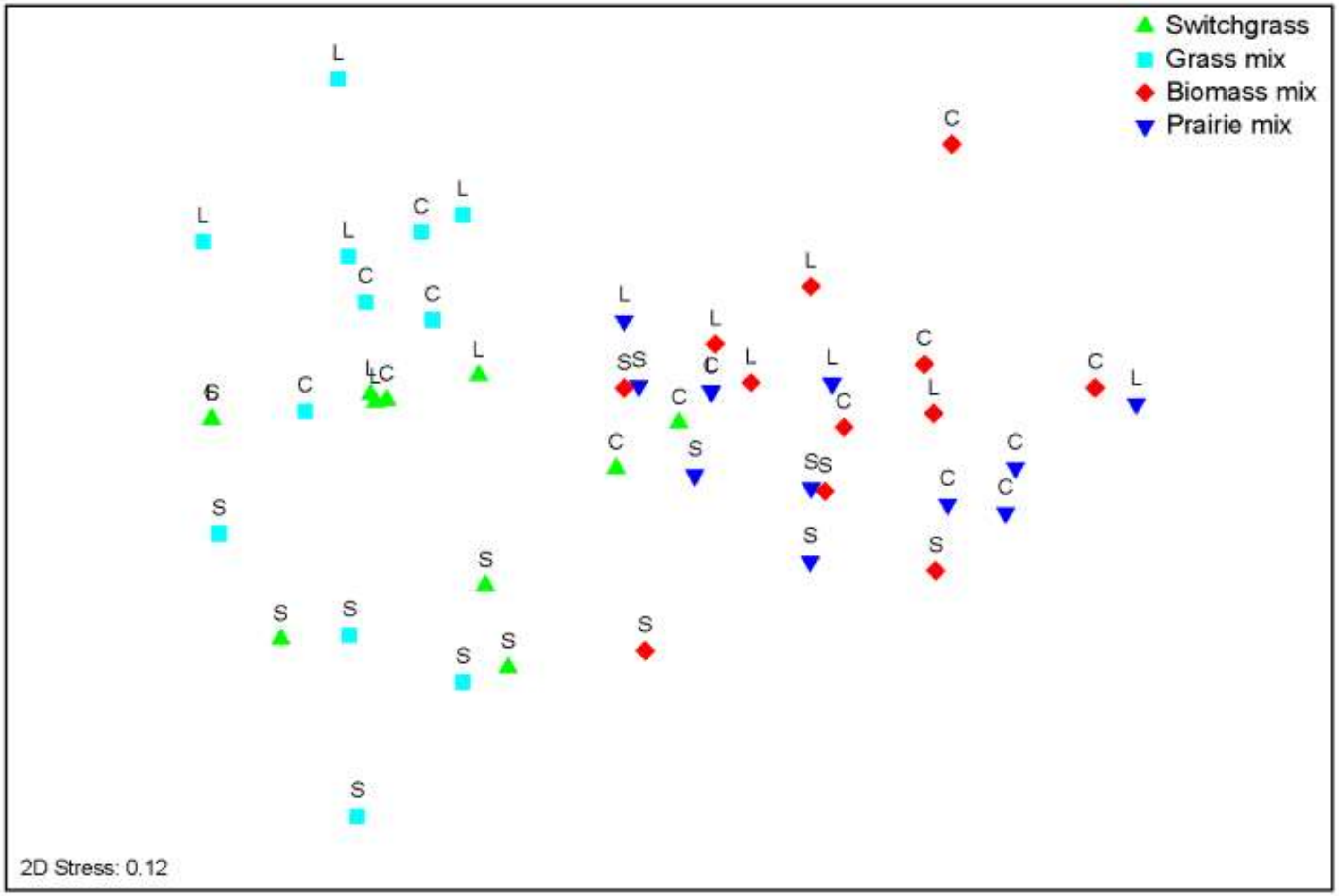

Figure 8c. NMDS of 2012 breeding bird community composition in four perennial biofuel feedstocks on three soil types. Soil type labels are: C = clay loam, L = loam, and S = sandy loam.

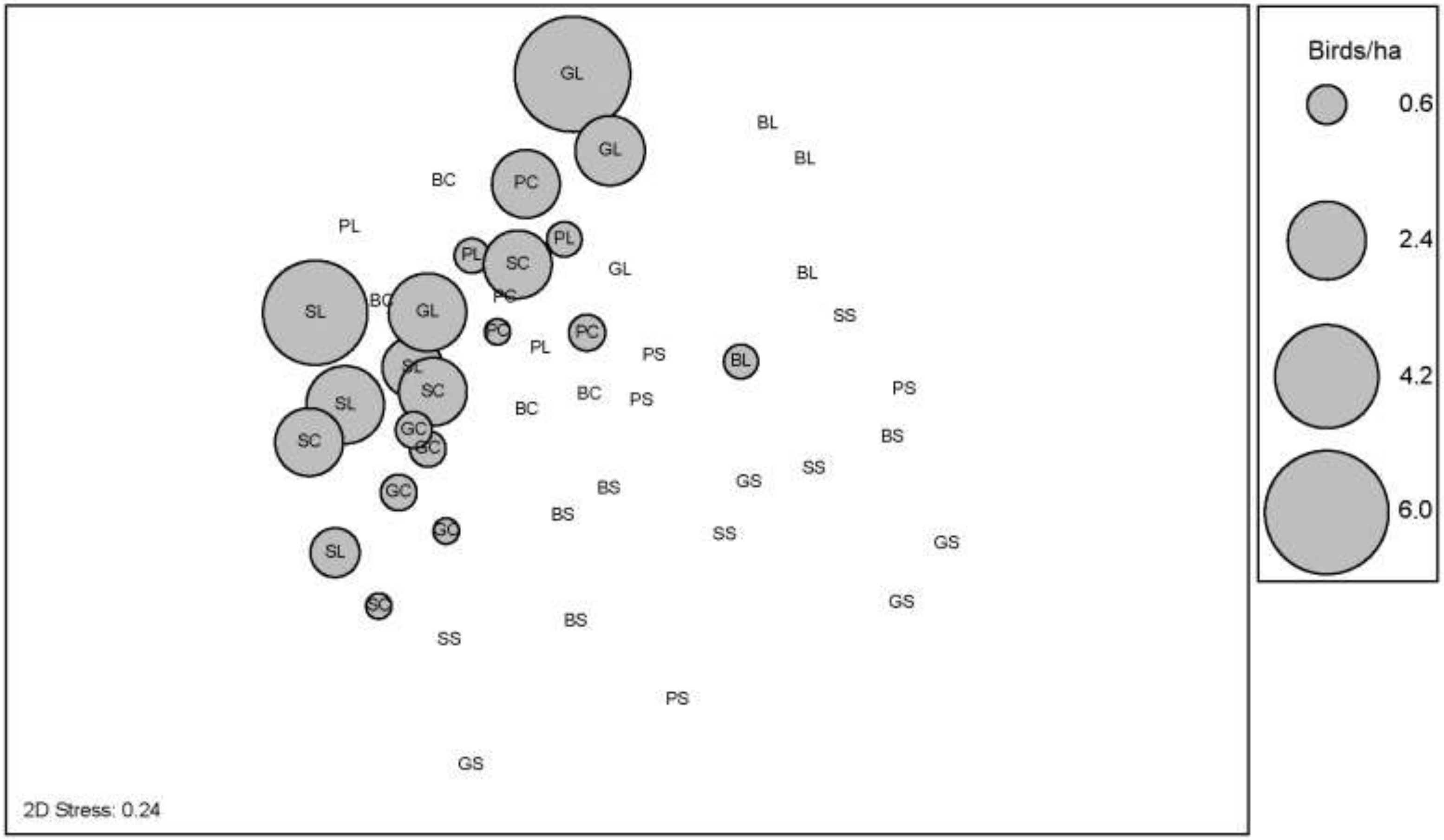

Figure 9a. NMDS bubble plot of Sedge Wren abundance in four perennial biofuel feedstocks on three soil types during the 2010 breeding season. The first letter of the two-letter plot label refers to vegetation treatment: S = switchgrass, G = grass mix, B = biomass mix, p = prairie mix; the second refers to soil type: C = clay loam, L = loam, and S = sandy loam. A plot label with no bubble indicates that no Sedge Wrens were observed in the plot.

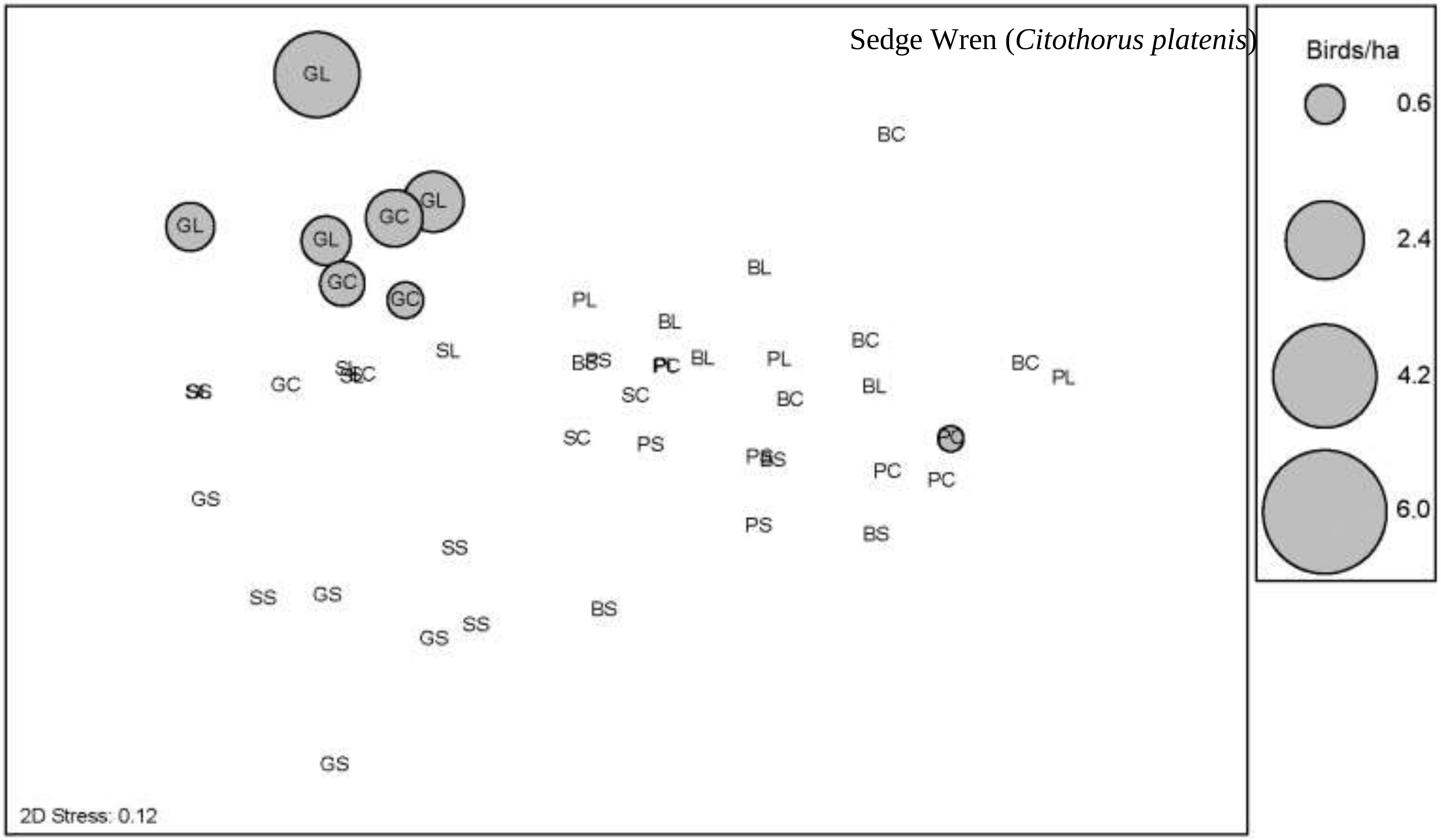

Figure 9b. NMDS bubble plot of Sedge Wren abundance in four perennial biofuel feedstocks on three soil types during the 2012 breeding season. The first letter of the two-letter plot label refers to vegetation treatment: S = switchgrass, G = grass mix, B = biomass mix, p = prairie mix; the second refers to soil type: C = clay loam, L = loam, and S = sandy loam. A plot label with no bubble indicates that no Sedge Wrens were observed in the plot.

Table 9. Bird community composition by functional group and mean Partners in Flight Regional Combined Scores of birds observed in perennial biofuel feedstocks from 2010 to 2012.

	2010	2011	2012
% generalist	8.1	7.9	3.0
% facultative grassland	58.2	44.9	23.9
% obligate grassland	31.1	44.9	71.2
% woodland	2.6	2.4	1.9
Mean PIF Regional Combined score	11.9	13.1	15.2

Nesting

Eleven species nested in the biomass production plots (Table 5). I found and monitored a total of 101 nests (45 nests in 2011, 56 nests in 2012). The majority of nests were Dickcissel (64.7%) and Lark Sparrow (21.6%), with Indigo Bunting (5.9%), Common Yellowthroat (4.9%), Grasshopper Sparrow (2.0%), and Song Sparrow (1.0%) comprising the remainder. There was a significant positive linear association between breeding bird abundance and total number of nests found in each research plot ($y = 0.17x + 1.07$, $r^2 = 0.19$, $p = 0.002$).

Apparent nest success for all species in both years was 50.5%. Seventy-six percent of nest failures were caused by predation and 25% were due to the female abandonment. Predation varied among years (24.4% of all nests in 2011, 48.2% in 2012). Brown-headed Cowbirds (*Molothrus ater*) parasitized 14.9% of nests; however, there was no evidence that cowbird parasitism caused any nest to fail in either year. Cowbird abundance declined at the site over time (Tables 5 and 6).

Dickcissels began nesting at the site in the first year after seeding and their abundance and nesting activity increased each year. Of the 60 Dickcissel nests monitored in 2011 and 2012, apparent nest success was 56.7% and Mayfield nest success was 42.6% (Table 10). There was great variation in Mayfield nest success between years, and this appeared to be driven at least in part by increased nest predation in 2012 (43.2% of all nests) compared to 2011 (18.2% of all nests). Of all the Dickcissel nest failures, 83.3% occurred during the incubation stage. Mayfield daily survival probability and nest success rates were higher in the high diversity forb-rich plots than low diversity grass plots (Table 10).

Lark Sparrows began nesting at the site in the first year after seeding, but their abundance and nesting activity declined each year thereafter. Of 22 nests monitored in 2011 and 2012, apparent nest success was 50.0% and Mayfield nest success was 21.2% (Table 11). Of all Lark Sparrow nest failures, 90.9% were caused by predation, and 63.0% failed in the incubation stage.

Neither Dickcissel nor Lark Sparrow selected a particular feedstock or soil type disproportionately for nesting (Table 12); however, Dickcissel ($p = 0.022$) nested in high diversity forb-rich plots more frequently than if their use of all feedstocks were random (Table 12). Both Dickcissel and Lark Sparrow disproportionately selected nest sites with 75-100% forb cover (Table 12). The similarity in percent forb cover for nest site selection was interesting due to the drastic differences in nest construction. Dickcissel built nests in mid-vegetation at an average height of 20 cm and Lark Sparrow built all nests on the ground at the base of standing vegetation.

Table 10. Mayfield daily survival probabilities and nest success rates for Dickcissel in perennial biofuel feedstocks by year.

Variable	2011	2012	Total	Grass	Forb-rich
Nests	22	38	60	20	40
Unsuccessful nests	6	20	26	12	14
Apparent nest success	72.7	47.4	56.7	40.0	65.0
Exposure days	263	390	653	208	445
Mayfield daily nest survival	97.7	94.9	96.0	94.2	96.9
Mayfield nest success	61.6	33.1	42.6	28.7	51.1

Table 11. Mayfield daily survival probabilities and nest success rates for Lark Sparrow in perennial biofuel feedstocks by year. Mayfield values were not calculated in 2012 because no nest successfully fledged young.

Variable	2011	2012	Total
Nests	19	3	22
Unsuccessful nests	8	3	11
Apparent nest success	57.9	0.0	50.0
Exposure days	129.5	25	154.5
Mayfield daily nest survival	93.8	-	92.9
Mayfield nest success	24.6	-	21.2

Table 12. Chi-square analysis of 2011-2012 Dickcissel and Lark Sparrow nest site selection by treatment, soil type, and percent forb cover in four perennial biofuel feedstocks across three soil types.

Variable	Source	Dickcissel	Lark Sparrow
Treatment	Switchgrass	8	3
	Grass mix	14	6
	Biomass mix	18	7
	Prairie mix	22	6
	χ^2	6.903	1.636
	p-value	0.075	0.651
Pooled Treatment	Grass plots	22	9
	Forb-rich plots	40	13
	χ^2	5.226	0.727
	p-value	0.022	0.394
Soil	Sandy loam	14	12
	Loam	24	7
	Clay loam	24	3
	χ^2	3.226	5.545
	p-value	0.199	0.062
% forb cover	0-24	8	3
	25-49	3	0
	50-74	6	3
	75-100	45	16
	χ^2	75.677	15.364
	p-value	<0.000	<0.000

CHAPTER 4

DISCUSSION

Native temperate grasslands are one of the most endangered ecosystems in the world (Van Dyke *et al*. 2004). Since European settlement, the conversion of grasslands to agriculture has driven extensive habitat loss and fragmentation resulting in significant declines of North American grassland bird populations (Vickery and Herkert 2001, Green *et al.* 2005, Askins *et al.* 2007). Current mandates (EISA 2007) promoting increased cultivation of HILD row crops for biofuel production are driving extensive habitat losses (Faber *et al.* 2012, Wright and Wimberley 2013) and are predicted to promote further future decline of avian populations and grassland habitat (Meehan *et al*. 2010). As an alternative to further expansion of HILD crops, the establishment of LIHD native perennial biofuel crops could greatly benefit North American grassland birds (Meehan *et al.* 2010). However, there is currently a lack of empirical data on bird response to conversion of HILD crops to LIHD perennial biofuel feedstocks.

I studied bird use of four native perennial biofuel feedstocks from establishment through harvest and found significant differences in bird abundance, species richness, and community composition among treatments with different levels of plant diversity. In addition, multiple species of conservation concern successfully nested in the biomass production plots. These results suggest that cultivating native prairie species for biofuel production on marginal lands (floodplains, steep slopes, lower soil quality, etc.) could provide quality habitat for grassland birds and potentially offset habitat losses resulting from conversion of high quality (flat, high soil quality, etc.) land to agriculture (Rashford *et al.* 2011).

Prior studies (Petersen and Best 1999, Murray and Best 2003) suggest that grassland birds may require an extended period of time to become established in a new grassland reconstruction. This is true for particular species (i.e., Henslow's Sparrow, *Ammodramus henslowii*) depending on habitat requirements. However, my study has shown that grassland birds, including species of high conservation concern can become established relatively quickly in LIHD native perennial biomass feedstocks. Obligate grassland species including Dickcissel, Grasshopper Sparrow, and Sedge Wren used and successfully nested in the biomass production plots within the first three years of habitat establishment.

My research documented the progression of habitat quality and bird use of native prairie biofuel production plots from initial establishment through the first biomass harvest, resulting in a proportional increase in grassland obligate bird species over time. The heterogeneous mosaic of the various feedstocks studied and annual variation in site management practices supported different bird species over time and provided quality nesting habitat to obligate grassland species.

Breeding Bird Response to Biofuel Management

Bird abundance, species richness, and community composition changed overtime in response to site management and vegetation establishment. Initial assessment of bird response to various management practices (i.e., spring prescribed burning and biomass harvest) required for biofuel production suggested that bird abundance and species richness was declining over time. However, evaluation of the Partners in Flight (PIF) species Regional Concern Scores (Eastern Tallgrass Prairie Region) demonstrated that the declines in abundance and species richness were related to the absence or decline in abundance of generalist and facultative grassland species. At the same time, grassland obligate birds increased in abundance and species richness as the site aged and the quality of the prairie reconstruction improved.

Fluctuations in community composition by year were driven by variation in vegetation composition and structure associated with site management and site age. Annual site management determined differences in vegetation structure, while site age determined differences in vegetation composition (i.e., fewer weeds and more grass and forb cover over time in respective treatments). These factors are interrelated and a thorough understanding of changes in community composition must be analyzed by assessing differences between years at the individual species level.

No management was conducted in the first full growing season in 2010. Vegetation during this early establishment phase was characterized by extensive, deep litter and abundant residual standing dead vegetation. These habitat characteristics were attractive to a variety of generalist and facultative grassland birds including Chipping Sparrow, American Goldfinch, Song Sparrow, Lark Sparrow, Mourning Dove, and Indigo Bunting. The abundance of many of these species was highest in 2010 and declined over time. For example, Mourning Doves were abundant in 2010 but were completely absent in 2011 and 2012, and Lark Sparrow was prevalent in 2010 due to the lower vegetation density as result being a newly established reconstruction (Lusk *et al.* 2003). Due to the presence of many volunteer forbs during the early growing season, vegetation characteristics in the low diversity grass plots and high diversity forb rich plots were more similar in 2010 compared to subsequent years; consequently, many birds were observed using plots of all treatments in 2010.

Some obligate grassland species used the biomass production plots at this stage; however, their proportional representation in the bird community at the site increased over time. For example, Dickcissel abundance was lowest in 2010, most likely due to the lack of habitat heterogeneity and low forb species richness (Winter 1999, Olechnowski *et al*. 2009). However, oxeye sunflower (*Heliopsis helianthoides*) flourished at this stage and provided quality habitat for birds requiring dense herbaceous vegetation.

The first prescribed burn of the site was conducted in 2011to stimulate production of native prairie species and minimize woody and non-native plant establishment. Extensive bare ground and increased structural heterogeneity (VORCV) distinguished habitat characteristics in 2011 from other years. Lark Sparrow abundance increased greatly in 2011, becoming the second most abundant species at the site. Lark Sparrows favor bare ground areas with decreased vegetation density but sturdy surrounding forbs or woody species for nesting cover (Lusk *et al.* 2003). The spring prescribed burn created habitat characteristics favorable to Lark Sparrows in 2011Eastern Meadowlark (*Sturnella magna*), a species preferring large grasslands comprised of shorter live vegetation

(Herkert 1994), was only observed in the biomass production plots in 2011Dickcissel abundance increased dramatically from 2010 to 2011, and Dickcissels were the most abundant species in 2011.

The first biomass harvest on the research site was conducted in 2012, completing the full feedstock production cycle from establishment to harvest. Habitat characteristics in 2012 featured extensive litter cover and high VOR readings, but litter depth and standing dead residual vegetation were greatly reduced compared to 2010. In addition, habitat characteristics between high diversity forb-rich plots and low diversity grass plots continued to diverge over time. Forb cover in low diversity grass plots was lowest and forb cover in high diversity forb-rich plots was highest in 2012 compared to other years As the site matured over the years, Dickcissel became increasingly dominant, comprising 59% of all bird observations in 2012. Olechnowski *et al*. (2009) also observed Dickcissel abundance to peak two to three years after reconstruction. Another dynamic shift in 2012 was the presence of Grasshopper Sparrows, which quickly became the third most common species in 2012. This is surprising, due to the fact they were completely absent in 2010 and 2011. The early spring harvest created habitat characteristics favorable to Grasshopper Sparrows, which prefer lower mean grass height and available litter cover (Herkert 1994, Bollinger 1995).

While there was generally little difference between switchgrass and grass mix plots over the course of my study in terms of bird abundance, richness, or diversity, in 2012 I saw the first evidence of divergence among the low diversity grass treatments in terms of their habitat value do birds. Bird community composition was significantly different between switchgrass and grass mix on the loam soil type. This difference was driven entirely by Sedge Wren, which used and nested in grass mix plots extensively but completely avoided switchgrass. Grass mix plots on loam had a lower canopy height and greater heterogeneity in vegetation height-density compared to switchgrass plots in 2012. This was in contrast to 2010, when vegetation characteristics were similar across treatments and Sedge Wrens were commonly observed in all treatment types. Variation in vegetation structural characteristics along PC3 appeared to be driven by successional changes associated with the establishment of species in the seed mixes and the reduction of volunteer forbs over time. Each year, grass cover increased and forb cover decreased in the low diversity grass plots, and forb cover increased in the high diversity forb-rich plots.

This study demonstrates that birds responded rapidly to newly established grasslands seeded on marginal agricultural land, and that fluctuations in annual grassland management practices for biofuel feedstock production could provide quality habitat for breeding bird species of conservation concern.

Nesting

Evaluation of the overall benefit of native prairie biofuel production requires a thorough understanding of how songbirds perceive the managed habitat in regards to nesting. My results indicated that management of native prairie for biofuel production during early establishment provided quality nesting habitat for multiple species of conservation concern with nest success rates comparable to other Midwestern grassland habitats (Patterson and Best 1996, McCoy *et al.* 1999, Churchwell *et al.* 2008). Species nesting at a particular site may fluctuate annually in abundance depending on the management practice conducted. In terms of nest site selection, Dickcissels appeared to distinguish between low diversity grass plots and high diversity forb-rich plots, but not among treatments within those groups. Continued monitoring and research is needed to see if or how bird community composition and individual bird species change as habitat matures and annual management practices are continued.

Lark Sparrow abundance and the number of Lark Sparrow nests found were higher in 2011 than 2012. Lark Sparrow is a ground nesting species (McNair 1982, Lusk *et al.* 2003) and habitat characteristics created in 2011 by prescribed burning maximized the habitat qualities (increased bare ground and decreased lower canopy vegetation density) favorable to Lark Sparrow. Even in grass plots, Lark Sparrows typically selected nest sites at the base of a large forb, perhaps to increase overhead concealment or structural security from predators or to decrease the lower canopy density to allow for nest access (McNair 1982). The 2012 harvest resulted in increased litter cover and as a result only three Lark Sparrow nests were found. These observations suggest that diverse native prairie biofuel production could potentially benefit Lark Sparrow populations on non-harvest years when prescribed burn management is required.

Dickcissel abundance and nests both increased over time, peaking in 2012. This increase may have been driven by a combination of two factors: 1) increased habitat diversity and density over time and 2) earlier arrival of Dickcissels the research in 2012 compared to 2010 and 2011. However, the true underlying cause of why Dickcissel nest abundance almost doubled in 2012 is hard to determine without continued research. Dickcissels typically built nests 20 cm off the ground at locations with high overhead forb cover. Dickcissel may be selecting nest sites with increased concealment and structural stability for mid-vegetation nest building (Winter 1999). Volunteer forbs were present in all low-diversity grass plots, and many Dickcissel nests (77.2%) in these plots were built in forb species even though they comprised a small percentage of the vegetation. The results of this study demonstrated the benefit of diverse forb-rich native prairie biofuel production as quality nesting habitat for Dickcissels.

Losses to nest predation were much higher in 2012 than 2011, and my observations and encounters suggest an increase in predator diversity and abundance at the site over time. Bull snakes (*Pituophis catenifer sayi*), including one that was infiltrating a nest at the time of monitoring, were first observed at the site in 2012. Additionally, 2012 was the first year American mink (*Neovison vison*) were observed at the site, and they were observed within the biomass production plots on multiple occasions. Increased predation rates in 2012 may have been affected by drought, like conditions, which significantly affected vegetation structure likely reduced nest concealment compared to 2011. Brown-headed Cowbird parasitism occurred in 14.9% of monitored, which is equivalent or less than rates documented in previous studies in the region (Herkert *et al*. 2003, Churchwell *et al*. 2008). No nests failed due to Brown-headed Cowbird parasitism. My study demonstrated that as a new restoration develops, Brown-headed Cowbird observations and the percent of parasitized nests decline. However, additional research is needed to confirm this result. Prior research has shown that Brown-headed Cowbirds abundance may be driven by breeding bird densities, specifically Dickcissels (Jensen and Cully Jr. 2005). My results agree with past research suggesting parasitism plays a smaller role in overall nest success than depredation (Schmidt and Whelan 1999).

Implications and Recommendations

Historic crop prices and federal mandates for continuously increasing production of corn-based ethanol are driving the intensification of HILD crop production on current agricultural lands and supporting the conversion of grasslands to agriculture (Secchi and Babcock 2007, Stephens *et al.* 2008, Wright and Wimberly 2013). Historical land use changes (i.e., grassland to agriculture conversion) transformed continuous unbroken grasslands into fragmented refugia and several grassland bird species experienced rapid declines throughout the Midwestern U.S.A. (Fletcher and Koford 2002). With continued agricultural intensification currently underway, birds are increasingly being forced to settle on intensively managed lands for habitat (Askins *et al*. 2007). How much more can the landscape be rigorously altered without causing irreversible impacts to grassland bird populations?

My research provides additional evidence that policies promoting establishment of LIHD feedstocks on marginal lands using native prairie species could provide greatly improved habitat conditions for grassland birds compared to current policies promoting first-generation HILD feedstocks. The diversity of native prairie biofuel feedstocks, as well as their annual management, significantly affects bird abundance, species richness, diversity, and community composition. Incorporating any native prairie feedstock in an agriculture dominated landscape will greatly benefit grassland birds. However, diverse native prairie biofuel feedstocks will support the greatest grassland bird abundance and species richness. I recommend a mosaic composition of vegetation, plant diversity, and management techniques be implemented to provide suitable habitat for multiple avian species varying in habitat requirements over time. As establishment of LIHD feedstocks progresses, my results suggest that community composition will shift from generalist birds towards grassland obligate species of greater conservation concern.

There are still many gaps in my knowledge of bird response to the establishment and management of perennial biofuel feedstocks on agricultural lands. While my research has shown that native prairie species managed for biofuel production provide quality breeding habitat with nest success rates comparable to other Midwestern U.S.A. grassland habitats, past research has shown that some restored and reconstructed grasslands in the Midwest are sink habitats for songbirds (McCoy *et al*. 1999, Fletcher *et al*. 2006). Additional demographic research and monitoring of fledgling survival is needed assess the source-sink dynamics of perennial biofuel feedstocks.

Additional research is also needed to understand the long-term effects of harvest timing and frequency on the native prairie communities. The early spring harvest conducted on my research site was designed to minimize effects on wildlife by maintaining residual standing dead vegetation as migratory and wintering habitat and by taking place before the spring nesting period began. However, further research is needed to weigh the costs and benefits of harvest time to maximizing biomass production and wildlife habitat value.

Finally, future research is needed on native prairie biofuel production at different landscape scales and spatial context. Large-scale reconstructions in more open landscapes could provide habitat for area-sensitive species such as the Bobolink (*Dolichonyx oryziyorus)* that were absent in this study.

REFERENCES

Anderson MJ. 2001. A New Method for Non-Parametric Multivariate Analysis of Variance. Austral Ecology 26: 32-46.

Anderson MJ, Corley RN, Clarke KR. 2008. PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. PRIMER-E, Plymouth, UK.

Askins RA, Chavez-Ramirez F, Dale BC, Haas CA, Herkert JR, Knopf FL, Vickery PD. 2007. Conservation of Grassland Birds in North America: Understanding Ecological Processes in Different Regions. Ornithological Monographs 64:1–46.

Brennan LA, Kuvlesky WP. 2005. North American Grassland Birds: An Unfolding Conservation Crisis? The Journal of Wildlife Management 69.1:1–13.

Bollinger EK. 1995. Successional Changes and Habitat Selection in Hayfield Bird Communities. The Auk 112(3):720-730.

Churchwell RT, Davis CA, Fuhlendorf SD, Engle DM. 2008. Effects of Patch-Burn Management on Dickcissel Nest Success in a Tallgrass Prairie. The Journal of Wildlife Management 72.7: 1596–1604.

Claassen R, Carriazo F, Cooper JC, Hellerstein D, Ueda K. 2011. Grassland to Cropland Conversion in the Northern Plains: The Role of Crop Insurance, Commodity, and Disaster Programs. USDA Economic Research Service. ERR-120

Clarke KR, Gorley RN. 2006. PRIMER v6: User Manual/Tutorial. Primer-E, Plymouth.

Daubenmire R. (1959) A canopy-coverage method of vegetational analysis. Northwest Sci 33:43–64.

Diefenbach DR, Brauning DW, Mattice JA. 2003. Variability in Grassland Bird Counts Related to Observer Differences and Species Detection Rates. The Auk 120.4:1168–1179.

Edwards W. 2012. Cash Rental Rates for Iowa. Iowa State Extension. File C2-10. http://www.extension.iastate.edu/agdm/wholefarm/pdf/c2-10

[EISA] Energy Independence and Security Act. 2007. 110-140 H. R. 6.

Faber S, Rundquist S, Male T. 2012. Plowed Under: How Crop Subsidies Contribute to Massive Habitat Losses. Environmental Working Group research report. Accessed 31 January 2012. http://static.ewg.org/pdf/plowed_under.pdf.

Fargione JE, Cooper TR, Flaspohler DJ, Hill J, Lehman C, McCoy T, Mcleod S, Nelson EJ, Oberhauser KS, Tilman D. 2009. Bioenergy and Wildlife: Threats and Opportunities for Grassland Conservation. Bioscience 59:767-777.

Fargione J, Plevin RJ, Hill JD. 2010. The Ecological Impact of Biofuels. Annual Review of Ecology, Evolution, and Systematics 41:351–377.

Fletcher RJ, Koford RR. 2002. Habitat and Landscape Associations of Breeding Birds in Native and Restored Grasslands. The Journal of Wildlife Management 66(4):1011-1022.

Fletcher RJ, Koford RR, Seaman DA. 2006. Critical Demographic Parameters for Declining Songbirds Breeding in Restored Grasslands. Journal of Wildlife Management 70.1: 145–157.

Green RE, Cornell SJ, Scharlemann JPW, Balmford A. 2005. Farming and the Fate of Wild Nature. Science 307(5709):550-555.

Herkert JR. 1994. The Effects of Habitat Fragmentation on Midwestern Grassland Bird Communities. Ecological Applications 4: 461-471.

Herkert JR, Reinking DL, Wiedenfeld DA, Winter M, Zimmerman JL, Jensen WE, Fink EJ, Koford RR, Wolfe DH, Sherrod SK, Jenkins MA, Faaborg J, Robinson SK. 2003. Effects of Prairie Fragmentation on the Nest Success of Breeding Birds in the Midcontinental United States. Conservation Biology 17:587-594.

Hill J. 2009. Environmental Costs and Benefits of Transportation Biofuel Production from Food- and Lignocellulose-Based Energy Crops: A Review. Agronomy for Sustainable Development 27:1-12.

Hill J, Nelson E, Tilman D, Polasky S, Tiffany D. 2006. Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels. Proceedings of the National Academy of Science 103:11206–11210.

Hughes JP, Robel RJ, Kemp KE, Zimmerman JL. 1999. Effects of Habitat on Dickcissel Abundance and Nest Success in Conservation Reserve Program Fields in Kansas. The Journal of Wildlife Management 63:523-529.

Jensen WE, Cully Jr. JF. 2005. Density-Dependent Habitat Selection by Brown-Headed Cowbirds (Molothrus Ater) in Tallgrass Prairie. Oecologia 142.1: 136–149.

Johnson RG, Temple SA. 1990. Nest Predation and Brood Parasitism of Tallgrass Prairie Birds. The Journal of Wildlife Management 54:106-111.

Kerns CK, Ryan MR, Murphy RK, Thompson FR, Rubin CS. 2010. Factors Affecting Songbird Nest Survival in Northern Mixed-Grass Prairie. The Journal of Wildlife Management 74:257–264.

Knopf FL. 1994. Avian Assemblages in Altered Grasslands. Studies in Avian Biology 15:247–257.

Lusk JJ, Wells KS, Guthery FS, Fuhlendorf SD. 2003. Lark Sparrow (Chondestes grammacus) Nest-Site Selection and Success in a Mixed-Grass Prairie. The Auk 120:120–129.

Mayfield HF. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

McCoy TD, Ryan MR, Kurzejeski EW, Burger, Jr. LW. 1999. Conservation Reserve Program: Source or Sink Habitat for Grassland Birds in Missouri? The Journal of Wildlife Management 63:530-538.

McNair, D.B. 1982. Lark Sparrows Breed in Richmond County, N.C. Chat 46:1-8.

Meehan TD, Hurlbert AH, Gratton C. 2010. Bird Communities in Future Bioenergy Landscapes of the Upper Midwest. Proceedings of the North American Academy of Science 107:18533-18538.

Murphy, M. T. 2003. Avian population trends within the evolving agricultural landscape of eastern and central United States. The Auk 120:20–34.

Murray LD, Best LB. 2003. Short-Term Bird Response to Harvesting Switchgrass for Biomass in Iowa. The Journal of Wildlife Management 67:611-621.

Olechnowski BFM, Debinski DM, Drobney P, Viste-Sparkman K, Reed WT. 2009. Changes in Vegetation Structure through Time in a Restored Tallgrass Prairie Ecosystem and Implications for Avian Diversity and Community Composition. Ecological Restoration 27:449-457.

Patterson MP, Best LB. 1996. Bird Abundance and Nesting Success in Iowa CRP Fields: The Importance of Vegetation Structure and Composition. American Midland Naturalist 135:153-167.

Petersen KL, Best LB. 1999. Design and Duration of Perturbation Experiments: Implications for Data Interpretation. Studies in Avian Biology 19:230-236.

Ralph CJ, Geupel GR, Pyle P, Martin TE, DeSante DF. 1993. Handbook of Field Methods for Monitoring Landbirds. U.S. Department of Agriculture, General Technical Report PSW-GTR-144. 41 p.

Rashford BS, Walker JA, and Bastian CT. 2011. Economics of Grassland Conversion to Cropland in the Prairie Pothole Region. Conservation Biology 25.2:276–284.

Renfrew RB, Ribic CA, Nack JL. 2005. Edge Avoidance by Nesting Grassland Birds: A Futile Strategy in a Fragmented Landscape. The Auk 122.2:618–636.

Robel RJ, Briggs JN, Dayton AD, Hulbert LC. 1970. Relationships Between Visual Obstruction Measurements and Weight of Grassland Vegetation. Journal of Range Management 23:295–297.

Robertson BA, Doran PJ, Loomis LR, Robertson JR, Schemske DW. 2011a. Perennial Biomass Feedstocks Enhance Avian Diversity. Bioenergy 3:235-246.

Robertson BA, Doran PJ, Loomis ER, Robertson JR, Schemske DW. 2011b. Avian Use of Perennial Biomass Feedstocks as Post-Breeding and Migratory Stopover Habitat. PLOS ONE 6:e16941.

Robertson BA, Rice RA, Sillett TS, Ribic CA, Babcock BA, Landis DA, Herkert JR, Fletcher Jr. RJ, Fontaine JJ, Doran PJ, Schemske DW. 2012. Are Agrofuels a Conservation Threat or Opportunity for Grassland Birds in the United States?. The Condor 114:679–688.

Samson FB, Knopf FL. 1994. Prairie Conservation in North America. BioScience 44.6:418–421.

Sauer JR, Hines JE, Fallon JE, Pardieck KL, Ziolkowski Jr. DJ, Link WA. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2009. Version 3.23.2011 USGS Patuxent Wildlife Research Center, Laurel, MD.

Schmidt KA,Whelan CJ. 1999. The Relative Impacts of Nest Predation and Brood Parasitism on Seasonal Fecundity in Songbirds. Conservation Biology 13.1:46–57.

Secchi S, Babcock B. 2007. Impact of high crop prices on environmental quality: a case of Iowa and the Conservation Reserve Program. Center for Agricultural and Rural Development (CARD) Publication. Iowa State University, Ames, IA.

Smith DD. 1998. Iowa prairie: original extent and loss, preservation and recovery attempts. Proceedings of the Iowa Academy of Science 105:98–108.

Steckley SR. 2006. Soil Survey of Black Hawk County, Iowa. USDA NRCS; 526 p.

Stephens SE, Walker JA, Blunck DR, Jayaraman A, Naugle DE, Ringelman JK, Smith AJ. 2008. Predicting Risk of Habitat Conversion in Native Temperate Grasslands. Conservation Biology 22.5:1320–1330.

Sumner DA, Zulauf C. 2012. Economic and Environmental Effects of Agricultural Insurance Programs. The Council on Food, Agriculture and Resource Economics.

Tilman D, Hill J, Lehman C. 2006. Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass. Science 314:1598–1600.

Van Dyke F, Van Kley SB, Page CB, Van Beek JG. 2004. Restoration Efforts for Plant and Bird Communities in Tallgrass Prairies Using Prescribed Burning and Mowing. Restoration Ecology 12.4:575–585.

Vickery PD, Herkert JR. 2001. Recent Advances in Grassland Bird Research: Where do we go from here? The Auk 118:11-15.

Warner RE. 1994. Agricultural Land Use and Grassland Habitat in Illinois: Future Shock for Midwestern Birds. Conservation Biology 8(1):147-156.

Wiens J, Fargione J, Hill J. 2011. Biofuels and Biodiversity. Ecological Applications 21(4):1085-1095.

Wright CK, Wimberly MC. 2013. Recent Land Use Change in the Western Corn Belt Threatens Grasslands and Wetlands. Proceedings of the National Academy of Sciences.

Williams DW, Jackson LL, Smith DD. 2007. Effects of Frequent Mowing on Survival and Persistence of Forbs Seeded into a Species-poor Grassland. Restoration Ecology. 15:24-33.

Winter M. 1999. Nesting Biology of Dickcissels and Henslow's Sparrows in Southwestern Missouri Prairie Fragments. The Wilson Bulletin. 111. 4:515-526.

APPENDIX

ADDITIONAL INFORMATION

Table A1. Species composition and seeding rates for four perennial biofuel feedstocks All feedstocks were seeded with Iowa source identified seed (Prairie Moon Nursery; Winona, MN U.S.A.) in Black Hawk County, Iowa, U.S.A.

Species (common name)	Seeding Rate (seeds m^{-2})			
	Switchgrass	Grass	Biomass	Prairie
Panicum virgatum (switchgrass)	561	86	43	32
Andropogon gerardii (big bluestem)		151	151	135
Bouteloua curtipendula (side-oats grama)		86	43	32
Schizachyrium scoparium (little bluestem)		151	151	135
Sorghastrum nutans (indiangrass)		86	43	32
Agropyron smithii (western wheatgrass)			43	32
Elymus canadensis (Canada wildrye)			43	32
Elymus virginicus (Virginia wildrye)			43	32
Astragalus canadensis (milk vetch)			38	16
Desmodium canadense (showy tick trefoil)			38	16
Heliopsis helianthoides (ox-eye sunflower)			38	16
Lespedeza capitata (round-headed bush clover)			38	16
Solidago rigida (stiff goldenrod)			38	16
Ratibida pinnata (yellow coneflower)			38	16
Helianthus grosseserratus (saw-tooth sunflower)			38	16
Silphium laciniatum (compass plant)			3	3
Carex bicknellii (copper-shoulder oval sedge)				32
Carex brevior (plains oval sedge)				32
Carex gravida (long-awned bracted sedge)				32
Sporobolus asper (tall dropseed)				32
Amorpha canescens (leadplant)				16
Artemisia ludoviciana (prairie sage)				16
Aster laevis (smooth blue aster)				16
Aster novae-angliae (New England aster)				16
Baptisia leucantha (white wild indigo)				1
Dalea purpurea (purple prairie clover)				16
Echinacea pallida (pale purple coneflower)				16
Erynigium yuccifolium (rattlesnake master)				16
Monarda fistulosa (wild bergamot)				16
Phlox pilosa (prairie phlox)				3
Tradescantia bracteata (prairie spiderwort)				16
Zizia aurea (golden alexanders)				16

Table A2. Bird abundance in perennial biofuel feedstocks by year, Partners in Flight (PIF) Regional Concern Scores (RCS), and bird species habitat guild classifications.

Common name	Species Name	2010	2011	2012	PIF RCS	Classification
Ruby-throated Hummingbird	*Archilochus colubris*	4	0	1	11	Generalist
Chipping Sparrow	*Spizella passerine*	57	37	13	9	Generalist
American Robin	*Turdus migratorius*	5	20	2	9	Generalist
Red-winged Blackbird	*Agelaius phoeniceus*	4	0	1	13	Facultative grassland
American Goldfinch	*Carduelis tristis*	80	35	14	13	Facultative grassland
Lark Sparrow	*Chondestes grammacus*	70	169	19	9	Facultative grassland
Common Yellowthroat	*Geothlypis trichas*	98	40	60	13	Facultative grassland
Song Sparrow	*Melospiza melodia*	123	29	13	10	Facultative grassland
Indigo Bunting	*Passerina cyanea*	68	38	17	10	Facultative grassland
Field Sparrow	*Spizella pusilla*	3	6	2	17	Facultative grassland
Eastern Kingbird	*Tyrannus tyrannus*	1	5	3	15	Facultative grassland

(Table continues)

Species	Species Name	2010	2011	2012	PIF RCS	Classification
Mourning Dove	*Zenaida macroura*	30	0	0	10	Facultative grassland
Grasshopper Sparrow	*Ammodramus savannarum*	0	0	42	16	Obligate Grassland
Sedge Wren	*Cistothorus platensis*	81	0	24	12	Obligate Grassland
Brown-headed Cowbird	*Molothrus ater*	29	14	1	10	Obligate Grassland
Savannah Sparrow	*Passerculus sandwichensis*	1	0	0	12	Obligate Grassland
Vesper Sparrow	*Pooecetes gramineus*	3	0	0	12	Obligate Grassland
Eastern Bluebird	*Sialis sialis*	0	2	0	11	Obligate Grassland
Dickcissel	*Spiza americana*	141	305	317	17	Obligate Grassland
Eastern Meadowlark	*Sturnella magna*	0	1	0	17	Obligate Grassland
Northern Cardinal	*Cardinalis cardinalis*	1	0	0	9	Woodland
Northern Flicker	*Colaptes auratus*	0	0	1	16	Woodland

(Table continues)

Species	Species Name	2010	2011	2012	PIF RCS	Classification
Eastern Wood Peewee	*Contopus virens*	1	1	0	12	Woodland
Gray Catbird	*Dumetella carolinensis*	2	1	1	10	Woodland
Baltimore Oriole	*Icterus galbula*	1	0	0	12	Woodland
Wild Turkey	*Meleagris gallopavo*	5	1	0	11	Woodland
Hairy Woodpecker	*Picoides villosus*	1	0	0	12	Woodland
Eastern Phoebe	*Sayornis phoebe*	0	2	0	10	Woodland
Brown Thrasher	*Toxostoma rufum*	5	7	4	16	Woodland
House Wren	*Troglodytes aedon*	0	0	3	9	Woodland
Sparrow spp.	*Emberizidae spp.*	2	2	1		
Lincoln Sparrow	*Melospiza lincolnii*	0	2	0		
White-throated Sparrow	*Zontrichia albicollis*	3	0	0		
Tot. abundance		819	718	539		
Tot. species richness		26	21	20		
Avg. PIF score		11.94	13.09	15.15		