# HABITAT USE BY BIRDS IN THE NORTHERN SHORTGRASS PRAIRIE OF NORTH AMERICA: A LOCAL AND LANDSCAPE APPROACH

By

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LANDSCAPE APPROACH

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# INTRODUCTION

## Synopsis of Research

My research examines habitat use by birds in the northern half of the shortgrass prairie of North America. To do this, I analyze data collected through an annual bird-monitoring program, the Section Survey, operated by Rocky Mountain Bird Observatory and supported by the Colorado Division of Wildlife, U.S. Forest Service, Nebraska Game and Parks Commission, Kansas Department of Wildlife and Parks, and Oklahoma Department of Wildlife Conservation.

My research is comprised of three studies which address separate but related questions regarding habitat use by shortgrass prairie birds. In Study I, I compare species use of the three dominant habitat types in the study area including shortgrass prairie, dryland agriculture, and land in the Conservation Reserve Program (CRP). I also compare the vegetation structure between shortgrass prairie and CRP and, likewise, species use of these varying vegetation conditions. In Study II, I calculate and compare the conservation value (*CV*) of the three habitat types using species conservation prioritization scores as presented by Partners in Flight. Finally, in Study III, I model and compare species response to local vegetation conditions of shortgrass prairie habitat and surrounding landscape features at multiple spatial scales. I conclude by summarizing the findings from all three studies and offer recommendations on how this information can be used toward advancing the conservation of shortgrass prairie birds and their habitat.

## Goal and Intent

The overall goal of my research is to provide valuable information about the habitat needs of breeding birds in the northern portion of the shortgrass prairie of North America. I intend for this information to assist natural resource professionals in making effective planning and management decisions regarding the conservation of shortgrass prairie birds and their habitat. Therefore, I designed my research to examine shortgrass prairie bird habitat use from multiple ecological and spatial scales. I believe this research is unique and valuable for several reasons. First, I analyze data collected at an ecoregion scale, spanning more than 200,000 ha across four states (Nebraska, Colorado, Kansas, and Oklahoma). Additionally, I examine shortgrass prairie bird use of multiple habitat types including the three dominant habitats in the study area, shortgrass prairie, dryland agriculture, and land in the CRP. Furthermore, I not only analyze bird use of the select habitats but I also examine their response to the surrounding landscape features and at multiple spatial scales. In designing this broad, multilevel research, I am able to address several essential questions regarding habitat use of individual species such as: (1) what habitats does the species use and how does use compare among habitats, (2) within these habitats what vegetation conditions does the species use and does use vary with condition, (3) do the landscape features surrounding these habitats influence use and how influential are they, and (4) what landscape features influence habitat use and does influence change with spatial scale? Together this information can help biologists view bird habitat use from multiple perspectives, leading to a stronger understanding of the complex relationship between bird species and their environment.

## Background

*The shortgrass prairie*

The shortgrass prairie of North America is located along the eastern edge of the Rocky Mountains and extends from South Dakota to Texas, containing portions of Wyoming, Nebraska, Colorado, Kansas, New Mexico, and Oklahoma. This is a semi-arid region with flat to gently sloping terrain comprised of loamy to sandy soils. Shortgrass prairie vegetation is characterized by blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). Intermixing shrub species include sand sagebrush (*Artemisia filifolia*), rabbitbrush (*Ericameria nauseosus*), winterfat (*Krascheninnikovia lanata*), and four-wing saltbush (*Atriplex canescens*). Woodland in this region is sparse and scattered and is usually comprised of cottonwood trees (*Populus* spp.) found along riparian corridors but can also include other plantings of Siberian elm (*Ulmus pumila*) or Russian olive (*Elaeagnus angustifolia*).

As compared to other North American grassland biomes, the shortgrass prairie retains the largest portion of its original estimated acreage, about 20% (Beidleman 2000). In contrast, as little as 1% of the tallgrass prairie exists today (Samson and Knopf 1994). Overall, it is estimated that more than 80% of native grasslands in North America have been lost since the mid-1800's (Samson and Knopf 1994). Consequently, grassland wildlife habitat restoration has become a priority conservation issue. Some even predict the decline of grassland species "to become a prominent wildlife conservation crisis of the 21st century (Brennan and Kuvlesky 2005)." Grassland birds, in particular, have drawn considerable attention as they are declining faster and more consistently than any other guild of birds in North America (Samson and Knopf 1994).

*Decline of shortgrass prairie birds*

The shortgrass prairie of North America is experiencing widespread declines in grassland bird species. According to the Partners In Flight (PIF) Species Assessment and Prioritization Database, 11% of upland species breeding in the shortgrass prairie Bird Conservation Region (BCR 18) are declining, and for 85% we lack sufficient data to address current population trends (Partners In Flight Species Assessment Database 2004). There are currently twenty-one shortgrass prairie bird species listed as species of concern by PIF and one species, Mountain Plover (*Charadrius montanus*), is listed as a candidate for listing under the U.S. Endangered Species Act of 1973.

The decline of grassland bird species is a cumulative effect of loss, fragmentation, and degradation of remnant grasslands (World Wildlife Fund Canada 1998, Brennan and Kuvlesky 2005). The shortgrass prairie has decreased significantly in area, by as much as 85% in some areas (Samson and Knopf 1994), and over 70% of what remains is in private ownership (Gillihan et al. 2001), primarily as grazing land. Consequently, conservation of existing shortgrass prairie and restoration of degraded or cultivated shortgrass prairie are central to stabilizing or reversing declining population trends of shortgrass prairie birds.

*The Conservation Reserve Program (CRP)*

Many consider the Conservation Reserve Program (CRP) a vehicle for reversing declining population trends of grassland birds (Johnson and Igl 1995). The CRP, a provision under the 1985 Federal Food Security Act, is a voluntary program that provides economic incentives to private landowners to remove highly erodible and environmentally sensitive land from crop production through establishment of vegetative cover. Over 34 million acres of marginal cropland were enrolled in the Conservation Reserve Program (CRP) by 2003, with approximately 25 million acres planted to grassland (U.S. Department of Agriculture 2004a). The majority of this grassland was planted throughout the Great Plains region of the United States, with high concentrations in the shortgrass prairie region.

When the CRP was developed in 1985, however, its primary objectives were to reduce soil erosion and surplus commodities, with little consideration given to CRP as potential wildlife habitat. Many CRP fields in the shortgrass prairie were planted to monocultures or mixtures of introduced mid- and tallgrass species and, as mandated, most CRP fields remained virtually undisturbed for the life of their contracts (10 – 15 years). As a result, many CRP fields in the shortgrass prairie have disproportionately taller vegetation (McIntyre and Thompson 2003, Kamler et al. 2003, Samson et al. 2004, Kamler et al. 2005) than native shortgrass prairie. Accordingly, some suggest that CRP provides poor quality habitat to shortgrass dependent wildlife (Milchunas et al. 1998, McIntyre and Thompson 2003, Kamler et al. 2003, Samson et al. 2004, Kamler et al. 2005).

In addition to dissimilar vegetation conditions, CRP fields in the shortgrass prairie are often located in highly fragmented landscapes dominated by cropland. Also, CRP fields can take any number of shapes and sizes from long, narrow strips, to triangular corner plots, to 690-acre blocks. These are important habitat features when considering conservation of shortgrass prairie birds because grassland birds are thought to be sensitive to habitat fragmentation (O'Connor 1999, Brennan and Kuvlesky 2005), size and shape of habitat patches (Johnson and Temple 1986, Herkert 1994, Vickery 1994, Johnson and Igl 2001, Brennan and Kuvlesky 2005, Cunningham 2005), and landscape composition (Rotenberry and Wiens 1980, Knick and Rotenberry 1995, Cunningham and Johnson 2006). However, the relative importance of these factors in defining an individual species' habitat requirements is not well understood or well documented for many shortgrass prairie bird species.

*Grassland bird habitat requirements*

The success of shortgrass prairie bird conservation through habitat conservation and restoration efforts depends largely on identifying habitat requirements of shortgrass prairie bird species. Traditionally, research on grassland bird habitat requirements has been conducted at small spatial scales, generally referred to as local or proximate scales, and may be site-specific. Often these studies quantify or classify habitat characteristics within territories or at nest sites and then relate these variables to species population measures.

More recent research, however, indicates that grassland birds also respond to variables at broader spatial scales and that response can vary by spatial scale and geographic region (Bergin et al. 2000, Bakker et al. 2002, Hamer et al. 2006, Cunningham and Johnson 2006). Research supports the statement: "…each species observes the environment on its own unique suite of scales of space and time (Levin 1992)." These dynamic responses are a function of the heterogeneity and patchiness that occurs within all ecological systems (Levin 1992). Therefore, there exists some complexity in identifying habitat requirements for individual species. Insight into how individual bird species respond to their environment at varying spatial scales can help in that identification and, thus, facilitate effective conservation and restoration efforts.

# RESEARCH DESIGN

## Overview

My research is comprised of three studies in which I address separate but related questions regarding habitat use by birds breeding in the northern shortgrass prairie. In each study I analyze data collected through an annual shortgrass prairie bird monitoring program, the Section Survey, which is conducted throughout the northern half of the shortgrass prairie Bird Conservation Region (BCR 18, Figure 1). Therefore the data collection process and study area for all three studies are the same and, as such, are presented once in this document. Conversely, I present the objectives, hypothesis, methods, results, and discussion separately for each study. See Appendix A for a list of all scientific names of bird species.

## Study Area

The study area included portions of 45 counties in Nebraska, Colorado, Kansas, and Oklahoma and is near congruent with the northern half of the shortgrass prairie Bird Conservation Region (BCR 18) (Figure 1). This region has a semi-arid climate, receiving less than 50 cm of annual precipitation, and extended droughts are common. It is a fragmented landscape comprised of agricultural land (45%), grassland (43%), shrubland (7%), woodland (3%), developed areas (1%), wetlands (1%), open water (<1%), and barren land (<1%, including sand). Agricultural land in the study area is cropland planted primarily to dryland crops including winter wheat and sorghum. Shortgrass prairie is the dominant grassland type of the study area and is characterized by flat to gently sloping terrain of blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). CRP fields are planted primarily to introduced (Conservation Practice 1, CP1) or native (Conservation Practice 2, CP2) grasses and legumes typically less divers and more homogeneous than native prairie. Shrubland in the study area is dominated by sand sagebrush (*Artemisia filifolia*) but also includes rabbitbrush (*Ericameria nauseosus*), winterfat (*Krascheninnikovia lanata*), and four-wing saltbush (*Atriplex canescens*). Woodland is characterized by cottonwood trees (*Populus* spp.) typically found along riparian corridors but also include other plantings of as Siberian elm (*Ulmus pumila*) or Russian olive (*Elaeagnus angustifolia*).

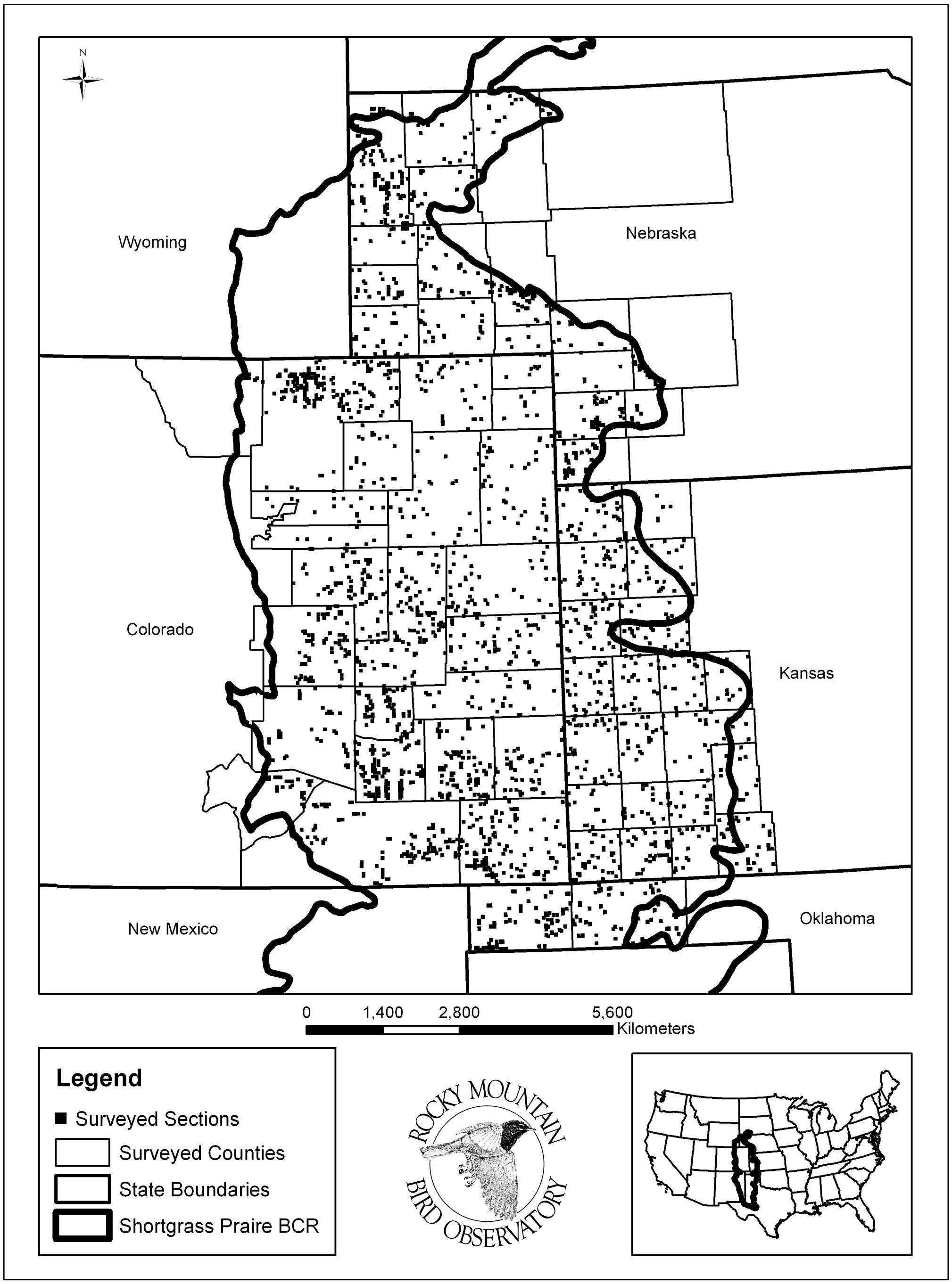


Figure 1. Map of study area including locations of sections surveyed in 2003 and 2004 under the Section Survey monitoring program, operated by Rocky Mountain Bird Observatory. Also shown are the surveyed counties and the boundary of shortgrass prairie Bird Conservation Region (entire Region shown in inset).

## Data Collection

I analyzed data collected in 2003 and 2004 through a shortgrass prairie bird-monitoring program referred to as the Section Survey, operated by Rocky Mountain Bird Observatory (Hanni 2002, Hanni and McLachlan 2004). Under this program, trained field technicians survey 1-$mi^2$ sections of land (259ha), as defined by the Public Land Survey System (PLSS), for birds. Sections were located throughout the northern half of the shortgrass prairie Bird Conservation Region (BCR 18), including regions of Nebraska, Colorado, Kansas, and Oklahoma. Sections are fixed and surveyed once annually using road-based point counts. Roads, landownership boundaries, land use, and landcover are often congruent with section boundaries.

RMBO biologists randomly selected sections for survey using a Geographic Information System (GIS). For a section to qualify as a candidate for survey it had to contain at least 240 hectares of shortgrass prairie (including associated shrubland) or dryland agriculture and lay adjacent to at least one road. Most CRP fields were surveyed incidentally because spatial data layers were not available for most of the monitoring region. They used a point count data collection process, modified from Buckland et al. (1993) and Ralph et al. (1993), to establish three road-based point count locations at each section (Hanni 2002). Point count locations were distributed among the roads bordering each section based on the number of roads, minimizing the number of point counts per road (Figure 2). All point count locations were at least 0.32 km (0.20 mi) apart and 0.16 km (0.10 mi) from the section corners. Technicians established permanent point count locations along each road using a random number table and recorded spatial coordinates using a Garmin etrex global positioning system (GPS) unit.

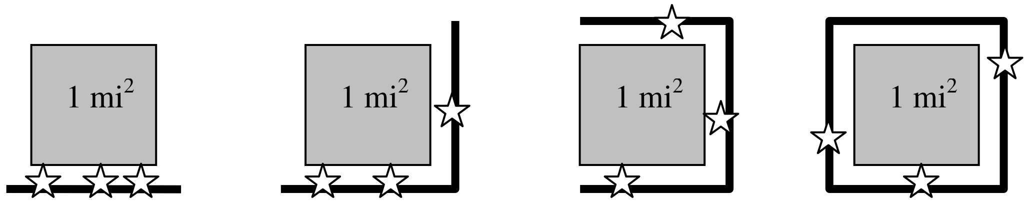


Figure 2. Examples of point count locations (stars) at a surveyed section (1-mi2). The number of point count locations on each road (black lines) was based on the number of roads adjacent to the section. Locations of point counts along each road were determined using a random numbers table and spaced at least 0.32 km (0.20 mi) apart and 0.16 km (0.10 mi) from the section corners.

At each point count location, a technician conducted a five-minute survey from the road looking 180° into the section (Figure 3). Technicians conducted surveys from mid-May through the first week of July with surveys commencing one half hour before local sunrise and ending at 1100. Surveys were not conducted under high wind or rain. At each point count location, the technician recorded both bird and vegetation data. For each bird seen and/or heard within the section, the technician recorded: species, sex (if known), distance from observer to point of first detection, method of detection (e.g., visually or aurally), and associated habitat (e.g., shrub, ground, fence, etc). The technician recorded vegetation characteristics within a 150m radius semi-circle from the point count location. Vegetation characteristics included grass height and percent shrub cover. Grass height was classified as <15 cm or >15 cm (about ankle height) so the technician records the proportion of each grass height class present in the 150-m radius. Shrub cover was classified and recorded as <1%, 1-3%, 3-10%, or >10%.

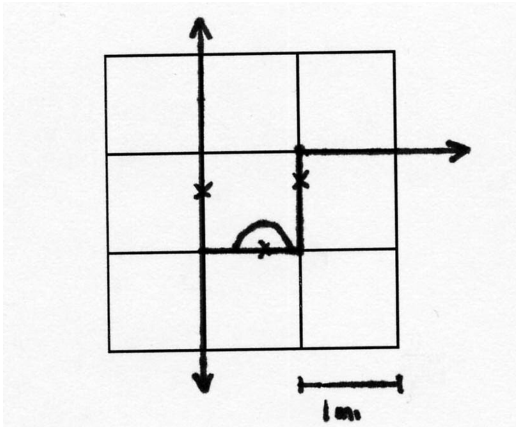


Figure 3. Example of the 180° search radius (arc) at a point count location (x).

**Scope and Limitations**

The geographic scope of my research includes the northern half of the shortgrass prairie Bird Conservation which includes portions of four states including Nebraska, Colorado, Kansas, and Oklahoma. Although this area constitutes a large part of the BCR, it should be acknowledged that the vegetation, soil types, topography, and climate of the southern half of this BCR can differ significantly. Therefore, one must use caution in extrapolating results from my research to the entire BCR. Furthermore, my research is based off data collected during the breeding season only. Consequently, my findings do not address questions regarding habitat needs of wintering or migratory birds. Additionally, my data are limited to two breeding seasons. Readers should be aware of the dynamic nature of bird populations (regarding both geographic range and population size), and, thus, recognize this limitation. Limitations specific to each of the separate studies are presented in the respective *Discussion*.

## STUDY I: A COMPARISON OF BREEDING BIRD USE AMONG SHORTGRASS PRAIRIE, CONSERVATION RESERVE PROGRAM (CRP) LAND, AND DRYLAND AGRICULTURE

### Overview

In this study my objective is to compare bird use of the three dominant habitat types in the study area (the northern half of the shortgrass prairie BCR, Figure 1). Specifically, I compare species abundance and bird community composition among CRP, shortgrass prairie, and dryland agriculture. I also compare vegetation structure between CRP and shortgrass prairie habitat. Based on my findings, I make recommendations on how CRP acres can be managed to benefit shortgrass prairie birds.

### Hypotheses

My hypotheses are: (1) shortgrass prairie obligates species will be significantly more abundant at shortgrass prairie point counts than at either CRP or dryland agriculture point counts, (2) species associated with taller grasses, such as mixedgrass prairie, will be significantly more abundant at CRP point counts, (3) there will be significantly more tall grass (>15cm) at CRP point counts than at shortgrass prairie point counts, and (4) shrub cover will be significantly less on CRP point counts than at shortgrass prairie point counts.

### Methods

I randomly selected one of the three point counts conducted at each surveyed section to include in the analysis given that the three point counts on each section are not independent of one another. I analyzed data taken at a total of 2,132 point counts, including 52 CRP, 1,595 shortgrass prairie, and 485 dryland agriculture point counts (Figure 1). I filtered the Section Survey data to include only birds observed within150m of the point count location, excluding birds flying over. Raptors, swallows, and nighthawks were included if flying over the sections being surveyed. Additionally, I analyzed only species that occurred at more than three point counts. I analyzed only species with ≥ 25 observations. Bird populations can fluctuate significantly with year, so I tested for difference (SAS, PROC TTEST, paired) in species richness and bird abundance between years 2003 and 2004.

*Bird Communities*

I compared several characteristics of bird communities among the three habitat types. Although comparing three habitat types, I selected multiple t-tests as the statistical method over analysis of variance because of the largely unbalanced data set (PROC TTEST; SAS 2002). T-tests also allowed me to address unequal variances between samples, in which case I used the Satterthwaite approximate t-statistic (Satterthwaite 1946). I compared bird abundance and species richness between CRP, shortgrass prairie, and dryland agriculture. Then I calculated the frequency at which each species was observed within each habitat type. I used multiple t-tests to compare bird abundance of individual species between the three habitats. Priority species were identified according to the PIF Species Assessment Database (Panjabi et al. 2005) and the U.S. Fish and Wildlife Shorebird Conservation Plan (Fellows et al. 2001). Priority species are classified hereafter as species of Continental Concern (CC), Regional Concern (RC), or a Priority Shorebird (PS).

*Vegetation structure*

To compare vegetation structure of CRP fields to shortgrass prairie, I examined two categorical variables, grass height (percent of grass >15cm within 150m of the point count location) and shrub cover (percent shrub cover within 150m of the point count location). To compare grass height, I compared the frequency of CRP and shortgrass prairie point counts in each of four categories: having <25%, 26-50%, 51-75%, or >75% of grass >15cm in height. For percent shrub cover, I compared the frequency of CRP and shortgrass prairie point counts in each of five categories: having no shrub cover, <1%, 1-3%, 3-10%, or >10% shrub cover. I did not compare vegetation structure of dryland agriculture to the other habitat types because of the difference in vegetation types (i.e., commercial crop versus grassland). Vegetation data was not collected on all CRP or shortgrass prairie points so the vegetation structure analysis is based on data collected at 64 CRP point counts and 3,110 shortgrass prairie point counts.

**Results**

I found no significant difference in species richness between years for CRP ($P = 0.16$), shortgrass prairie ($P = 0.29$), or dryland agriculture ($P = 0.23$). I found no significant differences in bird abundance between years for CRP ($P = 0.07$) or dryland agriculture ($P = 0.29$). I did find a significant difference in bird abundance between years for shortgrass prairie ($P < 0.0001$) with a difference of 0.5373 birds/point count between the means of each year. However, I concluded that this difference was likely the result of the very large sample size ($n = 1,595$) more so than a true biological difference. Therefore, I pooled data across years 2003 and 2004 such that each of the randomly selected point counts was sampled once in each year. The total number of data points used in analysis was 4,264, including 104 conducted in CRP, 3,190 in shortgrass prairie, and 970 in dryland agriculture.

*Bird Communities*

I observed a total of 16,504 individual birds of 55 species including: 447 individuals of 19 (18%) species on CRP, 12,257 individuals of 54 (98%) species on shortgrass prairie, and 3,800 individuals of 40 (74%) species on dryland agriculture. I observed 19 species of concern including seven (37%) on CRP, 18 (95%) on shortgrass prairie, and 16 (84%) on dryland agriculture (Table1).

Table 1. Bird species observed in 2003 and 2004 and the frequency of each species at CRP ($n$ = 104 point counts), shortgrass prairie ($n$ = 3,190), and dryland agriculture ($n$ = 970) point counts. Species are grouped by priority level according to Partner's In Flight Species Assessment Database (Panjabi et al. 2005) and the U.S. Fish and Wildlife Shorebird Conservation Plan (Fellows et al. 2001) and then listed alphabetically.

| | Frequency (%) | | |
|---|---|---|---|
| **Common Name** | **CRP** | **Shortgrass Prairie** | **Dryland Agriculture** |
| Species of continental and regional concern | | | |
| Brewer's Sparrow | | 1 | <1 |
| Lesser Prairie Chicken | | <1 | |
| Scaled Quail | 2 | 1 | |
| Species of continental concern | | | |
| Dickcissel | 5 | 1 | 2 |
| McCown's Longspur | | 1 | <1 |
| Species of regional concern | | | |
| Burrowing Owl | 1 | 1 | <1 |
| Cassin's Sparrow | 14 | 15 | 2 |
| Chestnut-collared Longspur | | 1 | |
| Common Nighthawk | | 2 | <1 |
| Ferruginous Hawk | | <1 | <1 |
| Grasshopper Sparrow | 42 | 11 | 14 |
| Lark Bunting | 32 | 29 | 29 |
| Lark Sparrow | 4 | 11 | 4 |
| Loggerhead Shrike | | 1 | 1 |
| Northern Harrier | | <1 | <1 |
| Prairie Falcon | | <1 | <1 |
| Priority shorebird species | | | |
| Long-billed Curlew | | <1 | <1 |
| Mountain Plover | | <1 | |
| Upland Sandpiper | | <1 | <1 |
| Non-priority species | | | |
| American Kestrel | 1 | <1 | <1 |
| Bank Swallow | 1 | <1 | <1 |
| Barn Swallow | 3 | 3 | 3 |
| Brown-headed Cowbird | | 2 | 2 |
| Bobolink | | <1 | |
| Brewer's Blackbird | | 1 | <1 |
| Brown Thrasher | | <1 | <1 |
| Bullock's Oriole | | 1 | <1 |
| Cassin's Kingbird | | <1 | |
| Chihuahuan Raven | | <1 | |
| Cliff Swallow | 3 | 4 | 1 |
| Common Grackle | | 1 | 2 |
| Common Raven | | <1 | |
| Eastern Kingbird | | 1 | <1 |
| Eastern Meadowlark | | <1 | |
| European Starling | | 1 | <1 |

Table 1 continued.

| Common Name | Frequency (%) | | |
|---|---|---|---|
| | CRP | Shortgrass Prairie | Dryland Agriculture |
| Great-tailed Grackle | | <1 | <1 |
| Horned Lark | 21 | 50 | 65 |
| Killdeer | | 2 | 3 |
| Mourning Dove | 29 | 15 | 18 |
| Northern Bobwhite | 2 | 1 | 1 |
| Northern Mockingbird | | 2 | <1 |
| Northern Rough-winged Swallow | | <1 | |
| Ring-necked Pheasant | 5 | 1 | 7 |
| Rock Pigeon | | <1 | <1 |
| Rock Wren | | <1 | |
| Red-tailed Hawk | | <1 | |
| Red-winged Blackbird | 7 | 2 | 14 |
| Say's Phoebe | | 1 | <1 |
| Sage Thrasher | | 1 | |
| Savannah Sparrow | | | <1 |
| Swainson's Hawk | 2 | 1 | 2 |
| Turkey Vulture | | <1 | |
| Vesper Sparrow | | 1 | |
| Western Kingbird | 5 | 8 | 5 |
| Western Meadowlark | 60 | 52 | 44 |

Species richness was not significantly different among the three habitats (CRP versus shortgrass prairie, P = 0.27; CRP versus dryland agriculture, P = 0.21; shortgrass prairie versus dryland agriculture, P = 0.51) with a mean of about two species occurring at each point count. Bird abundance also did not differ significantly between any of the habitats (CRP versus shortgrass prairie, P = 0.21; CRP versus dryland agriculture, P = 0.20; shortgrass prairie versus dryland agriculture, P = 0.50) with a mean of about four individuals occurring at each point count.

The five species most frequently observed at CRP point counts were Western Meadowlark (60), Grasshopper Sparrow (42%), Lark Bunting (32%), Mourning Dove (29%), and Horned Lark (21%) (Table 1). At shortgrass prairie point counts the most frequently observed species were Western Meadowlark (52%), Horned Lark (50%), Lark Bunting (29%), Cassin's Sparrow (15%), and Mourning Dove (15%). At dryland agriculture point counts they were Horned Lark (65%), Western Meadowlark (44%), Lark Bunting (24%), Mourning Dove (18%), and Red-winged Blackbird (14%).

<u>CRP versus Shortgrass Prairie</u>

I had a sufficient number of observations ($n \geq 25$) for 30 species to compare mean abundance between CRP and shortgrass prairie point counts (Table 2). Three species were significantly more abundant on CRP than shortgrass prairie including two priority species and one game species. The priority species included Grasshopper Sparrow (P < 0.001, $n$ = 505, RC) and Dickcissel (P = 0.038, $n$ = 34, CC), and the game species was Mourning Dove (P = 0.011, $n$ = 783). Grasshopper Sparrows occurred at 42% of all CRP point counts compared to 11% of shortgrass prairie and 14% of dryland agriculture point counts (Table 1). Dickcissels occurred at 5% of CRP point counts compared to <1% of shortgrass prairie and 2% of dryland agriculture point counts. Mourning Doves occurred at 29% of all CRP point counts compared to 15% of shortgrass prairie and 18% of dryland agriculture point counts.

Seventeen species were significantly more abundant on shortgrass prairie than CRP (Table 2). Fourteen of the 17 species were not observed on CRP including four priority species. Priority species included: Common Nighthawk ($P < 0.001$, $n = 90$, RC), Loggerhead Shrike ($P < 0.001$, $n = 30$, RC), McCown's Longspur ($P < 0.001$, $n = 73$, CC), and Chestnut-collared Longspur ($P < 0.001$, $n = 40$, RC). Common Nighthawks, Loggerhead Shrikes, McCown's Longspurs, and Chestnut-collared Longspurs each occurred at ≤ 2% of shortgrass prairie and ≤ 1% dryland agriculture point counts, except Chestnut-collared Longspur which occurred only at shortgrass prairie point counts. Only three of the 17 species that were significantly more abundant on shortgrass prairie than CRP occurred in both habitats including one priority species, Lark Sparrow ($P < 0.001$, $n = 527$, RC). Lark Sparrows occurred in all three habitats and occurred at 11% of shortgrass prairie and 4% of both CRP and dryland agriculture point counts. Horned Larks and Cliff Swallows also occurred in both CRP and shortgrass prairie. Horned Larks occurred at 50% of shortgrass prairie point counts, 21% of CRP point counts, and 65% of dryland agriculture point counts. Cliff Swallows occurred at 4% of shortgrass prairie point counts, 3% of CRP point counts, and 1% of dryland agriculture point counts.

Ten species showed no significant difference in mean abundance between CRP and shortgrass prairie point counts including four priority species and two game species (Table 2). All ten of these species occurred at both CRP and shortgrass prairie point counts. Priority species included: Burrowing Owl ($P = 0.698$, $n = 44$), Cassin's Sparrow

(P =0.768, *n* = 718), Lark Bunting (P = 0.181, *n* = 2,094), and Scaled Quail (P = 0.336, *n* = 33). Burrowing Owls occurred at ≤1% of point counts in each of the three habitats. Cassin's Sparrows occurred at 15% of shortgrass prairie, 14% of CRP, and 2% of dryland agriculture point counts. Lark Buntings occurred at 29% of shortgrass prairie, 32% of CRP, and 29% of dryland agriculture point counts. Scaled Quail occurred at 1% of shortgrass prairie, 2% of CRP, and none of the dryland agriculture point counts. The two game species that occurred in similar abundance between CRP and shortgrass prairie point counts were Northern Bobwhite (P = 0.309, *n* = 25) and Ring-necked Pheasant (P = 0.057, *n* = 29). The other species that showed no significant difference (P ≥ 0.05) in mean abundance between CRP and shortgrass prairie included Barn Swallow, Red-winged Blackbird, Western Kingbird, and Western Meadowlark (Table 2).

Dryland Agriculture versus Shortgrass Prairie

I had a sufficient number of observations for 31 species to compare mean abundance between dryland agriculture and shortgrass prairie (Table2). Seven of these species were significantly more abundant at dryland agriculture point counts than shortgrass prairie including two priority species and two game species. The priority species included Grasshopper Sparrow (P = 0.028, *n* = 576) and Dickcissel (P = 0.006, *n* = 54) which occurred at 2% and 14% of dryland agriculture point counts compared to 1% and 11% of shortgrass prairie point counts, respectively. The two game species included Mourning Dove (P = 0.002, *n* = 1,060) and Ring-necked Pheasant (P < 0.001, *n* = 101) which occurred at 18% and 7% of dryland agriculture point counts as compared to 15% and 1% of shortgrass prairie point counts, respectively. Seven species showed no significant difference (P ≥ 0.05) in mean abundance between shortgrass prairie and dryland agriculture including Loggerhead Shrike, Brown-headed Cowbird, European Starling, Barns Swallow, Brewer's Blackbird, Common Grackle, and Killdeer (Table 2). All other species were significantly more abundant ($P < 0.05$) at shortgrass prairie point counts than dryland agriculture point counts (Table 2).

CRP versus Dryland Agriculture

I had a sufficient number of observations for 15 species compare mean abundance between CRP and dryland agriculture point counts. Three priority species were significantly more abundant at CRP point counts than dryland agriculture point counts including Cassin's Sparrow ($P < 0.001$, $n = 38$), Grasshopper Sparrow ($P < 0.001$, $n = 251$), and Lark Bunting ($P = 0.042$, $n = 563$). Western Meadowlark was also significantly more abundant on CRP than dryland agriculture ($P = 0.001$, $n = 692$). Conversely, Common Grackle ($P < 0.001$, $n = 47$), Horned Lark ($P < 0.001$, $n = 1{,}542$), Killdeer ($P < 0.001$, $n = 32$), and Red-winged Blackbird ($P = 0.001$, $n = 245$) were significantly more abundant on dryland agriculture than CRP. The other seven species showed no significant difference ($P \geq 0.05$) in mean abundance including, Dickcissel, Lark Sparrow, Mourning Dove, Ring-necked Pheasant, Barns Swallow, Cliff Swallow, and Western Kingbird (Table 2).

Table 2. Mean abundance (number of birds/point count) of species observed in CRP, shortgrass prairie, and dryland agriculture and significance levels of t-tests comparing mean abundance among the habitats. I conducted t-tests only for species with ≥ 25 observations pooled between the two compared habitats. Continued.

| | **CRP** | | | **Shortgrass Prairie** | | | **Dryland Agriculture** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | $\bar{X}$ | **se** | **α-level** [a] | $\bar{X}$ | **se** | **α-level** | $\bar{X}$ | **se** | **α-level** |
| *Priority* | | | | | | | | | |
| Burrowing Owl | 0.01 | 0.01 | | 0.01 | <0.01 | ** | <0.01 | <0.01 | *n/a* |
| Cassin's Sparrow | 0.20 | 0.05 | | 0.22 | 0.01 | *** | 0.02 | <0.01 | *** |
| Chestnut-collared Longspur | 0 | 0 | *** | 0.01 | <0.01 | *** | 0 | 0 | *n/a* |
| Common Nighthawk | 0 | 0 | *** | 0.03 | <0.01 | *** | <0.01 | <0.01 | *n/a* |
| ***Dickcissel*** [b] | 0.12 | 0.05 | * | 0.01 | <0.01 | ** | 0.03 | 0.01 | |
| ***Grasshopper Sparrow*** | 0.87 | 0.13 | *** | 0.13 | 0.01 | * | 0.17 | 0.01 | *** |
| Lark Bunting | 0.82 | 0.15 | | 0.61 | 0.02 | ** | 0.49 | 0.03 | * |
| Lark Sparrow | 0.05 | 0.03 | *** | 0.16 | 0.01 | *** | 0.06 | 0.01 | |
| Loggerhead Shrike | 0 | 0 | *** | 0.01 | <0.01 | | 0.01 | <0.01 | *n/a* |
| McCown's Longspur | 0 | 0 | *** | 0.02 | <0.01 | *** | <0.01 | <0.01 | *n/a* |
| Scaled Quail | 0.04 | 0.03 | | 0.01 | <0.01 | *** | 0 | 0 | *n/a* |
| *Game* | | | | | | | | | |
| ***Mourning Dove*** | 0.47 | 0.09 | * | 0.23 | 0.01 | ** | 0.34 | 0.03 | |
| Northern Bobwhite | 0.03 | 0.02 | | 0.01 | <0.01 | | 0.01 | <0.01 | *n/a* |
| *Ring-necked Pheasant* [b] | 0.05 | 0.02 | | 0.01 | <0.01 | *** | 0.08 | 0.01 | |
| *Other* | | | | | | | | | |
| Brown-headed Cowbird | 0 | 0 | *** | 0.02 | <0.01 | | 0.02 | 0.01 | *n/a* |
| Barn Swallow | 0.05 | 0.03 | | 0.04 | 0.01 | | 0.05 | 0.01 | |

[a] Asterisks indicate statistically significant difference between habitat types in adjacent columns; *n/a* indicates that I did not perform a t-test because of insufficient number of observations: * = P < 0.05, ** = P ≤ 0.01, and *** = P ≤ 0.001. Last column is the significance levels between dryland agriculture and CRP.

[b] Bold indicates that mean abundance was significantly greater at CRP point counts than shortgrass prairie; italics indicates that mean abundance was significantly greater on dryland agriculture than shortgrass prairie

Table 2 continued.

| | CRP | | | Shortgrass Prairie | | | Dryland Agriculture | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | $\overline{X}$ | **se** | **α-level** [a] | $\overline{X}$ | **se** | **α-level** | $\overline{X}$ | **se** | **α-level** |
| *Other* | | | | | | | | | |
| Brewer's Blackbird | 0 | 0 | ** | 0.01 | 0.15 | | 0.01 | <0.01 | *n/a* |
| Bullock Oriole | 0 | 0 | *** | 0.01 | <0.01 | * | <0.01 | <0.01 | *n/a* |
| Cliff Swallow | 0.04 | 0.02 | ** | 0.13 | 0.02 | *** | 0.03 | 0.01 | |
| Common Grackle | 0 | 0 | *** | 0.03 | 0.01 | | 0.05 | 0.01 | *** |
| Eastern Kingbird | 0 | 0 | *** | 0.02 | <0.01 | *** | <0.01 | <0.01 | *n/a* |
| European Starling | 0 | 0 | * | 0.05 | 0.03 | | <0.01 | <0.01 | *n/a* |
| *Horned Lark* | 0.42 | 0.09 | *** | 0.98 | 0.02 | *** | 1.54 | 0.06 | *** |
| Killdeer | 0 | 0 | *** | 0.02 | <0.01 | | 0.03 | 0.01 | *** |
| Northern Mockingbird | 0 | 0 | *** | 0.02 | <0.01 | *** | <0.01 | <0.01 | *n/a* |
| *Red-winged Blackbird* | 0.10 | 0.04 | | 0.04 | 0.01 | *** | 0.24 | 0.02 | ** |
| Say's Phoebe | 0 | 0 | *** | 0.01 | <0.01 | * | <0.01 | <0.01 | *n/a* |
| *Swainson's Hawk* | 0.02 | 0.01 | *n/a* | 0.01 | <0.01 | ** | 0.02 | 0.00 | *n/a* |
| Vesper Sparrow | 0 | 0 | *** | 0.01 | <0.01 | *** | 0 | 0 | *n/a* |
| Western Kingbird | 0.07 | 0.03 | | 0.12 | 0.01 | *** | 0.07 | 0.01 | |
| Western Meadowlark | 0.94 | 0.01 | | 0.78 | 0.02 | *** | 0.61 | 0.03 | ** |

*Vegetation structure*

At 5% of CRP point counts (*n* = 3) <25% of the grass within 150m of the point count was taller than >15cm (Figure 4). At 19% of CRP point counts (*n* = 12) 26-50% of the grass was taller than >15cm. At 9% of CRP point counts (*n* = 6) 51-75% of the grass was taller than >15cm. At 67% of CRP point counts (*n* = 43) 75-100% of the grass was taller than >15cm. Additionally, about 65% of CRP point counts (*n* = 42) had no shrub cover, 26% (*n* = 17) had <1%, 5% (*n* = 3) had 1-3%, 2% (*n* = 1) had 3-10%, and 2% (*n* = 1) had >10% shrub cover (Figure 5).

At 28% of shortgrass prairie point counts (*n* = 876) <25% of the grass within 150m of the point count was taller than 15cm (Figure 4). At 22% of shortgrass prairie point counts (*n* = 673) 26-50% of the grass was taller than 15cm. At 20% of shortgrass prairie point counts (*n* = 619) 51-75% of the grass was taller than 15cm. At 30% of shortgrass prairie point counts (*n* = 942) 75-100% of the grass was taller than 15cm. About 25% of shortgrass prairie point counts (*n* = 762) had no shrub cover, 37% (*n* = 1,196) had <1%, 22% (*n* = 671) had 1-3%, 11% (*n* = 328) had 3-10%, and 5% (*n* = 153) had >10% shrub cover (Figure 5).

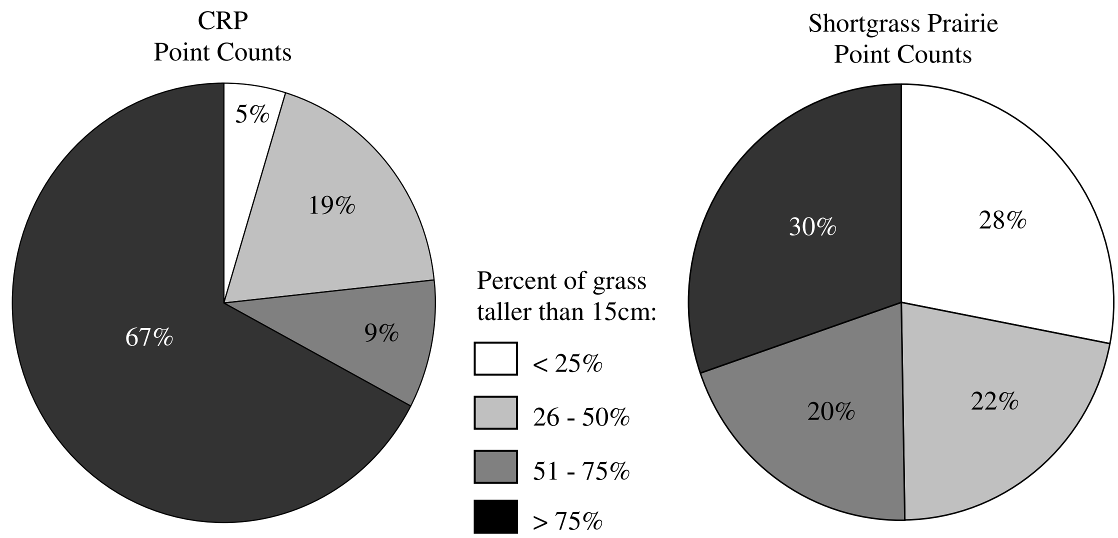


Figure 4. Percent of CRP ($n$ = 64) and shortgrass prairie ($n$ = 3,110) point counts in each of the four grass height categories. Categories estimate the percent of grass, within 150m of the point count location, that is >15cm in height.

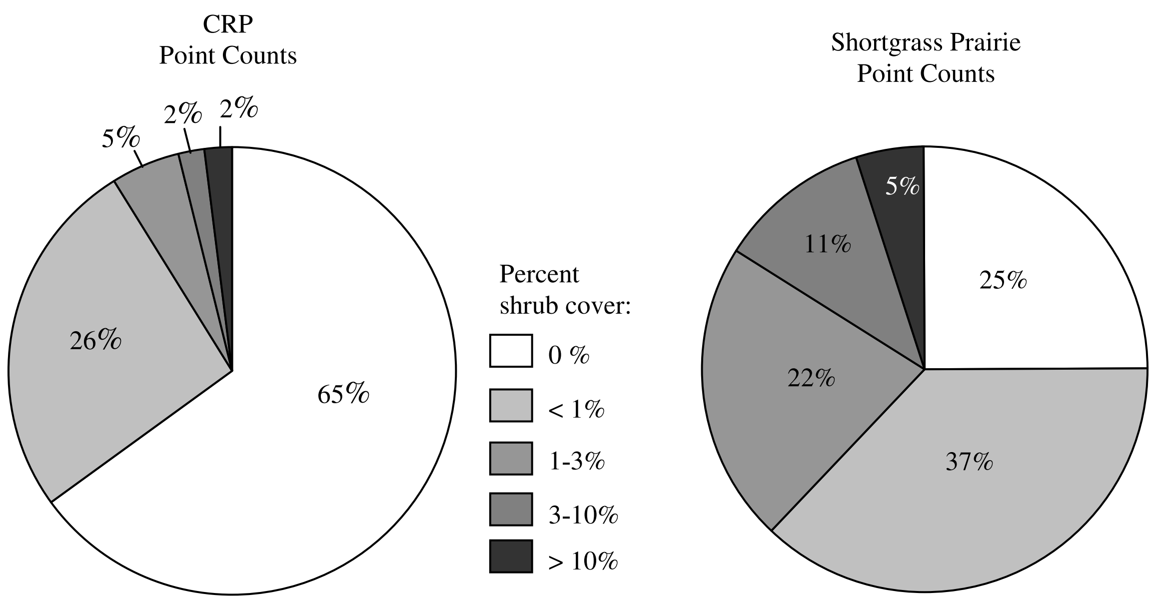


Figure 5. Percent of CRP ($n$ = 64) and shortgrass prairie ($n$ = 3,110) point counts in each of the shrub cover categories. Categories estimate the percent of ground, within 150m of the point count location, covered by shrubs.

## Discussion

My research indicates that CRP is not restoring shortgrass prairie habitat but is providing habitat that has taller grasses and less shrub cover than shortgrass prairie. Accordingly, Grasshopper Sparrows and Dickcissels were not only significantly more abundant on CRP than shortgrass prairie, but they occurred at frequencies four and five times greater, respectively. Grasshopper Sparrows prefer grass of intermediate height, moderately deep litter, and sparse woody vegetation (Dechant et al. 2003c). Dickcissels prefer moderate to tall grass, and moderately deep litter (Dechant et al. 2003a). Except Mourning Dove, no other species was more significantly abundant on CRP than shortgrass prairie. Mourning Dove is one of the most widely distributed and abundant birds in North America (Droege and Sauer 1990), and as a result, did not provide much insight into the habitat characteristics of CRP. However, all three of these species were also significantly more abundant on dryland agriculture than shortgrass prairie, suggesting that restoring cropland with CRP may not be essential to conserve these species. Considering that both Grasshopper Sparrow and Dickcissel are priority species, it is important to recognize the potential conservation benefits of CRP; however, it is just as important to note that neither Grasshopper Sparrow nor Dickcissel is a shortgrass prairie obligate species. Rather both species occur widely throughout the Great Plains with prominence in the mid- and tallgrass prairies (Dechant et al. 2003a, Dechant et al. 2003c). This begs the question as to whether such species, although priority species, should strongly influence potential management of CRP fields in the shortgrass prairie.

I suggest that regional CRP objectives be focused on managing for priority species that are also shortgrass prairie obligates or closely associated species (such as

Mountain Plover, Ferruginous Hawk, McCown's Longspur, Chestnut-collared Longspur, Cassin's Sparrow, Lark Bunting, and Long-billed Curlew) or for species for which management benefits multiple species. My research indicates that CRP may be currently providing some habitat requirements to several such species but only limited habitat for others. For example, Scaled Quail, Burrowing Owl, Cassin's Sparrow, and Lark Bunting all occurred in similar abundance between CRP and shortgrass prairie. That said, I recognize that other factors besides habitat type, grass height, and shrub cover influence resource selection by birds such as patch size, landscape composition, population density, competition, availability of forage, heredity, predation, weather, and inter-patch distances (Manly et al. 2002). The difficulty of assessing shortgrass prairie bird habitat requirements is not certain through my analysis but it does provide a starting point for further analysis and offers baseline information on how to more effectively manage CRP to benefit priority bird species.

I suggest that CRP can be more effective in providing suitable habitat for shortgrass prairie birds if its management activities are designed to provide a variety of habitat conditions based off the habitat requirements of multiple species. In considering which species to manage for, I suggest managing for priority bird species, species that are endemic to the ecoregion (occur or have historically occurred in the area), and/or species for which management will maximize production of several other species (i.e., umbrella species). Also important is that plantings and management activities on CRP are ecologically appropriate to the landscape at both local and regional scales. I suggest using Ecological Site Guides, developed by the Natural Resource Conservation Service (NRCS), to guide decisions on appropriate plantings and management activities.

# STUDY II: THE RELATIVE CONSERVATION VALUES OF SHORTGRASS PRAIRIE, CONSERVATION RESERVE PROGRAM (CRP) LAND, AND DRYLAND AGRICULTURE TO BREEDING BIRDS

## Overview

The objective of my second study is to compare the relative conservation values of shortgrass prairie, CRP, and dryland agriculture using species conservation prioritization ranks. Most research that has evaluated CRP as wildlife habitat, such as Study I, has relied on traditional summary statistics, comparing species richness, total abundance, or abundance of select species between CRP and other habitats. However, as pointed out by Nuttle et al., such summary statistics can obscure information on species composition (2003), often neglecting the significance of rare species and focusing on more abundant species for which statistical testing is more applicable. An alternative approach to evaluating habitats is to use a conservation value (*CV*) index where the derived *CV* serves as a correlate of the community's true conservation value. A *CV* index weights the abundance measure (e.g., count, presence/absence, density) of each species relative to their conservation priority and the *CV* is estimated by summing all weighted abundance measures per community. I derive and compare the *CV*s of shortgrass prairie, CRP, and dryland agriculture relative to breeding birds, by using Partners In Flight (PIF) species prioritization ranks as weights.

PIF developed a prioritization system that scores a species' risk of extinction relative to other North American birds. The purpose of prioritizing species is to efficiently direct limited monetary and human resources toward the species and habitats in most need (Beisinger et al. 2000). This system prioritizes each species based on the scores of seven variables including three globally-based variables (breeding distribution, wintering distribution, and abundance) and four regionally-based variables (local population trends, local threats on breeding and non-breeding grounds, and importance of an area to a species). All variables are scored independently with a value ranging from one to five, with five indicating high priority and one indicating low priority. PIF suggested that the sum of these seven variable scores could be considered a total conservation priority score. However, after review, the American Ornithologist's Union (AOU) Conservation Committee found problems with multicollinearity among the seven variables and, consequently, developed an alternative system to determine a species total conservation priority score. The Committee proposed a categorical ranking system that defines "six categories of conservation concern based on combinations of PIF variables" (Beisinger et al. 2000). These six categories have ranks ranging from zero to five as described in Table 3. Nuttle et al. (2003) evaluated the use of this new categorical ranking system in estimating conservation values (*CV*s) of communities and, consequently, suggested a revised version of the categories that does not assign threatened and endangered species to a separate and highest category. The resulting system contains five categories with ranks ranging from zero to four. These ranks are hereafter referred to as *PIF.ranks* (Nuttle et al. 2003). I used the *PIF.ranks* specific to the shortgrass prairie BCR to estimate and compare the *CV*s of CRP, shortgrass prairie, and dryland agriculture in the study area.

To compliment the CV index, I also evaluated bird community composition of the three habitat types using Jaccard's similarity index (Krebs 1998). Jaccard's similarity index measures community similarity between two samples (or habitat types, in this case) using species presence/absence data and produces a value indicating the percent overlap of species between the two samples.

**Hypotheses**

My hypotheses are: (1) the mean *CV* of shortgrass prairie point counts will be significantly greater than that of CRP and dryland agriculture point counts, (2) the mean *CV* of CRP point counts will be significantly greater than that of dryland agriculture point counts, and (3) CRP will be more similar in bird community composition to shortgrass prairie than to dryland agriculture.

**Methods**

I randomly selected one of the three point counts conducted at each surveyed section to include in the analysis because the three point counts conducted at each section are not independent of one another. I analyzed data taken at a total of 2,132 point counts, including 52 CRP, 1,595 shortgrass prairie, and 485 dryland agriculture point counts (Figure 1). I filtered the Section Survey data to include only birds observed within 150m of the point count location, excluding birds flying over. Raptors, swallows, and nighthawks were included if flying over the sections being surveyed. Unlike Study I, I included all species in this analysis regardless of rate of occurrence so as to include rare species. I then transformed these data from counts to binomial presence/absence data. I used presence/absence data instead of the count data to avoid the potential problem of very abundant low priority species overshadowing the presence of rare high priority species. Additionally, I tested for difference in species richness between years 2003 and 2004, (SAS, PROC TTEST, paired), to determine if I could pool data across years.

*Conservation Values (CVs)*

I calculated a *CV* index for each point count in the form

$$CV = \sum_{i=1}^{S} a_i w_i$$

where $S$ is the number of species in the community, $a_i$ is the abundance of species $i$, and $w_i$ is a weighting factor for that species (Gotmark et al. 1986). I used presence/absence data as the abundance measure ($a_i$), therefore, the number of individuals of a species did not increase the *CV* of a point count. I derived the weighting factor for each species ($w_i$) from a categorical ranking algorithm based on Partners In Flight (PIF) prioritization categories and specific to the shortgrass prairie BCR. The algorithm was developed by Beisinger et al. (2000) but I used a modified version developed by Nuttle et al. (2003) (Table 3). The algorithm assigns a rank (*PIF.rank*) to each bird species reflective of its level of conservation concern using a scale of zero to four, where *PIF.rank* = 0 indicates an introduced species and *PIF.rank* = 4 indicates a species of high concern (Table 3).

I compared mean *CV* among CRP, shortgrass prairie, and dryland agriculture point counts using multiple t-tests (PROC TTEST; SAS 2002). Although comparing three habitat types, I selected multiple t-tests as the statistical method over analysis of variance because of the largely unbalanced data set. T-tests also allowed me to address unequal variances between samples, in which case I used the Satterthwaite approximate t-statistic (Satterthwaite 1946). Using this same method, I also compared mean occurrence of species in each *PIF.rank* by habitat to evaluate which types of species (e.g., species of high concern) contribute the *CV*s of each habitat. Similarly, I calculated the frequency of each species by habitat type.

*Bird Community Composition*

I compared bird community composition among CRP, shortgrass prairie, and dryland agriculture using Jaccard's similarity index (Krebs 1998). Jaccard's similarity index measures community similarity between two samples (or habitat types, in this case) using species presence/absence data and produces a value indicating the percent overlap of species between the two samples. For this calculation, I randomly selected a subset of the point counts conducted in shortgrass prairie and dryland agriculture such that the subsets were equal to the CRP sample size ($n$ = 104), thus, creating a balanced sample across all habitat types.

Table 3. Categorical ranking algorithm developed by Beissinger et al. (2000)[a] and adapted by Nuttle et al (2003).

| ***PIF.rank*** | **Category** | **Species attributes** | **Decision criteria** [b] |
|---|---|---|---|
| 4 | High concern | Populations are declining rapidly, have a small range, or high threats. | a. PT > 3 and (RA, BD,TB, or TN > 3), or<br>b. RA = 5, or<br>c. RA = 4 and (BD or ND > 3), or<br>d. AI = 5 and RA > 3. |
| 3 | Moderate concern | Populations are declining and experiencing moderate threats, or population trends are not known and threats are high. | a. PT > 3 and (RA, BD,TB, or TN = 3), or<br>b. PT = 3 and (RA, BD,TB, or TN > 3), or<br>c. RA = 3 and (BD or ND > 2), or<br>d. RA = 4 and (BD or ND ≤ 3), or<br>e. AI = 4 and RA > 3. |
| 2 | Low concern | Species is common. | a. PT = 3 and (RA, BD,TB, or TN = 3), or<br>b. PT = 2 and (RA, BD,TB, or TN > 3), or<br>c. RA > 2 and (Rank ≠ 3 or 4), or<br>d. AI > 2 and (Rank ≠ 3 or 4). |
| 1 | Not at risk | All remaining native species. | Rank ≠ (2, 3, or 4), i.e., all remaining native species |
| 0 | Introduced/ Non-native | Species are not native to North America, have spread into the area by anthropogenic means or because of anthropogenic factors, or is otherwise determined to not contribute to conservation needs of the site. | All non-native species as determined by attributes of interest. |

[a] Beissinger et al. (2000) included an additional rank = 5 for federal- or state-listed threatened and endangered species.
[b] Category definitions (Carter et al. 2000): PT = Population Trend, RA = Relative Abundance, BD = Breeding Distribution, TB = Threats to Breeding, TN = Threats to Non-breeding, ND, Non-breeding Distribution, and AI = Area Importance

## Results

I observed 85 species across the three habitats including, 30 of which occurred at ≤ 3 point counts (Table 4). Twenty-one species occurred at CRP point counts for a total of 244 observations (i.e., presence of a species at a point count). Forty-seven species occurred at dryland agriculture point counts for a total of 2,068 observations. Seventy-seven species occurred at shortgrass prairie point counts for a total of 9,765 observations. Species richness was not significantly different between years within habitat (CRP: $P = 0.16$; dryland agriculture: $P = 0.54$; shortgrass prairie: $P = 0.26$) with a mean of about two species occurring at each point count. Therefore, I pooled data across years within habitat.

I observed 13 species of high concern, 27 of moderate concern, 27 of low concern, 13 species not at risk, and five introduced/non-native species (Table 4). Species of low concern were most frequently observed, accounting for 65% of all observations (Figure 6). Species of high and moderate concern accounted for 19% and 13% of all observations, respectively. Species at no risk and introduced species accounted for <1% and 2%, respectively. I present the *PIF.rank* for each species and frequency of occurrence for each species by habitat (Table 4).

Table 4. Species observed by *PIF.rank* and frequency in each and all habitats. Continued on next two pages.

| Species | Frequency CRP | Dryland Agriculture | Shortgrass Prairie | All Habitats |
|---|---|---|---|---|
| *PIF.rank* = 4, Species of high concern | | | | |
| American Kestrel | 1 | <1 | <1 | <1 |
| Burrowing Owl | 1 | <1 | 1 | 1 |
| Cassin's Sparrow | 14 | 2 | 15 | 12 |
| Ferruginous Hawk | | <1 | <1 | <1 |
| Lark Bunting | 32 | 29 | 29 | 29 |
| Mountain Plover | | | <1 | <1 |
| Northern Harrier | | <1 | <1 | <1 |
| Prairie Falcon | | <1 | <1 | <1 |
| Say's Phoebe | | <1 | 1 | 1 |
| Swainson's Hawk | 2 | 2 | 1 | 1 |
| Upland Sandpiper | | <1 | <1 | <1 |
| Yellow-headed Woodpecker | | <1 | <1 | <1 |
| Yellow Warbler | | | <1 | <1 |
| *PIF.rank* = 3, Species of moderate concern | | | | |
| American Avocet | | | <1 | <1 |
| Black-crowned Night Heron | | <1 | | <1 |
| Blue Grosbeak | 1 | <1 | <1 | <1 |
| Bobolink | | | <1 | <1 |
| Brewer's Sparrow | | <1 | 1 | <1 |
| Brown Thrasher | | <1 | <1 | <1 |
| Bullock’s Oriole | | <1 | 1 | 1 |
| Cassin's Kingbird | | | <1 | <1 |
| Chestnut-collared Longspur | | | 1 | 1 |
| Chihuahuan Raven | | | <1 | <1 |
| Common Nighthawk | | <1 | 2 | 2 |
| Eastern Kingbird | | <1 | 1 | 1 |
| Grasshopper Sparrow | 42 | 14 | 11 | 12 |
| Lark Sparrow | 4 | 4 | 11 | 9 |
| Lazuli Bunting | | | <1 | <1 |
| Long-billed Curlew | | <1 | <1 | <1 |
| Lesser Prairie Chicken | | | <1 | <1 |
| McCown's Longspur | | <1 | 1 | 1 |
| Northern Rough-winged Swallow | | | <1 | <1 |
| Orchard Oriole | | 1 | <1 | <1 |
| Red-headed Woodpecker | | <1 | <1 | <1 |
| Red-tailed Hawk | | | <1 | <1 |
| Scaled Quail | 2 | | 1 | 1 |
| Vermillion Flycatcher | | | <1 | <1 |
| Virginia Rail | | | <1 | <1 |
| Warbling Vireo | | | <1 | <1 |
| Western Bluebird | | | <1 | <1 |

Table 4 continued.

| Species | Frequency | | | |
|---|---|---|---|---|
| | CRP | Dryland Agriculture | Shortgrass Prairie | All Habitats |
| *PIF.rank* = 2, Species of low concern | | | | |
| Barn Swallow | 3 | 3 | 2 | 3 |
| Black-billed Magpie | | <1 | <1 | <1 |
| Bewick's Wren | | | <1 | <1 |
| Black-throated Sparrow | | <1 | | <1 |
| Blue-winged Teal | | | <1 | <1 |
| Cliff Swallow | 3 | | 4 | 3 |
| Common Grackle | | 2 | 1 | 1 |
| Common Raven | | | <1 | <1 |
| Dickcissel | 5 | 2 | 1 | 1 |
| Eastern Meadowlark | | | <1 | <1 |
| Eastern Phoebe | | | <1 | <1 |
| Field Sparrow | | <1 | <1 | <1 |
| Horned Lark | 21 | 65 | 50 | 53 |
| House Wren | | | <1 | <1 |
| Killdeer | | 3 | 2 | 2 |
| Loggerhead Shrike | | 1 | 1 | 1 |
| Mallard | 1 | <1 | <1 | <1 |
| Mourning Dove | 29 | 18 | 15 | 16 |
| Northern Bobwhite | 2 | 1 | 1 | 1 |
| Northern Mockingbird | | <1 | 2 | 1 |
| Rock Wren | | | <1 | <1 |
| Red-winged Blackbird | 7 | 14 | 2 | 5 |
| Sage Thrasher | | | <1 | <1 |
| Savannah Sparrow | | <1 | | <1 |
| Turkey Vulture | | | <1 | <1 |
| Western Kingbird | 5 | 5 | 8 | 7 |
| Western Meadowlark | 60 | 44 | 52 | 50 |
| *PIF.rank* = 1, Species at no risk | | | | |
| American Crow | | | <1 | <1 |
| American Goldfinch | | | <1 | <1 |
| American Robin | | <1 | <1 | <1 |
| Ash-throated Flycatcher | | | <1 | <1 |
| Bank Swallow | 1 | <1 | <1 | <1 |
| Blue Jay | | | <1 | <1 |
| Brewer's Sparrow | | <1 | <1 | <1 |
| Chipping Sparrow | | | <1 | <1 |
| Common Yellowthroat | | | <1 | <1 |
| Great-tailed Grackle | | <1 | <1 | <1 |
| House Finch | | <1 | <1 | <1 |
| Northern Flicker | | | <1 | <1 |
| Vesper Sparrow | | | 1 | 1 |

Table 4 continued.

| Species | Frequency CRP | Dryland Agriculture | Shortgrass Prairie | All Habitats |
|---|---|---|---|---|
| *PIF.rank* = 0, Introduced/non-native species | | | | |
| Brown-head Cowbird | | 2 | 2 | 2 |
| European Starling | | <1 | 1 | <1 |
| House Sparrow | | 1 | <1 | 1 |
| Ring-necked Pheasant | 5 | 7 | 1 | 2 |
| Rock Pigeon | | <1 | <1 | <1 |

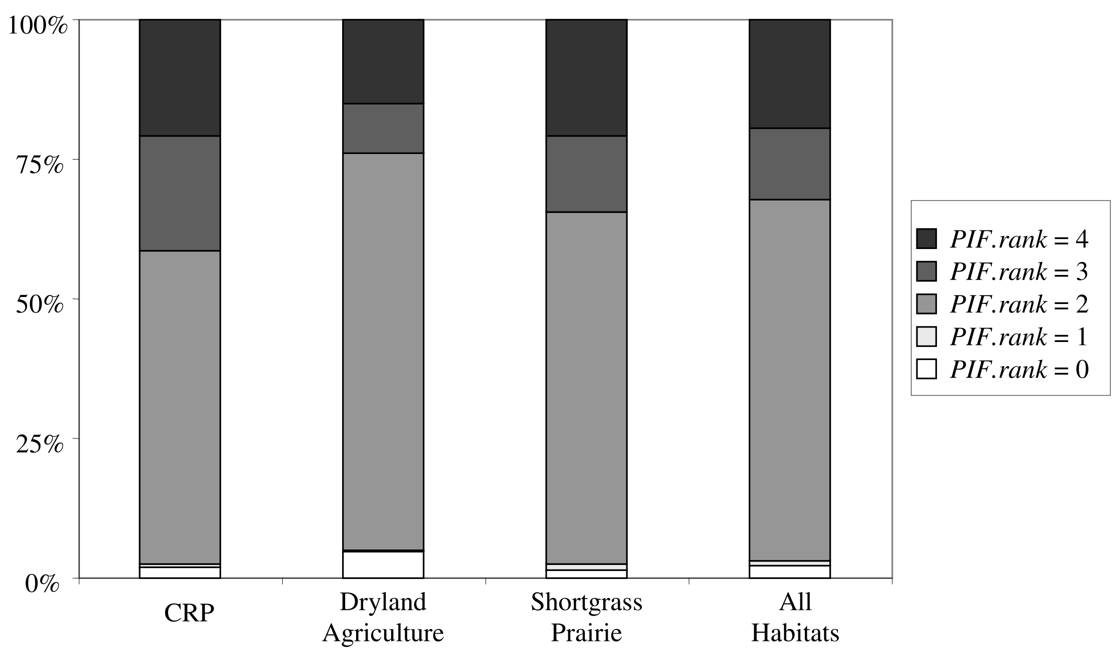


Figure 6. Frequency of observations by PIF prioritization rank (*PIF.rank*) by habitat and combined across all habitats. An observation is defined as the presence of a species at a point count.

*Conservation Values (CVs)*

The mean *CV* of dryland agriculture point counts ($\bar{x}$ = 5.12) was significantly less than the mean *CV* of CRP point counts ($\bar{x}$ = 6.17, P = 0.011) and shortgrass prairie point counts ($\bar{x}$ = 5.67, P < 0.001). For both these t-tests, I used the Satterthwaite statistic because of unequal variances (P ≤ 0.026). I found no significant difference between the mean *CV* of CRP and shortgrass prairie point counts (P = 0.147). For this t-test, variances proved equal (P = 0.053).

The mean number of species of high concern (*PIF.rank* = 4) per point count was significantly greater at both CRP (P = 0.013, $\bar{x}$ = 0.50) and shortgrass prairie (P < 0.001, $\bar{x}$ = 0.469) point counts than at dryland agriculture ($\bar{x}$ = 0.336) point counts. However, I found no significant difference in the mean number of species of high concern between CRP and shortgrass prairie point counts (P = 0.593). Lark Bunting and Cassin's Sparrow were the most frequent species of high concern, occurring on 29% and 12% of all point counts, respectively. All other species of high concern occurred at ≤1% of all point counts. Lark Bunting occurred at 32% of CRP point counts and 29% of both dryland agriculture and shortgrass prairie point counts. Cassin's Sparrow occurred at 15% and 14% of shortgrass prairie and CRP point counts, respectively, compared to 2% of dryland agriculture point counts.

The mean number of species of moderate concern (*PIF.rank* = 3) per point count was significantly greater at CRP point counts ($\bar{x}$ = 0.49) than at shortgrass prairie (P = 0.001, $\bar{x}$ = 0.31) and dryland agriculture (P < 0.001, $\bar{x}$ = 0.20). The mean number of species of moderate concern was significantly greater at shortgrass prairie point counts than at dryland agriculture (P < 0.001). Grasshopper Sparrow was the most frequent species of moderate concern, occurring at 12% of all point counts. Lark Sparrow was the next most frequent and occurred at 9% of all point counts. All other species of moderate concern occurred at ≤ 2% of point counts. Grasshopper Sparrow occurred at 42% of CRP point counts compared to 14% and 11% of dryland agriculture and shortgrass prairie point counts, respectively. Lark Sparrow occurred at 11% of shortgrass prairie point counts as compared to 4% of both CRP and dryland agriculture point counts.

The mean number of species of low concern (*PIF.rank* = 2) per point count was significantly greater on dryland agriculture ($\bar{x}$ = 1.58) than on CRP (P = 0.018, $\bar{x}$ = 1.35) and shortgrass prairie (P < 0.001, $\bar{x}$ = 1.42). I found no significant difference in the mean number of species of low concern between CRP and shortgrass prairie point counts (P = 0.44). The five most frequent specie of low concern were Horned Lark (53%), Western Meadowlark (50%), Mourning Dove (16%), Western Kingbird (7%), and Red-winged Blackbird (5%). All other species occurred at ≤3% of point counts. Horned Lark occurred at 65% of dryland agriculture point counts as compared to 50% and 21% of shortgrass prairie and CRP point counts, respectively. Western Meadowlark occurred at 60% of CRP point counts compared to 52% and 44% of shortgrass prairie and dryland agriculture point counts, respectively. Mourning Dove occurred at 29% of CRP point counts compared to 18% and 15% of dryland agriculture and shortgrass prairie point counts, respectively.

The mean number of species not at risk (*PIF.rank* = 1) per point count was significantly greater at shortgrass prairie point counts ($\bar{x}$ =0.25) than at dryland agriculture (P < 0.001, $\bar{x}$ = 0.01) point counts. However, I found no significant difference between shortgrass prairie and CRP (P = 0.133, $\bar{x}$ =0.01) or between CRP and dryland agriculture (P = 0.973). All species of *PIF.rank* = 1 accounted for ≤1% of all occurrences.

Introduced/non-native species (*PIF.rank* = 0) did not contribute to *CV*s as their weight = 0. Therefore, I did not perform t-tests to compare mean occurrence. The most frequently occurring introduced/non-native species were Ring-necked Pheasant (2%) and Brown-headed Cowbird (2%). Ring-necked Pheasant occurred at 7% of dryland agriculture point counts and 5% of CRP point counts compared to 1% of shortgrass prairie point counts. Brown-headed Cowbirds did not occur at CRP point counts but occurred at equal frequencies at dryland agriculture and shortgrass prairie point counts (2%).

*Bird Community Composition*

Results from the Jaccard's similarity index showed that the three habitat types overlapped in species presence/absence as follows: CRP and shortgrass prairie had a 47% overlap, CRP and dryland agriculture had a 50% overlap, and shortgrass prairie and dryland agriculture had a 52% overlap. Thirty-five species occurred in this subset ($n$ = 104 point counts in each habitat) of which 15 were species of conservation concern. Twenty-one species occurred on CRP, 26 species (74%) occurred on shortgrass prairie, and 21 species (60%) occurred on dryland agriculture. Seven species were observed only on shortgrass prairie including five species of high or moderate conservation concern. Four species were found only on CRP including one species of concern. Three species were found only on dryland agriculture including one species of concern.

## Discussion

A conservation value (*CV*) index is an alternative approach to evaluating and comparing the value of various habitat types relative to a given taxa. Traditionally, the conservation values of habitats are estimated using summary statistics such as abundance measures, species richness, or species diversity. A *CV* index compliments this traditional approach by weighting abundance measures with a predefined set of scores that reflect the conservation prioritization of each species. After previously comparing shortgrass prairie, CRP, and dryland agriculture using abundance measures in Study I, I applied a *CV* index to the data to further compare the three habitats. My findings indicate that shortgrass prairie and CRP have similar conservation values to birds breeding in the northern shortgrass prairie and that both have higher conservation values than dryland agriculture. I also found that shortgrass prairie and CRP are valuable to some different species, reflecting the findings from Study I. Furthermore, although all species were included in the analysis regardless of their rate of occurrence, the same ten species constituted the majority of the *CV* of each habitat – these, of course, were the most frequently occurring species.

Overall, both CRP and shortgrass prairie had more species of high and moderate concern that did dryland agriculture. The number of species of high concern was similar between CRP and shortgrass prairie and, considering only species of high concern, the same two species (Cassin's Sparrow and Lark Bunting) constituted the majority of the *CV* of both habitats. In other words, the species occurred at similar frequencies between the habitats, thus, contributing in similar amounts to the *CV*. Both Cassin's Sparrows and Lark Buntings will use a wide range of grassland habitats from short to moderate grass with sparse to frequent shrub cover (Ruth 2000, Dechant et al. 2003b). As for dryland agriculture, although Lark Buntings occurred at a similar frequency as on CRP and shortgrass prairie, Cassin's Sparrows occurred at far less on dryland agriculture. This explains, in part, the fewer number of species of high concern on dryland agriculture.

Conversely, the number of species of moderate concern was greater on CRP than on shortgrass prairie and, considering only species of moderate concern, different species constituted the majority of each habitat's *CV*. Most notably, Grasshopper Sparrows occurred at CRP point counts (42%) at nearly four times that of shortgrass prairie (11%). This disproportionably high frequency of Grasshopper Sparrows explains the higher the number of species of moderate concern occurring on CRP versus shortgrass prairie. Although Grasshopper Sparrow is a species of moderate concern, it is important to note that it is not a shortgrass prairie obligate species. Rather Grasshopper Sparrows occurs widely throughout the Great Plains with prominence in the mixed and tallgrass prairies. They prefer grass of intermediate height, moderately deep litter, and sparse woody vegetation (Dechant et al. 2003c).this species. The taller vegetation in CRP fields most likely accounts for its high frequency of Grasshopper Sparrows. Additionally, Lark Sparrows occurred at nearly three times the frequency on shortgrass prairie (11%) as on CRP (4%). Lark Sparrows will use short- and mixedgrass prairie with sparse litter and a shrub component (Dechant et al. 1999). Lark Sparrows occurred at the same frequency as Grasshopper Sparrows on shortgrass prairie; hence, they constituted the same proportion of the shortgrass prairie *CV*. As for dryland agriculture, Grasshopper Sparrows occurred far less frequently (14%) than on CRP (42%) but in similar frequency as on shortgrass prairie (11%). This difference may explain the fewer number of species of moderate concern on dryland agriculture versus CRP and the similar number between dryland agriculture and shortgrass prairie.

Species of low concern also contributed to the *CV*s of shortgrass prairie, CRP, and dryland (weight = 2) and were also the most frequently observed species (65%). Dryland agriculture had more species of low concern than either CRP or shortgrass prairie indicating that species of low concern contributed more to the dryland agriculture *CV* than to either the CRP or shortgrass prairie *CV*s. Horned Larks were the most frequently occurring species of low concern but occurred at much higher frequency in shortgrass prairie (50%) and dryland agriculture (65%) than in CRP (21%). Horned Larks use sparse vegetation with little to no shrub cover (Dinkins 2003), including fallow crop fields. The taller vegetation of CRP fields likely explains the relatively low frequency of this very abundant species on CRP. Western Meadowlarks were the second most frequently observed species occurring at 60% of CRP, 52% of shortgrass prairie, and 44% of dryland agriculture. Western Meadowlarks will use a variety of grass heights but prefer little to no woody cover (Dechant et al. 2003d). Thus, all three habitats may provide suitable habitat to this species.

In conclusion, I suggest that although the results indicate that CRP and shortgrass prairie have similar conservation values, the two habitats should not be considered surrogates. Unless a *CV* is evaluated in the context of its contributing species it may be a misleading indication of the habitats true conservation value. Most notably in the study was the disproportionate contribution of Grasshopper Sparrows to the CRP *CV* as compared to the shortgrass prairie *CV*. I suggest that CRP is providing conservation value to species that prefer moderate to tall grass and little to no shrub cover. Such habitat requirements do not characterize shortgrass prairie obligate species. Prescribing management activities on land in CRP, such as grazing, fire, or haying, to achieve habitat conditions more characteristic of shortgrass prairie may maximize benefits to shortgrass prairie obligate and associated species. Still, I do not suggest that CRP is not valuable to birds breeding in the shortgrass prairie. I remind the reader that the CRP *CV* was significantly greater than the dryland agriculture *CV*. Enrolling land in the CRP is a better alternative to leaving land in production when considering conservation of grassland birds.

## STUDY III: A COMPARISON OF BREEDING BIRD RESPONSE TO LOCAL AND LANDSCAPE FEATURES IN THE SHORTGRASS PRAIRIE

### Overview

The purpose of this study is to evaluate how shortgrass prairie bird species respond both to local variables (site-specific vegetation characteristics) and landscape variables (landcover composition) at varying spatial scales. Here I examine bird use of shortgrass prairie habitat alone, not considering CRP or dryland agriculture. I ask several questions: (1) Do species respond to local vegetation characteristics and, if so, what vegetation characteristics do the species respond to, (2) do species respond to variables in the surrounding landscape and, if so, what variables to they respond to, (3) do species respond to landscape variables differently at varying spatial scales, (4) at which spatial scales are landscape variables most effective in predicting species occurrence, and (5) are local variables, landscape variables, or a combination of local and landscape variables more effective in predicting species occurrence?

*Methods*

Unlike the previous two studies, I did not analyze data collected in dryland agriculture or CRP in this study because it would not contribute to the research objectives. Instead, I analyzed only data collected in shortgrass prairie habitat. Furthermore, I included data from only one of the three point counts conducted at each section of shortgrass prairie because the three surveys cannot be considered independent.

Therefore, I randomly selected one point count per section to contribute to the analysis. Each of these point counts was surveyed once in 2003 and once in 2004, giving me a grand total of 3,200 point counts pooled across years. Each point count included in the analysis was spatially referenced using UTM coordinates to create a spatial layer of the point counts. For species whose geographic range did not encompass the entire study area, I created subsets of the data that included only sections within each species' range. I delineated a species' range by determining minimum and maximum latitude and longitude based an 8km buffer of the species occurrence (according to the Section Survey data). I validated the ranges by comparing them to published species range maps.

I filtered the Section Survey data to include only singing males observed within 150m of the point count location, excluding birds flying over. Non-songbirds were included whether detected visually or aurally. Raptors, swallows, and nighthawks were included if soaring over the sections being surveyed. I also transformed the count data into presence/absence data and analyzed only species with ≥ 25observations. Bird populations can fluctuate significantly with year, so I tested for difference in occurrence between years 2003 and 2004 for each species using McNemar's test of agreement (SAS, PROC CORR). If the test indicated a significant difference ($P < 0.05$) in occurrence between years for a species, I conducted separate analyses by year for that species (if $n \geq 25$). Otherwise, I pooled data across years.

<u>Landcover Data</u>

I used GAP Analysis Program raster digital data from each of the four states to create a continuous landcover layer for the study area. For Nebraska, Kansas, and Oklahoma I used the state specific GAP datasets (University of Nebraska 2003, Kansas

Applied Remote Sensing Program 2002, Oklahoma State University 2001). Each of these was built from Landsat Thematic Mapper (TM) imagery with collection dates ranging from 1991 to 2000. For Colorado, I used a regional GAP dataset called the Southwestern Regional GAP Analysis Project (Utah State University 2004). This layer is built from the classification of Landsat Enhanced Thematic Mapper (ETM+) imagery (very similar to TM imagery) collected in 2000. All four datasets have a 30-m spatial resolution, however, the thematic resolution differed among states. Therefore, I reclassified the landcovers into eight general classes: agricultural land, grassland, shrubland, woodland, wetland, developed, water, and barren (including sand and outcrops). CRP fields were not classified in any but the Kansas GAP layer; therefore, I reclassified CRP as grassland. Once each dataset was reclassified, I created a mosaic of the state layers to produce one continuous landcover layer that encompassed the entire study area. This layer was checked for fluidity across state boundaries and compared against original raster datasets.

Local Variables

I used the vegetation data collected through the Section Survey as local habitat variables with which to analyze bird response and, subsequently, to compare any such response to bird response to landscape variables. I analyzed two local variables: GrassHeight (percent of grass >15cm in height within 150m of the point count) and ShrubCover (percent of total shrub cover within 150m of the point count). GrassHeight is classified into four categories: <25%, 26-50%, 51-75%, and >75% of grass >15cm in height. ShrubCover is also classified into four categories: <1%, 1-3%, 3-10%, and >10% shrub cover.

Landscape Variables

I identified nine landscape variables with which to measure bird response. They include the percent area of each of the eight the landcover classes (AG – agricultural land, BA – barren, DV – developed, GR – grassland, SH – shrubland, WA – water, WE – wetland, and WO – woodland) and the number of landcover patches (NUMP) within a fixed radius of each point count. The size of the radius (300m-, 600m-, 1200m-, or 2400m-radius) defined the four spatial scales at which I evaluated bird response to landscape variables. The 300m, 600m, 1200m, and 2400m radius buffers are equivalent to about 28ha, 113ha, 452ha, and 1,180ha, respectively. I defined these spatial scales by superimposing circular buffers on the landscape surrounding each point count, based on these radii (Figure 7). I used ArcMap 9.1 (ESRI 2005) to create the buffers such that each point count had four nested buffers, one of each spatial scale. To calculate the percent area of each landcover class within the buffers, I first clipped the landcover layer with the buffers and then calculated the area of each resulting landcover polygon using the Patch Analyst 3.1 extension (Rempel 2004) in ArcView 3.3 (ESRI 1992). Additionally, I tested for correlations between landscape variables and also between local variables and landscape variables (SAS, PROC CORR).

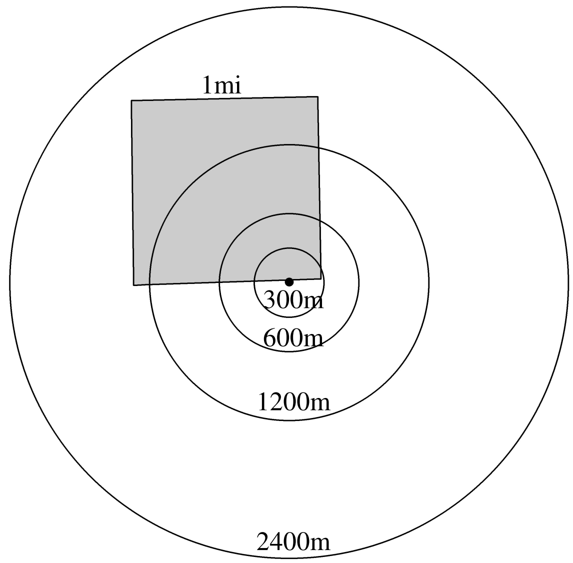


Figure 7. Example of the four buffer sizes (circles) surrounding a point count (black dot) at a section (gray square, $1mi^2$).

Models

I used logistic regression to model and compare bird species response to local variables, landscape variables, and a combination of local and landscape variables. To perform these regressions, I used the PROC LOGISITIC procedure in SAS version 9.1 (SAS Institute 2002). To evaluate resulting models, I adopted the model selection process presented by Cunningham and Johnson (2006). I used their approach because it addresses potential concerns of spatial autocorrelation among point count locations and multicollinearity among the nested explanatory variables (i.e., the 300-m scale landscape variables are nested within the 600-m scale variables and so on). In this study, spatial autocorrelation can be described as the similarity in habitat and bird communities among closely located point counts. Collecting data at closely located point counts can lead to repeatedly measuring the same habitat conditions and bird communities. This can lead to underestimation of error in models and, thus, increases the chance of falsely rejecting a true null hypothesis (Cunningham and Johnson 2006). I did not depend on significance tests in comparing models. Rather, I ranked models using the mutlimodel inference approach of Buckland et al (1997), allowing for multiple models to have competitive explanatory value. I present P-values of the models for the reader but, again, they were not used in the analysis. To address the issue of multicollinearity, I ran separate models for each spatial scale and ranked them to compare relative importance of landscape variables in predicting occurrence of the species at the different scales (Cunningham and Johnson 2006).

To rank models, I constructed three sets of models, a local set, a landscape set (for each spatial scale), and a combined set (including local and landscape variables for each spatial scale). For each set, I evaluated the models using the information-theoretic approach of Burnham and Anderson (2002) by identifying the most competitive models based on relative values of the Akaike Information Criterion (AIC) statistic. The best-fitting model had the lowest AIC. I considered competitive models those whose ΔAIC was < 2 units of the lowest AIC (Burnham and Anderson 2002). ΔAIC is defined as the numeric difference between the AIC of a given model and the lowest AIC. I then calculated Akaike weights for each of the competitive models in a set where the Akaike weight was equal to exp(-0.5ΔAIC). I used these weights to judge the influence of individual explanatory variables that may not appear in the best-fitting model by summing the weights of models in which each variable appeared. For example, if a given variable appeared in all competitive models of a set, its weight would be 100, and, conversely, if it did not appear in any of the competitive models, its weight would equal zero.

The local model set included a total of four models: the null model, a single-variable equation for each local variable (GrassHeight and ShrubCover), and a two-variable equation for the combination of the local variables. The landscape model set for each spatial scale included a minimum of 45 models including: a single-variable equation for each of the nine landscape variables and a two-variable equation for each possible two-way combination of landscape variables. I included all landscape variables and all possible two-way combinations of these variables in the model sets because I considered this an exploratory analysis. In other words, I did not to construct *a priori* hypothesis as to which landscape variables may influence habitat use of individual species because of the lack of knowledge about the effects of landscape features and spatial scale on individual shortgrass prairie bird species habitat selection. If multiple two-variable models were competitive, I added a three-variable equation containing the three variables with the most weight. Likewise, if multiple three-variable models were competitive, I added a four-variable model containing the four variables with the most weight. The combined model set included the variables from the best-fitting and competitive local and landscape models. If the null model for either the local or landscape model sets was the best-fitting model without competition, then a combined model was not constructed.

*Results*

Eighteen species had a sufficient number of observations for analysis ($n \geq 25$, Table 5). Occurrence was significantly different between years for two species, Lark

Sparrow ($P = 0.0214$) and Western Meadowlark ($P < 0.0001$). Both species had sufficient number of observations per year; therefore, I conducted analyses separately by year for these species. For all other species, I pooled data across years. I created subsets of data for two species (McCown's Longspur and Northern Mockingbird) because their ranges did not encompass the entire study area. The McCown's Longspur subset included 293 point counts and the Northern Mockingbird subset included 963 point counts. I analyzed the other species using all 1,600 point counts.

GrassHeight at the 3,200 point counts (1,600 pooled over the two years) was classified as follows: 870 had <25% grass taller than 15cm, 699 had 26-50%, 648 had 51-75%, and 983 had >75% grass taller than 15cm. ShrubCover at the 3,200 point counts was classified as follows: 2,010 had <1% shrub cover, 660 had 1-3%, 371 had 3-10%, and 159 had >10% shrub cover. GrassHeight and ShrubCover at the point counts were not correlated ($r = 0.04$). ShrubCover showed a weak positive correlation to the amount of shrubland (SH) in the surrounding landscape at all four spatial scales ($0.32 \geq r \leq 0.34$) but there were no other correlations between local and landscape variables.

Grassland was the dominant landcover type at all spatial scales (72% - 76%) followed by agricultural land (14% - 18%), shrubland (8%), woodland (1%, Table 6). All other landcover types accounted for <1% of buffer area. Several landscape variables showed correlations that held consistent across the four spatial scales. The area of grassland in the buffer was inversely correlated to the area of agriculture ($-0.75 \geq r \leq -0.72$ across spatial scales) and shrubland ($-0.63 \geq r \leq -0.61$). Area of grassland showed a weak negative correlation to the number of landcover patches in the surrounding landscape ($-0.38 \geq r \leq -0.35$) while area of shrubland showed a weak positive correlated the number of patches in the buffer ($0.31 \geq r \leq 0.37$).

Table 5. For each species, total number of observations, best local model, P-value of model, and frequency of occurrence by GrassHeight and ShrubCover categories. GrassHeight category refers to the percent of grass within 150m of the point count that was >15cm in height. ShrubCover category refers to the total percent of shrub cover within the 150m search radius of the point count.

| Species | *n* | Best Local Model | | P | Frequency by GrassHeight Category | | | | Frequency by ShrubCover Category | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | <25% (*n*=870) | 26-50% (*n*=699) | 51-75% (*n*=648) | >75% (*n*=983) | <1% (*n*=2,010) | 1-3% (*n*=660) | 3-10% (*n*=371) | >10% (*n*=159) |
| Barn Swallow | 75 | GrassHeight | | 0.0234 | 2 | 2 | 1 | 4 | 3 | 2 | 2 | 3 |
| Brown-headed Cowbird | 63 | ShrubCover | | 0.0273 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 2 |
| Burrowing Owl | 34 | GrassHeight | | 0.0006 | 2 | 1 | 1 | 0 | 1 | 1 | 2 | 0 |
| Cassin's Sparrow | 407 | ShrubCover | | <0.0001 | 10 | 14 | 15 | 13 | 6 | 19 | 34 | 28 |
| Cliff Swallow | 97 | Null | | | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 4 |
| Common Nighthawk | 72 | ShrubCover | | 0.0023 | 2 | 2 | 2 | 2 | 2 | 3 | 5 | 3 |
| Grasshopper Sparrow | 312 | GrassHeight | | <0.0001 | 2 | 8 | 9 | 18 | 10 | 8 | 9 | 11 |
| Horned Lark | 1,212 | GrassHeight | ShrubCover | <0.0001 | 45 | 36 | 36 | 33 | 40 | 38 | 33 | 20 |
| Lark Bunting | 889 | GrassHeight | ShrubCover | 0.0003 | 31 | 30 | 26 | 24 | 29 | 23 | 30 | 25 |
| Lark Sparrow 2003 [a] | 84 | GrassHeight | ShrubCover | <0.0001 | 2 | 5 | 6 | 7 | 3 | 9 | 9 | 7 |
| Lark Sparrow 2004 | 114 | GrassHeight | ShrubCover | <0.0001 | 4 | 8 | 8 | 9 | 5 | 7 | 18 | 11 |
| Loggerhead Shrike | 42 | Null | | | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| McCown's Longspur* | 31 | GrassHeight | | 0.0252 | 1 | 1 | 4 | 5 | 6 | 3 | 3 | 0 |
| Mourning Dove | 494 | GrassHeight | ShrubCover | <0.0001 | 1 | 14 | 17 | 19 | 14 | 16 | 19 | 22 |
| Northern Mockingbird* | 30 | ShrubCover | | 0.0065 | 2 | 1 | 2 | 1 | 1 | 2 | 3 | 3 |
| Ring-necked Pheasant | 28 | Null | | | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| Red-winged Blackbird | 54 | Null | | | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 1 |
| Western Kingbird | 38 | ShrubCover | | 0.0137 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 |
| Western Meadowlark 2003 | 774 | GrassHeight | | <0.0001 | 35 | 49 | 49 | 51 | 48 | 46 | 46 | 33 |
| Western Meadowlark 2004 | 590 | GrassHeight | | <0.0001 | 27 | 42 | 41 | 43 | 37 | 39 | 34 | 36 |

[a] Year after species name indicates it was analyzed separately by year because occurrence was significantly different between years. In these cases, the number of point counts in each GrassHeight and ShrubCover category is roughly half of the listed value.

* A subset of data was used because their geographic range was restricted to a portion of the study area (see *Methods*).

Table 6. Mean percent area and standard deviation (sd) of the eight landcover classes and number of landcover patches in the buffers of the 1,600 point counts, listed by spatial scale. Percent area of each landcover class and number of landcover patches in each buffer are the landscape variables.

| Landscape Variable | Abbrev. | 300m Buffers Mean (%)* | 300m Buffers sd | 600m Buffers Mean (%)* | 600m Buffers sd | 1200m Buffers Mean (%)* | 1200m Buffers sd | 2400m Buffers Mean (%)* | 2400m Buffers sd |
|---|---|---|---|---|---|---|---|---|---|
| Agriculture | AG | 14 | 22 | 14 | 21 | 16 | 19 | 18 | 19 |
| Barren | BA | <1 | 3 | <1 | 3 | <1 | 2 | <1 | 2 |
| Developed | DV | <1 | 2 | <1 | 1 | <1 | 1 | <1 | 1 |
| Grassland | GR | 76 | 28 | 76 | 27 | 75 | 25 | 72 | 24 |
| Shrubland | SH | 8 | 19 | 8 | 19 | 8 | 17 | 8 | 16 |
| Water | WA | <1 | 1 | <1 | 1 | <1 | 1 | <1 | 2 |
| Wetland | WE | <1 | 2 | <1 | 1 | <1 | 1 | <1 | 1 |
| Woodland | WO | 1 | 3 | 1 | 2 | 1 | 2 | 1 | 3 |
| Number of patches* | NUMP | 7 | 7 | 18 | 18 | 58 | 57 | 216 | 188 |

* Units for number of patches are counts, not percentages like the landcover types.

Local Models

The null model was the best-fitting local model for four species (Cliff Swallow, Loggerhead Shrike, Ring-necked Pheasant, and Red-winged Blackbird) suggesting that these species did not respond to differences in grass height or amount of shrub cover at the local scale (Table 5). Five species responded to GrassHeight but not ShrubCover including Barn Swallow, Burrowing Owl, Grasshopper Sparrow, McCown's Longspur, and Western Meadowlark. Mean occurrence of Barn Swallow ($\bar{x}$ = 0.04), Grasshopper Sparrow ($\bar{x}$ = 0.18), and Western Meadowlark ($\bar{x}$ = 0.51 in 2003; $\bar{x}$ = 0.43 in 2004) was greatest where > 75% of the grass was taller than 15cm. Conversely, mean occurrence of Burrowing Owl ($\bar{x}$ = 0.02) and McCown's Longspur ($\bar{x}$ = 0.09) was greatest where <25% of the grass was taller than 15cm. Additionally, five species responded differences in ShrubCover but not GrassHeight including Brown-headed Cowbird, Cassin's Sparrow, Common Nighthawk, Northern Mockingbird, and Western Kingbird. Mean occurrence of Brown-headed Cowbird ($\bar{x}$ = 0.04), Cassin's Sparrow ($\bar{x}$ = 0.34), and Common

Nighthawk ($\bar{x}$ = 0.05) was greatest where there was 3-10% shrub cover. Mean occurrence of Northern Mockingbird was greatest where there was > 3% shrub cover ($\bar{x}$ = 0.03). Mean occurrence of Western Kingbird was greatest where there was 1-3% shrub cover ($\bar{x}$ = 0.02).

Four species responded to a combination of GrassHeight and ShrubCover categories including Horned Lark, Lark Bunting, Lark Sparrow, and Mourning Dove. Mean occurrence of Horned Lark was greatest where < 25% of the grass was taller than 15cm and where there was <1% shrub cover ($\bar{x}$ = 0.45, $\bar{x}$ = 0.40). Mean occurrence of Lark Bunting was greatest where < 25% of the grass was taller than 15cm and where there was 3-10% shrub cover ($\bar{x}$ = 0.31, $\bar{x}$ = 0.30). In both years, mean occurrence of Lark Sparrow was greatest where > 75% of the grass was taller than 15cm ($\bar{x}$ = 0.07 in 2003; $\bar{x}$ = 0.09 in 2004) and where there was 3-10 % shrub cover ($\bar{x}$ = 0.09 in 2003; $\bar{x}$ = 0.18 in 2004). Finally, mean occurrence of Mourning Dove was greatest where >75% of the grass was taller than 15cm ($\bar{x}$ = 0.19) and where there was >10% shrub cover ($\bar{x}$ = 0.22).

Landscape Models

Ten of the 18 species responded most to landscape variables at the largest spatial scale, the 2400m radius buffer (Table 7). Four species responded most at the 1200m scale, two species at the 600m scale, and three species at the 300m scale (Table 7). However, for some species, response was comparable at multiple scales because the best-fitting models were competitive ($\Delta$AIC $\leq$ 2.0). For example, Barn Swallows, Burrowing Owls, Cliff Swallows, Morning Doves, and Red-winged Blackbirds, responded comparably at the two largest spatial scales as their best-fitting 1200m and 2400m models were competitive ($0.1 \geq \Delta AIC \leq 1.8$). Likewise, response of Loggerhead Shrikes was comparable at the two smallest spatial scales as the best-fitting 300m and 600m models were competitive ($\Delta AIC \leq 0.7$). Ring-necked Pheasants responded comparably to landscape variables at three spatial scales, 600m, 1200m, and 2400m ($\Delta AIC \leq 0.5$).

Three species responded to the same landscape variables at all spatial scales while 15 species responded to different landscape variables at different scales. For example, Horned Larks responded positively to the amount of grassland in the surrounding landscape and negatively to the amount of woodland at all spatial scales. Furthermore, those two landscape variables were the only variables that occurred in the competitive models (Akaike weight = 100). Similarly, Grasshopper Sparrows responded positively to the amount of agricultural land and positively to the number of patches in the surrounding landscape at all spatial scales. Again, these two variables were the only variables in the competitive models. Ring-necked Pheasants responded negatively to the amount grassland in the surrounding landscape at all spatial scales and, at all scales, amount of grassland was the only weighted variable.

Table 7. The best landscape model for each species by buffer size. For each species, the model with ΔAIC=0 is considered the best overall landscape model; however, models with ΔAIC <2 are considered competitive. The variable weights indicate the influence of explanatory variables that appeared in all competitive models and signs indicate the direction of the influence on the species. Landscape variables include the total number of landcover patches in the buffer (NUMP) and the percent area of each landcover class (*n* = 8) in the buffer, abbreviated as follows: AG – agricultural land, BA – barren, DV – developed, GR – grassland, SH – shrubland, WA – water, WE – wetland, and WO – woodland.

| | | Scale | Best Landscape | | | Weights and Signs of Variables in Competitive Landscape Models | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | *n* | (m) | Model | Δ AIC | P | AG | BA | DV | GR | SH | WA | WE | WO | NUMP |
| Barn Swallow | 75 | 300 | AG + NUMP | 8.7 | 0.0003 | 100 + | | | | | | | | 100 + |
| | | 600 | AG + NUMP | 7.3 | 0.0002 | 100 + | | | | | | | | 100 + |
| | | 1200 | AG + NUMP – DV | 1.8 | <0.0001 | 100 + | | 100 - | | | | | | 100 + |
| | | **2400** | **AG + NUMP** | **0.0** | **<0.0001** | **100 +** | | | | | | | | **100 +** |
| Brown-headed Cowbird | 63 | **300** | **NUMP + WO + WE +SH** | **0.0** | **<0.0001** | | | | | **100 +** | | **73 +** | **100 +** | **100 +** |
| | | 600 | NUMP + WO + SH | 5.7 | <0.0001 | | | | 49 - | 80 + | | | 80 + | 100 + |
| | | 1200 | NUMP - GR | 9.4 | <0.0001 | | | | 100 - | | | | | 100 + |
| | | 2400 | NUMP - GR | 9.4 | <0.0001 | | | | 100 - | | | | | 100 + |
| Burrowing Owl | 34 | 300 | NULL | 9.9 | | | | | | | | | | |
| | | 600 | - GR - WA - DV | 5.3 | 0.1548 | | | 55 - | 100 - | | 79 - | 20 - | | |
| | | 1200 | - GR - WA - DV | 0.3 | 0.0561 | | | 53 - | 100 - | | 100 - | 14 - | | |
| | | **2400** | **- DV + AG** | **0.0** | **0.0107** | **59 +** | | **100 -** | **55 -** | | **39 -** | | | |
| Cassin's Sparrow | 407 | 300 | SH - NUMP | 57.1 | <0.0001 | | | | | 100 + | | | | 100 - |
| | | 600 | SH - NUMP | 40.1 | <0.0001 | | | | | 100 + | | | | 100 - |
| | | **1200** | **SH - NUMP - BA** | **0.0** | **<0.0001** | | **100 -** | | | **100 +** | | | | **100 -** |
| | | 2400 | SH - NUMP | 3.7 | <0.0001 | | | | | 100 + | | | | 100 - |
| Cliff Swallow | 97 | 300 | WE + GR + NUMP | 9.1 | 0.0159 | | | | 100 + | | | 79 + | | 66 + |
| | | 600 | WE + GR | 6.2 | 0.0018 | | | | 67 + | 29 - | | 100 + | | |
| | | 1200 | WE - SH + WO | 0.7 | <0.0001 | | | 34 + | | 57 - | | 100 + | 44 + | |
| | | **2400** | **WE - SH + DV** | **0.0** | **<0.0001** | | | **57 +** | | **100 -** | | **100 +** | | |

| Species | *n* | Scale (m) | Best Landscape Model | Δ AIC | P | Weights and Signs of Variables in Competitive Landscape Models | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | AG | BA | DV | GR | SH | WA | WE | WO | NUMP |
| Common Nighthawk | 72 | 300 | SH + WO - BA | 2.6 | <0.0001 | | 100 - | | | 100 + | | | 100 + | |
| | | **600** | **SH + WO - BA** | **0.0** | **<0.0001** | | **100 -** | | | **100 +** | | | **100 +** | |
| | | 1200 | SH + WO - BA | 5.7 | <0.0001 | | 100 - | | | 100 + | | | 100 + | |
| | | 2400 | SH - GR | 11.3 | <0.0001 | 71 - | | | 84 - | 61 + | | | | |
| Grasshopper Sparrow | 312 | 300 | AG + NUMP | 39.6 | <0.0001 | 100 + | | | | | | | | 100 + |
| | | 600 | AG + NUMP | 31.8 | <0.0001 | 100 + | | | | | | | | 100 + |
| | | 1200 | AG + NUMP | 17.6 | <0.0001 | 100 + | | | | | | | | 100 + |
| | | **2400** | **AG + NUMP** | **0.0** | **<0.0001** | **100 +** | | | | | | | | **100 +** |
| Horned Lark | 1,212 | 300 | GR - WO | 28.1 | <0.0001 | | | | 100 + | | | | 100 - | |
| | | 600 | GR - WO | 5.7 | <0.0001 | | | | 100 + | | | | 100 - | |
| | | 1200 | GR - WO | 4.5 | <0.0001 | | | | 100 + | | | | 100 - | |
| | | **2400** | **GR - WO** | **0.0** | **<0.0001** | | | | **100 +** | | | | **100 -** | |
| Lark Bunting | 889 | 300 | - WO - SH | 44.8 | <0.0001 | | | | | 100 - | | | 100 - | |
| | | 600 | - WO - SH | 36.6 | <0.0001 | | | | | 69 - | | | 100 - | 31 - |
| | | 1200 | - WO - NUMP | 22.8 | <0.0001 | | | | | 48 - | | | 100 - | 52 - |
| | | **2400** | **- WO - NUMP** | **0.0** | **<0.0001** | | | | | | | | **100 -** | **100 -** |
| Lark Sparrow 2003 [a] | 84 | 300 | - GR + WO - DV | 19.2 | 0.0013 | | | 80 - | 100 - | | | | 69 + | |
| | | 600 | - GR + WO | 12.0 | <0.0001 | | | | 100 - | 35 + | | | 100 + | |
| | | 1200 | - GR + WO | 7.8 | <0.0001 | | | | 81 - | 55 + | | | 100 + | |
| | | **2400** | **- GR + WO** | **0.0** | **<0.0001** | | | | **100 -** | | | | **100 +** | |
| Lark Sparrow 2004 | 114 | 300 | NUMP - AG | 24.4 | <0.0001 | 100 - | | | | | | | | 100 + |
| | | 600 | NUMP + WO | 12.8 | <0.0001 | | | | | | | | 100 + | 100 + |
| | | 1200 | NUMP + WO + SH | 10.4 | <0.0001 | 32 - | | | | 68 + | | | 100 + | 100 + |
| | | **2400** | **NUMP + WO - AG** | **0.0** | **<0.0001** | **71 -** | | | | | | | **100 +** | **100 +** |
| Loggerhead Shrike | 42 | **300** | **WO + WE** | **0.0** | **0.0018** | | | | | | **48 -** | **64 +** | **100 +** | |
| | | 600 | WO | 0.7 | 0.0026 | | | | | | | 43 + | 100 + | |
| | | 1200 | WE - DV | 3.0 | 0.0733 | | | 62 - | | | | 100 + | | |
| | | 2400 | NULL | 4.2 | | | | | | | | | | |

| Species | *n* | Scale (m) | Best Landscape Model | Δ AIC | P | Weights and Signs of Variables in Competitive Landscape Models AG | BA | DV | GR | SH | WA | WE | WO | NUMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| McCown's Longspur* | 31 | **300** | **- NUMP - AG** | **0.0** | **0.0002** | **100 -** | | | | | | | | **100 -** |
| | | 600 | - NUMP - AG | 7.6 | 0.0006 | 27 - | | | | 14 - | 12 - | 19 - | 11 - | 100 - |
| | | 1200 | - NUMP - AG - BA | 7.8 | 0.0024 | 100 - | 37 - | | | | | | | 100 - |
| | | 2400 | - NUMP - AG - BA | 6.1 | 0.0015 | 75 - | 46 - | | | | 25 + | | | 100 - |
| Mourning Dove | 494 | 300 | NUMP - GR + WO | 31.4 | <0.0001 | | | | 100 - | | | | 100 + | 100 + |
| | | 600 | NUMP - GR + WO | 12.7 | <0.0001 | | | | 100 - | | | | 100 + | 100 + |
| | | 1200 | NUMP - GR + WO | 0.2 | <0.0001 | | | | 100 - | | | | 100 + | 100 + |
| | | **2400** | **NUMP - GR** | **0.0** | **<0.0001** | | | | **100 -** | | | | | **100 +** |
| Northern Mockingbird* | 30 | 300 | WA - AG + SH | 9.9 | 0.0007 | 100 - | | | | 100 + | 100 + | | | |
| | | **600** | **WA - AG + SH** | **0.0** | **<0.0001** | **100 -** | | | | **100 +** | **100 +** | | | |
| | | 1200 | WA - AG + SH | 10.2 | 0.0006 | 79 - | | | | 71 + | 100 + | | | |
| | | 2400 | WA - AG | 12.6 | 0.0035 | 100 - | | | | | 100 + | | | |
| Ring-necked Pheasant | 28 | 300 | - GR | 7.4 | <0.0001 | | | | 100 - | | | | | |
| | | 600 | - GR | 0.5 | <0.0001 | | | | 100 - | | | | | |
| | | **1200** | **- GR** | **0.0** | **<0.0001** | | | | **100 -** | | | | | |
| | | 2400 | - GR | 0.4 | <0.0001 | | | | 100 - | | | | | |
| Red-winged Blackbird | 54 | 300 | AG + WE - BA | 8.8 | <0.0001 | 86 + | 59 - | | 14 - | 14 - | | 65 + | | |
| | | 600 | AG + WE + DV | 6.6 | <0.0001 | 100 + | | 57 + | 23 - | 9 - | | 62 + | | |
| | | **1200** | **AG + DV** | **0.0** | **<0.0001** | **100 +** | | **100 +** | | | | | | |
| | | 2400 | AG + DV | 0.1 | <0.0001 | 100 + | | 100 + | | | | | | |
| Western Kingbird | 38 | 300 | SH + WE + WO | 8.3 | <0.0001 | | | | 26 - | 74 + | | 100 + | 72 + | |
| | | 600 | SH + WE + WO | 7.0 | <0.0001 | | | | | 100 + | | 100 + | 70 + | |
| | | 1200 | SH + WA | 5.2 | <0.0001 | | | | | 100 + | 100 + | | | |
| | | **2400** | **SH - AG - GR** | **0.0** | **<0.0001** | **62 -** | | | **62 -** | **100 +** | **38 +** | | **38 +** | |
| Western Meadowlark 2003 | 774 | 300 | - GR | 12.8 | <0.0001 | | | | 100 - | | | | | |
| | | 600 | - GR + BA | 9.7 | <0.0001 | | 74 + | | 100 - | | | | | |
| | | 1200 | - GR + BA | 6.8 | <0.0001 | | 100 + | | 100 - | | | | | |
| | | **2400** | **- GR + BA + WE** | **0.0** | **<0.0001** | | **100 +** | | **100 -** | | | **100 +** | | |

| Species | *n* | Scale (m) | Best Landscape Model | Δ AIC | P | Weights and Signs of Variables in Competitive Landscape Models | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | AG | BA | DV | GR | SH | WA | WE | WO | NUMP |
| Western | 590 | 300 | WO + DV | 6.0 | 0.0046 | | | 100 + | | | | | 100 + | |
| Meadowlark | | 600 | WE + DV + NUMP | 8.0 | 0.0120 | | | 90 + | | | | 69 + | 36 + | 65 + |
| 2004 | | **1200** | **WE - WA** | **0.0** | **0.0010** | | | | | | **100 -** | **100 +** | | |
| | | 2400 | WE - WA + WO | 3.0 | 0.0019 | | | | | | 70 - | 100 + | 100 + | |

[a] Year after a species name indicates that it was analyzed separately by year because occurrence was determined to be significantly different between years.
* A subset of point count data was used to model these species because their geographic range was restricted to a portion of the study area (see *Methods*).

Several species responded consistently to the same landscape variable(s) across all spatial scales with the exception of one additional variable ($n$ = 5, Table 7). For example, Barn Swallows responded positively to both the amount of agricultural land and the number of patches in the surrounding landscape at all spatial scales; however, it also responded negatively to the amount of developed land at the 1200m scale. Similarly, Cassin's Sparrows responded positively to the amount of shrubland and negatively to the number of patches in the landscape at all spatial scale; however, they also responded negatively to the amount of barren land at the 1200m scale. McCown's Longspurs responded negatively to both the number of patches and the amount of agricultural land at all scales; however, at the 1200m and 2400m scales, they also responded negatively to the amount of barren land. Mourning Doves responded positively to the number of patches, negatively to the amount of grassland, and positively to the amount of woodland at all scales except at the 2400m scale. At this largest spatial scale, Mourning Doves did not show a response to the amount of woodland (only number of patches and amount of grassland). Northern Mockingbirds responded positively to both the amount of water and shrubland and negatively to the amount of agricultural land at all scales except at the 2400m scale. At this largest scale, Northern Mockingbirds did not show a response to the amount of shrubland in the surrounding landscape (only water and agricultural land).

Four species responded consistently to just one landscape variable across all spatial scales while other influential landscape variables changed by scale (Table 7). For example, Brown-headed Cowbirds responded positively to the number of patches in the surrounding landscape at all four spatial scales and that variable had an Akaike weight = 100 at all scales. However, in addition to the number of patches, Brown-headed

Cowbirds also responded positively to woodland, wetland, and shrubland at the two smallest scales. In contrast, at the two largest scales, the species responded only to the number of patches and amount of grassland (negatively). Similarly, Cliff Swallows responded positively to the amount of wetland in the surrounding landscape at all spatial scales; however, other influential landscape variables changed at every scale (Table 7). Cliff Swallows responded positively to the amount of grassland at the 300m and 600m scales while they responded negatively to shrubland at the 1200m and 2400m scales. In addition, the number of patches, and the amount of woodland and developed land also contributed to best-fitting models at different scales. Lark Buntings responded negatively to woodland at all scales. In addition, they responded negatively to shrubland at the 300m and 600m scales and negatively to the number of patches at the 1200m and 2400m scales. Red-winged Blackbirds responded positively to the amount of agricultural land at all scales but they also responded positively to wetland at the 300m and 600m scales and positively to developed land at the 600m, 1200m , and 2400m scales. Western Kingbirds responded positively to shrubland at all scales. They also responded positively to wetland and woodland at the 300m and 600m scales, positively to water at the 1200m scale, and negatively to agricultural land and grassland at the 2400m scale. Common Nighthawks responded positively to shrubland at all spatial scales. However, at the 300m 600m, and 1200m scales, this species also responded positively to woodland and negatively to barren land while, at the 2400m scale, this species responded negatively to grassland.

For two species, Burrowing Owl and Loggerhead Shrike, the null model was the best-fitting model at one of the four spatial scales (Table 7). Burrowing Owl did not show a response to any landscape variables at the smallest spatial scale (300m). However, Burrowing Owls did show a negative response to developed land at all other spatial scales and this variable was heavily weighted in all best-fitting models (Akaike weight > 50), being the most heavily weighted in the 2400m scale model set (Akaike weight = 100). Yet, grassland, to which Burrowing Owls responded negatively, was the most heavily weighted variable at the 600m and 1200m scales. Similarly, Loggerhead Shrikes did not show a significant response to any landscape variables at the largest spatial scale (2400m). Additionally, its best-fitting 1200m model was competitive ($\Delta$AIC = 1.2) with the 2400m null model suggesting that neither model is more effective in predicting Loggerhead Shrike occurrence. Yet Loggerhead Shrikes did respond positively to woodland at the two smallest spatial scales and neither of the larger scale models were competitive ($\Delta\text{AIC} \geq 3.0$).

Landscape models for Lark Sparrow and Western Meadowlark were run separately for each year and neither species showed a consistent response to landscape variables across years (i.e., the best-fitting models were different between years). For example, Lark Sparrows responded negatively to grassland and positively to woodland at all spatial scales in 2003 (Table 7). In 2004, Lark Sparrows responded positively to the number of patches in the landscape across all spatial scales and positively to woodland at the 600m, 1200m, and 2400m scales. However, the amount of grassland in the buffers showed a weak inverse correlation to number of patches at all spatial scales ($-0.38 \geq r \leq -0.35$), suggesting that the two landscape variables may be indicative of each other. Similarly, in 2003, Western Meadowlarks responded negatively to grassland at all spatial scales and positively to the amount of barren land at the 600m, 1200m, and 2400m scales.

In 2004, this species responded positively to woodland and developed land at the smallest spatial scale, and positively to wetland at the 600m, 1200m, and 2400m scales (with varying additional influence from water, number of patches, and woodland, Table 7). None of these influential landscape variables showed correlations.

Local versus Landscape Models

When comparing the best-fitting local and landscape models for each species, the local model was the overall best-fitting model for four species including: Burrowing Owl, Cassin's Sparrow, Grasshopper Sparrow, and Western Meadowlark 2004 (Table 8). Landscape models were the overall best-fitting model for all other species expect Western Meadowlark (2003) and Lark Sparrow (2003 and 2004). The best-fitting landscape model at all four spatial scales was a better fit than the local model for these species (again, with the exception of Western Meadowlark 2003 and Lark Sparrow).

Based on 2003 data for Western Meadowlark, the best-fitting local model fit better than the 300m and 600m landscape models ($\Delta$AIC > 2.0) but not the 1200m or 2400m models ($\Delta$AIC < 2.0, Table 8). Similarly, based on 2003 data, the best-fitting local model for Lark Sparrow was a better fit than the three smallest scale landscape models but the 2400m scale model fit better than the local model. Based on 2004 data, the 600m, 1200m, and 2400m landscape models for Lark Sparrow were all better fits than the best-fitting local model. When considering the 300m scale, the local model was the better fit without competition.

Combined Models

Combining the best-fitting local and landscape models at each scale produced the best-fitting overall model for 11 species (Table 8). For all but two of these species

(Burrowing Owl and Cassin's Sparrow), the best-fitting combined model occurred at the same spatial scale as did the best-fitting landscape model. Although the local model fit better than all the landscape models for Burrowing Owl, Cassin's Sparrow, Grasshopper Sparrow, and Western Meadowlark (2004), the combined model for each of these species was a better fit than the local model by itself (129.4 ≤ ΔAIC ≥ 11.0). No local model for any species was competitive with their respective combined model (129.4 ≤ ΔAIC ≥ 4.2).

Combining the best-fitting local and landscape models did not always result in better fitting models. A landscape model was the overall best-fitting model for three species including: Barn Swallow (2400m scale model), Brown-headed Cowbird (300m scale model), and Common Nighthawk (600m scale model, Table 8). However, the respective combined model for each of these landscape models was competitive or near competitive (ΔAIC ≤ 2.5). In the case of Cliff Swallow, Loggerhead Shrike, Ring-necked Pheasant, and Red-winged Blackbird, I did not run combined models because the best-fitting local model for each of these species was the null model.

Table 8. For each species, ΔAIC of best local, landscape, and combined models. Models with ΔAIC = 0 had the lowest AIC of all models for the species and, thus, are considered the best overall model for the species; however, models with ΔAIC < 2 are considered competitive.

| Species | Best Local Model | Best Landscape Models | | | | Best Combined Models | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 300m | 600m | 1200m | 2400m | 300m | 600m | 1200m | 2400m |
| Barn Swallow | 15.6 | 8.7 | 7.3 | 1.8 | **0.0** | 9.0 | 7.9 | 2.9 | 2.1 |
| Brown-headed Cowbird | 21.3 | **0.0** | 5.7 | 9.4 | 9.4 | 2.5 | 8.2 | 11.0 | 10.4 |
| *Burrowing Owl*[a] | 11.4 | *25.4* | 20.8 | 15.8 | 15.5 | *n/a* | 4.6 | **0.0** | 0.6 |
| Cassin's Sparrow | 129.4 | 237.6 | 220.6 | 180.5 | 184.2 | 50.2 | 37.2 | 6.5 | **0.0** |
| *Cliff Swallow* | *13.5* | 9.1 | 6.2 | 0.7 | **0.0** | *n/a* | *n/a* | *n/a* | *n/a* |
| Common Nighthawk | 23.5 | 2.6 | **0.0** | 5.7 | 11.3 | 3.4 | 1.3 | 6.9 | 9.7 |
| Grasshopper Sparrow | 72.7 | 138.8 | 131.0 | 116.8 | 99.2 | 30.4 | 24.4 | 12.9 | **0.0** |
| Horned Lark | 80.6 | 46.9 | 24.5 | 23.3 | 18.8 | 24.5 | 4.8 | 4.2 | **0.0** |
| Lark Bunting | 64.3 | 47.3 | 39.0 | 25.2 | 2.4 | 38.1 | 30.4 | 18.2 | **0.0** |
| Lark Sparrow 2003 | 18.2 | 32.8 | 25.6 | 21.4 | 13.6 | 12.6 | 8.5 | 5.7 | **0.0** |
| Lark Sparrow 2004 | 30.2 | 32.9 | 21.3 | 18.9 | 8.5 | 14.9 | 6.3 | 10.1 | **0.0** |
| *Loggerhead Shrike* | *4.2* | **0.0** | 0.7 | 3.0 | 4.2 | *n/a* | *n/a* | *n/a* | *n/a* |
| McCown's Longspur* | 21.6 | 0.7 | 8.3 | 8.5 | 6.8 | **0.0** | 6.1 | 5.8 | 3.9 |
| Mourning Dove | 55.8 | 34.9 | 16.2 | 3.7 | 3.5 | 28.8 | 13.7 | 2.8 | **0.0** |
| Northern Mockingbird* | 13.7 | 12.9 | 3.1 | 13.2 | 15.7 | 9.0 | **0.0** | 6.8 | 7.1 |
| *Ring-necked Pheasant* | *31.9* | 7.4 | 0.5 | **0.0** | 0.4 | *n/a* | *n/a* | *n/a* | *n/a* |
| *Red-winged Blackbird* | *27.2* | 8.8 | 6.6 | **0.0** | 0.1 | *n/a* | *n/a* | *n/a* | *n/a* |
| Western Kingbird | 20.1 | 11.5 | 10.2 | 8.5 | 3.2 | 9.2 | 8.2 | 6.0 | **0.0** |
| Western Meadowlark 2003[b] | 21.3 | 26.5 | 23.3 | 20.4 | 13.6 | 11.1 | 8.0 | 5.4 | **0.0** |
| Western Meadowlark 2004 | 11.0 | 32.8 | 34.7 | 26.8 | 29.8 | 6.8 | 9.9 | **0.0** | 4.2 |

[a] Italics indicates a best local or landscape model was the null model so a combined model was not applicable (*n/a*).
[b] Year after a species indicates that it was analyzed separately by year because occurrence was determined to be significantly different between years.
* A subset of point count data was used to model these species because their geographic range was restricted to a portion of the study area (see *Methods*).

*Discussion*

Effective conservation of shortgrass prairie birds requires current, reliable, broad-based knowledge about their habitat requirements. To date, most research aimed at providing this information focuses on species' response to site-specific habitat conditions (usually based on vegetation measures) and often neglects to test for potential influence of the surrounding landscape. In addition, these studies are often limited to small geographic areas (frequently based on political boundaries) and short/seasonal time periods (typically including two to four breeding seasons). Although such research undoubtedly contributes to our knowledge base and, thus, advances our ability to manage effectively for shortgrass prairie bird species, its application has recognizable limits when considering large-scale, long-term, landscape-based habitat management. Recent research indicates that grassland birds also respond to landscape features at large spatial scales and that response can vary by spatial scale and geographic region (Bergin et al. 2000, Bakker et al. 2002, Fuhlendorf et al. 2002, Hamer et al. 2006, Cunningham and Johnson 2006). I agree with Levin (1992) that "cross-scale studies are critical to complement more traditional studies carried out on narrow single scales of space, time, and organizational complexity…" My objective was to examine and compare shortgrass prairie bird species' response to local scale vegetation characteristics in addition to landscape features at multiple spatial scales to determine which variables were most influential in predicting occurrence. The results indicated that: (1) the relative influence of local vegetation characteristics and landscape features on bird response varies by species, (2) the spatial scale at which birds respond to landscape features varies by species, and (3) the landscape features to which a species responds may vary by spatial and temporal scale. Below I discuss these findings further and offer implications for management of shortgrass prairie birds.

*Influence of Local Vegetation Conditions*

The grass height and percent shrub cover of the surveyed shortgrass prairie influenced habitat selection of most species. All but four species showed a response to these local vegetation conditions. The four species that did not show a response were Cliff Swallow, Loggerhead Shrike, Ring-necked Pheasant, and Red-winged Blackbird. Cliff Swallows use man-made structure such as buildings and bridges in open habitat such as grassland or agricultural areas (Colorado Division of Wildlife 2007). Loggerhead Shrike use trees and shrubs in open areas (Strong 1971). Ring-necked Pheasants use agricultural areas such as fields of grass and grain crops (Colorado Division of Wildlife 2007). Red-winged Blackbirds are a facultative wetland species that will use irrigated cropland (Colorado Division of Wildlife 2007). I do not suggest that these four species do not respond to local vegetation characteristics. Rather, I suggest that grass height and percent shrub cover in particular may not be influential in their habitat selection, while other local conditions such as presence trees or water may be of considerable influence. Likewise, I do not assume that grass height and percent shrub cover of shortgrass prairie are the only or even the most influential local vegetation measures for all shortgrass prairie bird species. Litter depth, visual obstruction, and plant species composition are a few examples of other vegetation characteristics that may be influential. Nevertheless, the results indicate that grass height and shrub cover are influential to many shortgrass prairie bird species.

*Influence of Landscape Features*

The landscape features surrounding the shortgrass prairie survey sites influenced habitat selection of most species. All but two species showed a response to landscape features (at all four spatial scales). The two species that did not respond at all four spatial scales, Burrowing Owl and Loggerhead Shrike, did respond to landscape features at two scales, suggesting that either landscape features may be influential only at certain spatial scales for these species or that landscape features may not be strong predictors of these species.

Additionally, the landscape features to which birds responded varied by species such that no feature(s) (e.g., amount of grassland, number of patches) had a prevailing influence across species. Furthermore, most species (17 of the 19) responded consistently to the same one or two landscape variables across all spatial scales. These findings suggest that particular landscape features (e.g., the number of patches, amount of agricultural land) are key elements of habitat selection for individual species. For example, Barn Swallows, Brown-headed Cowbirds, Grasshopper Sparrows, and Mourning Doves all responded positively to the number of patches in the surrounding landscape (at all spatial scales) suggesting that degree of habitat fragmentation is an important element in these species' habitat selection. Conversely, Cassin's Sparrows and McCown's Longspurs responded negatively to the number of patches in the surrounding landscape suggesting that these species may be area-sensitive.

Although most species responded consistently to one or two landscape features across all spatial scales, there was also evidence that particular landscape features are influential only at certain spatial scales. For example, Mourning Doves responded the number of patches (positively), the amount of grassland (negatively), and the amount of woodland (positively) in the surrounding landscape at all spatial scales expect at the largest spatial scale at which they did not show a response to woodland. This suggests that species' response to landscape features may vary by spatial scale. I also suggest that perhaps these scale-dependant landscape features may be less significant to the species' habitat selection in comparison to the landscape features that were consistently responded to.

*Influence of Local versus Landscape Features*

Overall, both local vegetation conditions and landscape features influenced bird response; however, their relative influence depended upon the species. When considered separately, the local vegetation conditions appeared to be more influential for a few species (Burrowing Owl, Cassin's Sparrow, Grasshopper Sparrow, and Western Meadowlark in 2004). Conversely, the landscape features (at all scales) appeared to be more influential than the local vegetation conditions alone for all other species. Yet, when the local and landscape variables were combined, the local models were no longer competitive for any species. Furthermore, for species whose overall best-fitting model was a landscape model, the respective combined model was always competitive or near competitive ($\Delta AIC \leq 2.5$), suggesting that considering both the local and landscape features may still be of value.

*Management Implications*

This study indicates that habitat use by bird species breeding in the northern shortgrass prairie is influenced both by local and landscape features. Therefore, I recommend to resource professionals that in developing conservation plans and prescribing management activities they recognize the potential influence of landscape features, in additional to local habitat conditions, and incorporate them into their decision-making process. The information provided through this and similar research can aid resource professionals in making effective decisions when considering where to focus management activities, program dollars, and land acquisition for shortgrass prairie bird conservation. For example, if considering conservation of McCown's Longspur, my research indicates that landscapes with low habitat fragmentation and little agricultural land may prove most effective in conserving the species. Additionally, my research suggests that managing the land for short stature grass would also promote conservation of McCown's Longspur.

*Comments*

My research has some limitations. First, my study was based only on breeding season data; therefore, this research does not address habitat selection of wintering or migratory birds. Additionally, in the GIS, I could not distinguish among different grassland types in the study area, including the difference between natural grassland and CRP fields planted to grass or between different CRP practices (native versus non-native plantings) because spatial layers of CRP were not available for most of the study region. I recognize that shortgrass prairie bird response may differ significantly between CRP and natural grassland considering that many CRP fields in the shortgrass prairie have disproportionately taller vegetation (Samson et al. 2004, McIntyre and Thompson 2003, Kamler et al. 2003, Kamler et al. 2005). I also recognize that vegetation conditions vary with CRP practices, especially if management activities have occurred. Furthermore, I recognize that many factors influence habitat selection of grassland birds and that I examined only select set reflective of basic vegetation structure and general landcover composition. Other factors such as weather trends, inter- and intra-species competition, resource availability, and land management activities can all influence bird response (Manly et al. 2002). Finally, the modeling process I used was based on several assumptions including the key assumptions of overcoming effects of spatial autocorrelation and intercorrelation among variables. I recognize the inherent risks of these assumptions but believe the process was valid and that the results presented here provide valuable and reliable information to those persons committed to shortgrass prairie bird conservation.

## CONCLUSIONS AND RECOMMENDATIONS

My research examines habitat use by birds during two breeding seasons in the northern shortgrass prairie of North America. In particular, I investigated their use of CRP relative to shortgrass prairie habitat and dryland agriculture as well as their response to local habitat conditions relative to characteristics of the surrounding landscape at multiple spatial scales. The results lead to two main conclusions and I offer recommendations as to how these findings can aid in the conservation of shortgrass prairie bird conservation.

My first conclusion is that CRP in the northern shortgrass prairie of North America provides habitat that is uncharacteristic of shortgrass prairie. Thus, it does not provide considerable conservation value to shortgrass prairie obligate or closely associated bird species. Its taller grass, relative to native shortgrass prairie, and sparse shrub cover is likely a result of non-native plantings and/or a lack of disturbance, as mandated by the program. In recent years, the focus of the CRP has expanded to include wildlife habitat as an additional program objective (Allen 1994). Beginning in 1996, eligible CRP offers were ranked according to an Environmental Benefits Index (EBI) which is a rating system aimed at maximizing the value of erosion reduction and wildlife habitat. Since then, the EBI has been refined to improve the quality of wildlife habitat by encouraging establishment of diverse native vegetation over monocultures of introduced species, and to promote restoration of rare and declining wildlife habitat. Additionally, in recognition of the need for periodic disturbance and management of CRP land, the USDA authorized managed haying and grazing in 2002 (which is to occur no more frequently than one out of every three years) to improve the quality of CRP land for wildlife (U.S. Department of Agriculture 2004b). These changes to the CRP are promising for wildlife conservation, especially in the shortgrass prairie, considering the impressive number of the acres enrolled in the CRP. Managed haying and grazing are a particularly important addition to the program as they allow the opportunity to alter the vegetation structure of existing CRP habitat to suit the requirements of target wildlife. However, there are no clear management objectives specified for managed haying and grazing on CRP in terms of wildlife benefits. The program does not identify target wildlife species nor desired habitat characteristics to be achieved through management. Additionally, there is no method in place for evaluating the effects, if any, of managed haying and grazing on wildlife. Therefore, it is only assumed that management is providing wildlife benefits.

I suggest that CRP can be more effective in conserving shortgrass prairie birds if management activities are prescribed and that they are designed to provide a variety of habitat conditions characteristic of local native habitat. Also important is that plantings are ecologically appropriate and that management activities on CRP are based off the needs of priority bird species (as identified by PIF or conservation plans). Furthermore, in considering which priority species to manage for, I suggest managing for priority bird species for which management will maximize production of several other species (i.e., umbrella species). In addition, I suggest using Ecological Site Guides, developed by the Natural Resource Conservation Service (NRCS), to guide decisions on appropriate plantings.

My second conclusion is that shortgrass prairie birds respond both to local habitat conditions, such as vegetation structure, and to surrounding landscape features, such landcover composition. For some species, surrounding landscape features may be just as or more determinate than the characteristics of the local habitat alone and response to these features can vary by species and spatial scale. For these reasons, I recommend that when determining where and how to conserve or restore grassland habitat, including new or current CRP, that natural resource professionals evaluate and incorporate the influence of the surrounding landscape features. However, this requires availability of reliable, current, and broad knowledge about individual bird species. Therefore, I also recommend that future research on grassland birds incorporates both local and landscape analyses to provide resource professionals with this necessary information. Equipped with this information, resource professionals can make more effective decisions when considering how and where to prescribe management activities and focus limited monetary resources for shortgrass prairie bird conservation.

## LITERATURE CITED

Allen, A. W. 1994. Regional and state perspectives on Conservation Reserve Program contributions to wildlife habitat, report prepared for the Habitat Protection Committee of the International Association of Fish and Wildlife Agencies. Fort Collins, Mid-continent Ecological Science Center, National Biological Survey, Federal Aid in Wildlife Restoration Report.

Beidleman, C. A. 2000. Partner's in Flight Land Bird Conservation Plan, Colorado. Partner's in Flight, Estes Park, Colorado, USA.

Bakker, K. K., D. E. Naugle, and K. F. Higgins. 2002. Incorporating landscape attributes into models for migratory grassland bird conservation. Conservation Biology 16:1638-1646.

Beissinger, S. R. J. M. Reed, J. M. Wunderle, Jr., S. K. Robinson, and D. M. Finch. 2000. Reports of the AOU conservation committee on the Partners in Flight Species Prioritization Plan. The Auk 117:549-561.

Bergin, T. M., L. B. Best, K. E. Freemark, and K. J. Koehler. 2000. Effects of landscape structure on nest predation in roadsides of a Midwestern agroecosystem: a mutliscale analysis. Landscape Ecology 15:131-143.

Brennan, L. A. and W. P. Kuvlesky Jr. 2005. North American grassland birds: An unfolding conservation crisis? Journal of Wildlife Management 69:1-13.

Buckland, S.T., D.R. Anderson, K.P. Burnham, and J.L. Laake. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London. Reprinted 1999. RUWPA, University of St. Andrews, Scotland. Buckland, S. T., K. P. Burnham, and N. H. Augustin. 1997. Model selection: an integral part of inference. Biometrics 53:603-916.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Carter, M. F., W. C. Hunter, D. N. Pashley, and K. V. Rosenberg. 2000. Setting conservation priorities for landbirds in the United States: The Partners In Flight approach. Auk 117:541-548.

Colorado Division of Wildlife. 2007. Natural Diversity Information Source. http://ndis.nrel.colostate.edu.

Cunningham, M. A. 2005. A Comparison of public lands and farmlands for grassland bird conservation. The Professional Geographer 57:51-65.

Cunningham, M. A. and D. H. Johnson. 2006. Proximate and landscape factors influence grassland bird distributions. Ecological Applications 16:1062-1075.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, B. D. Parkin, and B. R. Euliss. 1999 (revised 2002). Effects of management practices on grassland birds: Lark Sparrow. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, A. L. Zimmerman, and B. R. Euliss. 2003a. Effects of management practices on grassland birds: Dickcissel. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, A. L. Zimmerman, and B. R. Euliss. 2003b. Effects of management practices on grassland birds: Lark Bunting. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, M. P. Nenneman, and B. R. Euliss. 2003c. Effects of management practices on grassland birds: Grasshopper Sparrow. Northern Prairie Wildlife Research Center, Jamestown, North Dakota.

Dechant, J. A., M. L. Sondreal, D. H. Johnson, L. D. Igl, C. M. Goldade, M. P. Nenneman, and B. R. Euliss. 2003d. Effects of management practices on grassland birds: Western Meadowlark. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Dinkins, M. F., A. L. Zimmerman, J. A. Dechant, B. D. Parkin, D. H. Johnson, L. D. Igl, C. M. Goldade, and B. R. Euliss. 2003. Effects of management practices on grassland birds: Horned Lark. Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Droege, S. and J. R. Sauer. 1990. North American Breeding Bird Survey Annual Summary 1989. U. S. Fish and Wildlife Service Biological Rep. 90:16.

ESRI. 1992. ArcView GIS 3.3. Earth Systems Research Institute, Redlands, California, USA.

ESRI. 2005. ArcMap 9.1. Earth Systems Research Institute, Redlands, California, USA.

Fellows, S., K. Stone, S. Jones, N. Damude, and S. Brown. 2001. U.S. Shorebird Conservation Plan: Central Plains/Playa Lakes Regional Shorebird Conservation Plan. U. S. Fish and Wildlife Service.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US Southern Great Plains. Landscape Ecology 17: 617-628.

Gillihan, Scott W., D. J. Hanni, S. W. Hutchings, T. Toombs, and T. VerCauteren. 2001. Sharing your land with shortgrass prairie birds. Rocky Mountain Bird Observatory, Brighton, Colorado, USA.

Gotmark, F., M. Ahlund, and M. O. G. Eriksson. 1986. Are indices reliable for assessing conservation value of natural areas? An avian case study. Biological Conservation 38:55-73.

Hamer, T. L., C. H. Flather, and B. R. Noon. 2006. Factors associated with grassland bird species richness: the relative roles of grassland area, landscape structures, and prey. Landscape Ecology 21:569-583.

Hanni, D. 2002. A Comparison of Four Methodologies Used to Monitor Shortgrass Prairie Birds in Eastern Colorado. Colorado Bird Observatory, Brighton, Colorado, USA.

Hanni, D. J. and M. Mclachlan. 2004. Section-based Monitoring of Breeding Birds within the Shortgrass Prairie Bird Conservation Region (BCR 18). Rocky Mountain Bird Observatory, Brighton, Colorado, USA.

Herkert, J. R. 1994. The effects of habitat fragmentation of Midwestern grassland bird communities. Ecological Applications 4:461-471.

Johnson, D.H. and S. A. Temple. 1986. Assessing habitat quality for nesting birds in fragmented tallgrass prairies *in* Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin, Madison, Wisconsin, USA.

Johnson, D.H., and L. D. Igl. 1995. Contributions of the Conservation Reserve Program to populations of breeding birds in North Dakota: Wilson Bulletin, 107:.709-718.

Johnson, D. H. and L. D. Igl. 2001. Area requirements of grassland birds: A regional perspective. Auk 118:24–34.

Kamler, J. F., W. B. Ballard, E. B. Fish, P.R. Lemons, K. Mote, and C.C. Perchellet. 2003. Habitat use, home ranges, and survival of swift foxes in fragmented landscape: conservation implication. Journal of Mammalogy 84:989-995.

Kamler, J. F., W. B. Ballard, P. R. Lemons, R. L. Gillard, and K. Mote. 2005. Home range and habitat use of coyotes in an area of native prairie, farmland, and CRP fields. American Midland Naturalist 153:394-404.

Kansas Applied Remote Sensing (KARS) Program. 2002. Kansas GAP Land Cover Database. Kansas Applied Remote Sensing Program, Lawrence, Kansas, USA.

Knick, S. T, and J. T. Rotenberry. Landscape characteristics of fragmented shrubsteppe habitats and breeding passerine birds. Conservation Biology 9:1059-1071.

Krebs, C. J. 1998. Ecological methodology. Benjamin/Cummings, Menlo Park, California, USA.

Levin, S. A. 1992. The problem of pattern and scale in ecology. Ecology 73:1943-1967.

Manly B.F.J., L.L. McDonald, D.L. Thomas, T.L. McDonald, and W.P. Erickson. 2002. Resource Selection by Animals. 2nd ed. Kluwer Academic Publishers, Netherlands.

McIntyre, N. E. and T. R. Thompson. 2003. A comparison of Conservation Reserve Program habitat plantings with respect to arthropod prey for grassland birds. American Midland Naturalist 150:291-301.

Milchunas, D. G., Lauenroth, W. K., and Burke, I.C. 1998. Livestock grazing: animal and plant biodiversity of shortgrass prairie steppe and the relationship to ecosystem function. Oikos 83:65-74.

Nuttle, T., A. Leidolf, and L. W. Burger, Jr. 2003. Assessing conservation value of bird communities with Partners in Flight-based ranks. The Auk 120:541-549.

O'Connor, R. J. M. T. Jones, R. B. Boone, and T. B. Lauber. 1999. Linking continental climate and land use patterns with grassland bird distribution across the conterminous United States. Studies in Avian Biology 19:35-59.

Oklahoma State University. 2001. Oklahoma GAP Analysis Project. Oklahoma Cooperative Fish and Wildlife Unit and Oklahoma State University, Stillwater, Oklahoma, USA.

Panjabi, A. O., E. H. Dunn, P. J. Blancher, W. C. Hunter, B. Altman, J. Bart, C. J. Beardmore, H. Berlanga, G. S. Butcher, S. K. Davis, D. W. Demarest, R. Dettmers, W. Easton, H. Gomez de Silva Garza, E. E. Iñigo-Elias, D. N. Pashley, C. J. Ralph, T. D. Rich, K. V. Rosenberg, C. M. Rustay, J. M. Ruth, J. S. Wendt, and T. C. Will. 2005. The Partners In Flight handbook on species assessment. Version 2005. Partners In Flight Technical Series No. 3. Rocky Mountain Bird Observatory website, Brighton, Colorado, USA.

Partner's in Flight. 2004. Partner's in Flight Species Assessment Database. http://www.rmbo.org/pif/pifdb.html.

Ralph, C. J., G. R. Geupel, P. Pyle, T. Martin, D.F. De Sante. 1993. Handbook of field methods for monitoring land birds. Gen. Tech. Rep. PSW-GTR-144. USDA Forest Service, Pacific Southwest Research Station, Albany, California, USA.

Rempel, R. 2004. Patch Analyst 3.1. Centre for Northern Forest Ecosystem Research (OMNR), Lakehead University Campus, Thunder Bay, Ontario.

Rotenberry, J.T., and J.A. Wiens. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology 61:1228-1250.

Ruth, J.M. 2000. Cassin's Sparrow (*Aimophila cassinii* ) status assessment and conservation plan. Biological Technical Publication BTP-R6002-1999. U.S. Department of the Interior, Fish and Wildlife Service, Denver, Colorado, USA.

SAS Institute. 2002. SAS/STAT 9.1. SAS Institute, Cary, North Carolina, USA.

Saiwana, L, J. L. Holechek, A. Tembo, R. Valdez, and M. Cardenas. 1998. Scaled quail use of different seral stages in the Chihuahuan Desert. Journal of Wildlife Management 62:550-556.

Samson F. and F. Knopf. 1994. Prairie Conservation in North America. BioScience 44: 418-421.

Samson, F. B., Knopf, F.L., and Ostlie, W.R. 2004. Great Plains ecosystems: Past, present, and future. Wildlife Society Bulletin 32:6-15.

Satterthwaite F. W. 1946. An Approximate Distribution of Estimates of Variance Components. Biometrics Bulletin 2:110 -114.

Strong, M. A. 1971. Avian productivity on the shortgrass prairie of north-central Colorado. M.S. thesis. Colorado State University, Fort Collins, Colorado.

U. S. Department of Agriculture Farm Service Agency. 2004a. Conservation Reserve Program Fiscal year Summary 2003. U. S. Department of Agriculture Farm Service Agency.

U. S. Department of Agriculture Farm Service Agency. 2004b. Fact Sheet: Conservation Reserve Program Haying and Grazing of Acreage. Farm Service Agency Online, www.fsa.usda.gov/pas/publications/facts/haygraze04.htm.

University of Nebraska. 2003. Nebraska GAP Landcover Dataset. Center for Advanced Land Management Information Technologies (CALMIT), Lincoln, Nebraska, USA.

University of Utah. 2004. Southwestern Regional GAP Analysis Project. RS/GIS laboratory, College of Natural Resources, Logan, Utah, USA.

Vickery, P. D. 1994. Effects of habitat area of the distribution of grassland birds in Maine. Conservation Biology 8:1087-1097.

World Wildlife Fund Canada. 1988. Prairie Conservation Action Plan. World Wildlife Fund Canada, Toronto, Ontario.

## APPENDIX A

Alphabetical list of all species observed by common and scientific name.

| Species | Scientific Name |
|---|---|
| American Avocet | *Recurvirostra americana* |
| American Crow | *Corvus brachyrhynchos* |
| American Goldfinch | *Carduelis tristis* |
| American Kestrel | *Falco sparverius* |
| American Robin | *Turdus migratorius* |
| Ash-throated Flycatcher | *Myiarchus cinerascens* |
| Bank Swallow | *Riparia riparia* |
| Barn Swallow | *Hirundo rustica* |
| Bewick's Wren | *Thryomanes bewickii* |
| Black-billed Magpie | *Pica hudsonia* |
| Black-crowned Night Heron | *Nycticorax nycticorax* |
| Black-throated Sparrow | *Amphispiza bilineata* |
| Blue Grosbeak | *Passerina caerulea* |
| Blue Jay | *Cyanocitta cristata* |
| Blue-winged Teal | *Anas discors* |
| Bobolink | *Dolichonyx oryzivorus* |
| Brewer's Sparrow | *Spizella breweri* |
| Brown Thrasher | *Toxostoma rufum* |
| Brown-headed Cowbird | *Molothrus ater* |
| Bullock's Oriole | *Icterus bullockii* |
| Burrowing Owl | *Athene cunicularia* |
| Cassin's Kingbird | *Tyrannus vociferans* |
| Cassin's Sparrow | *Aimophila cassinii* |
| Chestnut-collared Longspur | *Calcarius ornatus* |
| Chihuahuan Raven | *Corvus cryptoleucus* |
| Chipping Sparrow | *Spizella passerina* |
| Cliff Swallow | *Petrochelidon pyrrhonota* |
| Common Grackle | *Quiscalus quiscula* |
| Common Nighthawk | *Chordeiles minor* |
| Common Raven | *Corvus corax* |
| Common Yellowthroat | *Geothlypis trichas* |
| Dickcissel | *Spiza americana* |
| Eastern Kingbird | *Tyrannus tyrannus* |
| Eastern Meadowlark | *Sturnella magna* |
| Eastern Phoebe | *Sayornis phoebe* |
| European Starling | *Sturnus vulgaris* |
| Ferruginous Hawk | *Buteo regalis* |
| Field Sparrow | *Spizella pusilla* |
| Grasshopper Sparrow | *Ammodramus savannarum* |

| Species | Scientific Name |
|---|---|
| Great-tailed Grackle | *Quiscalus mexicanus* |
| Horned Lark | *Eremophila alpestris* |
| House Finch | *Carpodacus mexicanus* |
| House Sparrow | *Passer domesticus* |
| House Wren | *Troglodytes aedon* |
| Killdeer | *Charadrius vociferus* |
| Lark Bunting | *Calamospiza melanocorys* |
| Lark Sparrow | *Chondestes grammacus* |
| Lazuli Bunting | *Passerina amoena* |
| Lesser Prairie Chicken | *Tympanuchus pallidicinctus* |
| Loggerhead Shrike | *Lanius ludovicianus* |
| Long-billed Curlew | *Numenius americanus* |
| Mallard | *Anas platyrhynchos* |
| McCown's Longspur | *Calcarius mccownii* |
| Mountain Plover | *Charadrius montanous* |
| Mourning Dove | *Zenaida macroura* |
| Northern Bobwhite | *Colinus virginianus* |
| Northern Flicker | *Colaptes auratus* |
| Northern Harrier | *Circus cyaneus* |
| Northern Mockingbird | *Mimus polyglottos* |
| Northern Rough-winged Swallow | *Stelgidopteryx serripennis* |
| Orchard Oriole | *Icterus spurius* |
| Prairie Falcon | *Falco mexicanus* |
| Red-headed Woodpecker | *Melanerpes erythrocephalus* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Red-winged Blackbird | *Agelaius phoeniceus* |
| Ring-necked Pheasant | *Phasianus colchicus* |
| Rock Pigeon | *Columba livia* |
| Rock Wren | *Salpinctes obsoletus* |
| Sage Thrasher | *Oreoscoptes montanus* |
| Savannah Sparrow | *Passerculus sandwichensis* |
| Say's Phoebe | *Sayornis saya* |
| Scaled Quail | *Callipepla squamata* |
| Swainson's Hawk | *Buteo swainsoni* |
| Turkey Vulture | *Cathartes aura* |
| Upland Sandpiper | *Bartramia longicauda* |
| Vermilion Flycatcher | *Pyrocephalus rubinus* |
| Vesper Sparrow | *Pooecetes gramineus* |
| Virginia Rail | *Rallus limicola* |
| Warbling Vireo | *Vireo gilvus* |
| Western Bluebird | *Sialia mexicana* |
| Western Kingbird | *Tyrannus verticalis* |
| Western Meadowlark | *Sturnella neglecta* |
| Yellow Warbler | *Dendroica petechia* |
| Yellow-headed Blackbird | *Xanthocephalus xanthocephalus* |

# VITA

Megan Marie McLachlan

Candidate of the Degree of

Master of Science

**THESIS**

HABITAT USE BY BIRDS IN THE NORTHERN SHORTGRASS PRAIRIE OF NORTH AMERICA: A LOCAL AND LANDSCAPE APPROACH

**MAJOR**

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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: HABITAT USE BY BIRDS IN THE NORTHERN SHORTGRASS PRAIRIE OF NORTH AMERICA: A LOCAL AND LANDSCAPE APPROACH

Pages in Study: 87 Candidate for the Degree of Master of Science

Major Field: Rangeland Ecology

Scope and Method of Study: My research examines habitat use by birds in the northern half of the shortgrass prairie of North America. I analyze data collected through a regional bird-monitoring program during the 2003 and 2004 breeding seasons. First, I compare species use of the three dominant habitat types in the study area, shortgrass prairie, dryland agriculture, and land in the Conservation Reserve Program (CRP). I also compare the vegetation structure between shortgrass prairie and CRP. Next, I calculate and compare the conservation vale (*CV*) of the three habitat types using species conservation prioritization scores as presented by Partners In Flight. Finally, I model and compare species response to local vegetation conditions of shortgrass prairie habitat to the surrounding landscape features, at multiple spatial scales.

Findings and Conclusions: Bird communities differed between shortgrass prairie, CRP, and dryland agriculture. Only three species were more abundant on CRP than shortgrass prairie (Grasshopper Sparrow, Dickcissel, and Mourning Dove) and all three were also more abundant on dryland agriculture than CRP. CRP had taller grass and less shrub cover than shortgrass prairie. CRP and shortgrass prairie had similar conservation values (*CV*s) and both had greater *CV*s than dryland agriculture; however, different species constituted the *CV*s of CRP and shortgrass prairie. Most notably, Grasshopper Sparrow constituted much of the CRP *CV*. Both local vegetation characteristics and landscape features influenced habitat use by bird species and influence varied by species and spatial scale. I conclude that CRP is providing habitat uncharacteristic of native shortgrass prairie – habitat with taller grass and little to no shrub cover. I suggest that CRP can be more effective in providing suitable habitat for shortgrass prairie birds if management activities are prescribed and designed to provide a variety of habitat conditions characteristic of local native habitat that meet requirements of multiple species. Furthermore, I recommend to resource professionals that in developing conservation plans and prescribing management activities (which may include enrollment or management of CRP fields) they recognize the potential influence of landscape features, in additional to local habitat conditions, and incorporate them into their decision-making process.

ADVISOR'S APPROVAL: Dr. Sam Fuhlendorf______________________________