AN EVALUATION OF HABITAT USE AND REQUIREMENTS FOR GRASSLAND BIRD SPECIES OF GREATEST CONSERVATION NEED IN CENTRAL AND WESTERN SOUTH DAKOTA

BY

MITCHELL J. GREER

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Kristel Bakker 2 June 09

Dr. Kristel K. Bakker **Date**
Thesis Advisor

Charles D Dieter per 2 2009

Dr. Charles D. Dieter **Date**
Major Advisor

6/3/09

Dr. Thomas Cheesbrough **Date**
Head, Department of Biology and Microbiology

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ABSTRACT

AN EVALUATION OF HABITAT USE AND REQUIREMENTS FOR GRASSLAND BIRD SPECIES OF GREATEST CONSERVATION NEED IN CENTRAL AND WESTERN SOUTH DAKOTA

Mitchell J. Greer

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Tall and mixed-grass prairies are being urbanized or converted to cropland at an accelerated rate. Nationwide, these losses total 99.9% for tall-grass and 70-80% for mixed-grass prairies. Previous research has shown that local vegetation structure affects habitat use by grassland birds. In addition, patch size and landscape composition affect the presence, density, and nesting success of some, but not all, grassland obligate bird species. Current trends in grassland conversion, fragmentation due to these conversions and man-made shelterbelts and degradation by exotic plant species have made grassland birds one of the fastest declining guilds in North America. Little research has been conducted on grassland birds of the mixed-grass prairie, and for many of these species, South Dakota constitutes area of highest abundance or the central portion of their breeding range.

Objectives of this study were to identify: (1) local habitat characteristics, (2) habitat associations, and (3) patch and landscape level habitat requirements for grassland birds in the mixed-grass prairies of South Dakota. These objectives evaluated and

determined the distribution and habitat use as related to historical ecosystem diversity for grassland birds of the mixed-grass prairie in South Dakota.

I used fixed-width belt transects to survey birds on 288 native sod sites in 29 counties within central and western South Dakota during the breeding seasons of 2007 and 2008. Vegetation structure and composition were surveyed at 50m increments along each bird survey transect. Arc-GIS, aerial photographs, and the National Land Cover Database (2001) were used to calculate grassland patch size, amount of woody edge and amount of grassland habitat within concentric buffers (400m, 800m, 1600m and 3200m) around the survey points.

Grasshopper sparrows (N=203) were the most common bird detected within our transects. Of the study species, Chestnut-collared longspurs had the highest male density (124 males/100ha) followed by the grasshopper sparrow (107males/100ha). I found that occurrence and density of grassland obligate bird species were influenced by numerous habitat characteristics and at multiple scales. These models showed a large variation in local vegetation characteristics being selected for by grassland bird species. Increasing coverage of grasslands by exotic plant species had a negative effect on four (chestnut-collared longspur, western meadowlark, grasshopper sparrow and lark bunting) of my focus species occurrence and/or densities, while having a positive effect on the bobolink.

At the patch level, chestnut-collared longspur, Sprague's pipit, grasshopper sparrow, savannah sparrow, and western meadowlark occurrences and/or densities were negatively affected by the increasing presence of patch edge surrounded by woody

species. Western meadowlarks and grasshopper sparrows were classified as area sensitive, having lower densities in small versus large grassland patches.

Increasing amounts of grassland at the landscape scale positively influenced the occurrence and/or densities of Baird's sparrows, chestnut-collared longspurs, dickcissels, grasshopper sparrows, lark buntings, savannah sparrows, and Sprague's pipits. Bobolinks were the only species whose occurrence and density had a negative association to the amount of grass in the surrounding landscape. There was not only variability in the effect the landscape variables had but also at what level they were still important. Baird's and grasshopper sparrow occurrence and densities showed positive associations at the 400m or 800m levels while occurrence and densities of bobolinks, chestnut-collared longspurs, lark buntings, savannah sparrows and Sprague's pipits were influenced up to the 1600m or 3200m levels.

These models supply baseline data to managers for preservation and restoration of grassland habitat to help maintain populations of grassland obligate bird species. To maintain current populations and species diversity, it is critical that managers preserve as much native grassland as possible. Due to the diverse habitat requirements of these species of concern grasslands should be under varying management regimes ranging from idle to heavily grazed or mowed. Reduction and removal of exotic plant species should be a key element in establishing habitat for grassland obligate species as many were negatively affected by increases in exotic plant coverage. Preserved patches should be large in size as some species were area sensitive and preferred patches ≥250-1600ha. Grassland patches should also have little to no woody edge. Finally, these patches should

be located in close proximity to one another, or in areas of little fragmentation, to help increase the amount of grassland habitat in the landscape, as many of these grassland bird species were positively associated with the landscape variables, some up to 3200m.

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CHAPTER 1

THESIS INTRODUCTION AND LITERATURE REVIEW

Introduction

South Dakota contains some of the largest intact blocks of mixed-grass prairie in North America; it also contains portions of short grass prairie in the west and tall-grass prairie in the east. The grasslands of South Dakota provide breeding habitat for numerous grassland obligate bird species. South Dakota also constitutes the central portion of many of these bird species geographical ranges (Sauer et. al 2008). With grasslands being increasingly depleted, it is important to survey and evaluate remaining blocks of grasslands for bird species before these prairies are gone. For biologists to be able to effectively manage these prairies to maximize both grassland bird diversity and productivity for the farmer/rancher, they must know habitat requirements for each species. Information on local and landscape habitat variables and how management practices affect grassland birds is required to maintain their populations.

The remaining blocks of grassland habitat in South Dakota are under varying ownerships, including private, state, federal, and non-profit agencies, and thus they are subject to many different management practices. In eastern South Dakota, where agriculture is prevalent, a large amount of native grassland is being urbanized or converted to row-crop agriculture. Grassland conversion results in smaller patches. Many grassland areas are further fragmented by the presence of woody edges. A majority of remaining grasslands are privately owned with management under the control of the land

owners. These privately owned fields may be used for grazing, left idle, or hayed, but serve as habitat for some grassland birds. Depending on the timing and extent of grazing and haying, breeding of grassland birds may be disrupted or nests may be destroyed or exposed to predators. A portion of remaining grasslands are in fee-title easements where management is under the control of a state or federal agencies. Of these easement areas, 57% are wetland production areas (WPA) owned by the U.S. Fish and Wildlife Service and 43% are game productions areas (GPA) owned by the S.D. Department of Game Fish and Parks. Both WPA's and GPA's consist of different habitat types that are primarily managed for game species like the ring-necked pheasant (*Phasianus colchicus*), waterfowl and deer (Bakker 2000). Many remaining native sod grasslands are being invaded by exotic plant species (Higgins 1999) which can alter the structure of the local vegetation (Scheiman 2003, Lloyd and Martin 2005). This change in structure can create a diverse continuum of grasslands depending on the extent of the invasion, but eventually monotypic stands of exotic vegetation will develop. In western South Dakota, the mixed-grass prairie is largely left intact as grazing and hay production are the dominant land use practices (Peterson 1995, May 2001). The extent and frequency of grazing or haying across the area can diversify grassland habitat in this region. There are also large blocks of native grassland under public jurisdiction in western South Dakota, such as the Buffalo Gap and Grand River National Grasslands, which are largely left idle, while some areas are on a grazing rotation.

As grassland habitat across the landscape changes, so does the avian community (Flather and Sauer 1996). With a change in habitat, we expect to see differences in

occurrence rates and species densities as birds select for preferred habitat within their distributions (Brown 1984). The large study area for this project was selected to encompass different land use practices across the state and to document the effects of habitat loss on grassland birds within their breeding ranges. Public and private grasslands under varying management practices were surveyed to help biologists, managers, and administrators develop land management plans to encompass the wide variety of habitats exhibited by both ownership schemes and that can benefit both the human and animal users.

The purpose of this study was to determine habitat requirements (local, patch and landscape) relative to historical ecosystem diversity for grassland bird Species of Greatest Conservation Need (SoGCN) (Le Conte's sparrow (*Ammodramus leconteii*), Baird's sparrow (*Ammodramus bairdii*), Sprague's pipit (*Anthus spragueii*), chestnut-collared longspur (*Calcarius ornatus*), lark bunting (*Calamospiza melanocorys*)), as stated in the South Dakota Comprehensive Wildlife Conservation Plan (SDCWCP), and species listed as Level I or II priority grassland birds (savannah sparrow (*Passerculus sandwichensis*), grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), bobolink (*Dolichonyx oryzivorus*) and the western meadowlark (*Sturnella neglecta*)) in the South Dakota All Bird Conservation Plan (SDABCP) (Bakker 2005). In an attempt to survey the historical ecosystem diversity of the mixed-grass prairie of South Dakota (SDGFP 2006), only grassland habitats that were determined to be of native sod (unbroken ground) were surveyed.

This study was conducted in central and western South Dakota which constitutes the primary breeding range and areas of highest abundance for the majority of these grassland birds. These species have been selected due to their reliance on grassland habitats and because there has been little research on the SoGCN that inhabit the northern and central portions of the mixed-grass sub-region of the Eastern Prairie Ecoregion and the Great Plains Steppe Ecoregion of South Dakota (SDGFP 2006). Some studies have examined grassland birds in parts of these regions or on different types of grassland habitats (planted, brome dominated) within these same regions (Bakker et. al. 2002, Bakker et. al 2003, Dejong et. al. 2004), but did not incorporate the entire mixed-grass prairie of South Dakota, did not consider native sod only, or did not encompass multiple scales (Table 1-1). Studies have shown the negative effects of invasive plant species on nesting success of grassland birds (Bragg and Steuter 1995, Lesica and DeLuca 1996, Lloyd and Martin 2005) but not on other aspects of their life cycle. Recent research (Winter and Faaborg 1999, Winter et. al. 2006) has shown that factors affecting nesting success may not be the same ones affecting avian occurrence and density. It has also been found by Johnson and Igl (2001) and Bakker et. al. (2002) that results from one study area may not apply to other areas because the habitat requirements of grassland birds may vary with species distribution, vegetation structure, and landscape composition.

The primary objectives of this project were to (1) describe local vegetational habitat requirements (quality of ecosystem) of SoGCN and Level I and II priority grassland bird species in western and central South Dakota, (2) describe habitat associations (grazing intensity, presence of exotic plant species) for SoGCN and Level I

Table 1-1. Summary of local vegetation habitat requirements for the 10 species of grassland birds designated as SoGCN or Priority Level I or II by the South Dakota Comprehensive Wildlife Conservation Plan and the South Dakota All Bird Conservation Plan.

Species Common Name	Description of Selected Habitat
Le Conte's Sparrow	Utilize open, level uplands and lowlands, with tall, thick herbaceous vegetation and thick litter (Tester and Marshal 1961, Walkinshaw 1968, and Murray 1969).
Baird's Sparrow	Utilize grasslands with moderate litter depth, moderately high, patchy forb and grass cover with little woody vegetation (Owens and Myres 1973, Stewart 1975, and Kantrud and Kologiski 1982).
Sprague's Pipit	Utilize grasslands of intermediate height and sparse to intermediate vegetation density, moderate litter cover and little or no woody vegetation (Wilson and Belcher 1989, Dale 1992, and Madden 1996).
Chestnut-Collared Longspur	Utilize level to rolling mixed-grass and short-grass uplands with little to no shrubs. Grasslands with excessive litter are avoided (Fairfield 1968, Stewart 1975, Kantrud and Kologiski 1982, and Berman 2007).
Lark Bunting	Utilize grasslands of low to moderate height, with high vegetative cover composed of a shrub super-story and 10 – 15% bare ground (Shane 1972, Creighton 1974, DeJong 2000 and Shane 2000).
Savannah Sparrow	Utilize habitat with short to intermediate vegetation height with intermediate vegetation density and a well established litter layer (Stewart 1975, Madden et. al 1999, Wheelwright and Rising 1993 and Bakker 2000).
Grasshopper Sparrow	Utilize grasslands of intermediate height with clumped vegetation and interspersed patches of bare ground, sparse woody plant coverage and moderate litter depth (Smith 1963, Blankespoor 1980, Bakker 2000, and Berman 2007).
Dickcissel	Utilize grasslands with dense, moderate to tall vegetation with some forbs and moderately deep litter (Gross 1921, Hamerson 1974, Sample 1989, and Bakker 2000).
Bobolink	Utilize habitat with moderate to tall vegetation with moderate to dense vegetation and moderately deep litter (Tester and Marshall 1961, Harrison 1974, Bollinger 1995, Bakker 2000, and Dejong 2001).
Western Meadowlark	Utilize a variety of grasslands with varying vegetation heights with high grass and forb cover, little or no woody cover and moderate litter cover (Kimmel et. al 1992, Patterson 1994, Patterson and Best 1996, and Berman 2007).

and II priority grassland bird species in western and central South Dakota, and (3) identify patch (patch size, tree edge) and landscape level (amount, size, distribution of grassland in the ecosystem) habitat requirements for SoGCN and Level I and II grassland species in western and central South Dakota. This information could be used to support recommendations for preservation and restoration when prioritizing vital grassland habitat to reach the goal for adequate ecological representation and biodiversity preservation as stated in the SDCWCP.

This project addressed the three major problem areas and causes of concern for loss of biodiversity as stated in the SDCWCP: conservation of ecosystems, suppression of historical disturbances, and introduction of non-native species. Objective one addressed the quality of the ecosystem by determining the effect of vegetation structure and non-native plant species on habitat quality for SoGCN. Objective two addressed suppression of natural disturbance regimes by evaluating species use of grasslands under different management and grazing regimes, and with varying amounts of woody edge and exotic plant species coverage. Objective three focused on the question of adequate ecological representation (SDGFP 2006). I attempted to determine "how much is enough" (SDGFP 2006) by identifying how big patches need to be and how they should be arranged in the landscape to support a healthy population of grassland bird SoGCN. Combined, these objectives evaluated and determined the distribution and habitat use related to historical ecosystem diversity for grassland birds SoGCN.

Literature Review

Avian History of the Plains

Avian records were started by the Surgeons General Office in 1868, when they required that post surgeons at every fort record ornithological information for their area (Chilson 1968). In South Dakota, records were gathered by Assistant Surgeon General Dr. B. Knickerbocker at Fort Wadsworth in Northeast South Dakota. The records kept by Knickerbocker showed large numbers of greater prairie chickens (*Tympanuchus cupido*) whose range and numbers are greatly reduced today (South Dakota Ornithologist Union (SDOU)1991, Tallman et. al. 2002). According to the SDOU (1991) and Peterson (1995), the long-billed curlew has seen a great decrease in numbers since 1940 and most of the remaining birds are located in western South Dakota. Other birds that utilize the grasslands of South Dakota have shown a great decline in numbers since the 1960's including waterfowl, upland game birds, song birds, shore birds and raptors (Sauer et. al. 2008). Inversely, there has been an increase in the number of some species many of which are exotic, edge or woodland species (Chilson 1968, SDOU 1991, Sauer et. al. 2008). In 1932, the list of documented birds for South Dakota contained 349 species. Today the number of species in South Dakota has climbed to 408 due to taxonomic changes and new species sightings, and of these, 219 breed within the state (Tallman et. al. 2002, Sauer et. al. 2008).

One reason for the wide diversity of birds is the variety of habitat types within South Dakota. The state contains numerous prairie pothole wetlands, vast grasslands (under different management regimes), crop and hay ground, forest, both small and large

rivers, lakes, wooded draws and shelter belts, among others (Bakker 2000). Costello (1969) attributed the wide variety of species partly to the central geographic location of South Dakota, noting that it was a transition zone where western and eastern species met. South Dakota also sees many northern species like burrowing owls, longspurs, sparrows, and shorebirds whose ranges seem to be drifting southward (Tallman et al. 2002).

Grassland Bird Decline

According to data from the United States Fish and Wildlife Service (USFWS) Breeding Bird Survey (BBS), grassland birds have been declining at an alarming rate. Based on the 28 species used for analysis, grassland birds have declined on average 1.24%/year since 1966 (Sauer et. al. 2008). Of these 28 species, 21% (6 species) had positive trends with 14% (4 species) being significant ($P<0.1$) (Sauer et. al. 2008). Approximately 79% of the 28 grassland bird species are either declining or remaining stable, with 50% (14 species) declining at a significant rate ($P<0.05$) (Sauer et. al. 2008). Given the current trends, grassland birds have become the fastest declining guild of birds in North America (Sampson and Knopf 1994, Herkert 1995, Vickery and Herkert 2001). Species specific trends in the US have shown a decline of 7.1% for Baird's sparrows, 3.3% for grasshopper sparrows, 3.6% for chestnut-collared longspurs and similar trends for many others from 1980 – 2008 (Table 1-2) (Sauer et. al. 2008). Current trends show that bobolinks, western meadowlarks and Henslow's sparrows (*Ammodramus henslowii*) are the fastest declining grassland bird species in North America (Peterjohn et. al.1994, North American Bird Conservation Initiative (NABCI) 2009). Johnson (2006) found that at current rates, within 40 years approximately only 10-25% of the population of these

Table 1-2. Grassland bird species population trends (%) for the United States, and South Dakota from 1966-2007 and 1980-2007 according to the USGS Breeding Bird Survey data (Sauer et. al. 2008).

Species Name[A]	U.S. Since 1966	U.S. Since 1980	SD Since 1966	SD Since 1980
Primary Study Species Population Trends				
Baird's Sparrow	-5.2**	-7.1**	+0.2	+4.8
Grasshopper Sparrow	-3.6**	-3.3**	-4.4**	-4.1*
Savannah Sparrow	-1.1**	-1.0**	+2.8	+4.7*
Bobolink	-0.8**	-0.9**	+2.1	+1.4
Chestnut-Collared Longspur	-2.5**	-3.6**	-6.1**	-10.8**
Dickcissel	-0.3	-0.3	-1.7	+1.1
Lark Bunting	-1.6**	-2.0**	-3.3**	-4.6**
Le Conte's Sparrow	+2.5**	+2.2**	N/A	N/A
Sprague's Pipit	-2.4	-3.1	-12.7	-3.5
Western Meadowlark	-0.9**	-1.0**	0.0	-0.7
Other Grassland Bird Species Trends				
Northern Harrier	-1.1	+0.2	-3.5	-1.4
Ring-necked Pheasant	-0.7**	-0.4	+2.7**	+4.6**
Sharp-tailed Grouse	+3.0	+1.2	+0.3	-13.0
Greater Prairie-Chicken	-2.4	-1.7	+38.1	+39.8
Upland Sandpiper	+0.5*	-0.7*	+0.9	-0.4
Long-billed Curlew	-1.0	-0.5	-2.6	-3.6
Marbled Godwit	+0.8	+1.2	+3.2	+2.5
Burrowing Owl	-1.4	+2.0	-5.2	-17.4
Short-eared Owl	-2.4	-3.3*	+12.6**	+2.1**
Horned Lark	-1.8**	-2.2**	-0.3	-3.2
Sedge Wren	+1.4**	+0.6	+4.9	+5.8
Vesper Sparrow	-1.3**	-1.3*	-0.5	-1.3
Clay-colored Sparrow	-0.1	+1.7	+1.4	-4.0
Brown-headed Cowbird	-0.8**	-0.7	+2.3**	+3.3*

* Indicates significant trend for long term data at P-value less than 0.1.
** Indicates significant trend for long term data at P-value less than 0.05.
[A] See Appendix A for scientific names.

grassland bird species will remain.

In South Dakota, where grasslands are far more prevalent than in the rest of the U.S., many grassland bird species are still declining but at slower rates. However, others like the chestnut-collared longspur are declining even faster. Of 14 species analyzed in South Dakota, 43% (6 species) showed a positive trend with only the Ring-necked pheasant (an exotic species) showing a significantly ($P<0.05$) positive trend. Eight (57%) species were found to be declining with 21% (3 species) showing significantly negative trends ($P>0.05$). In South Dakota since 1966, there has been an increase in Baird's sparrows (0.2%), a decrease in grasshopper sparrows (4.4%), chestnut-collared longspurs (6.1%), and mixed trends for the remaining grassland species when compared to the rest of the U.S. (Table 1-2) (Sauer et. al. 2008).Within South Dakota and the rest of the Great Plains, grasshopper sparrows, chestnut-collared longspurs, lark buntings, and western meadowlarks are the fastest declining grassland bird species (Herkert et. al. 1996, Sauer et. al 2008).

The reasons for the decline of grassland birds not only in South Dakota but nation wide are numerous. Herkert et. al. (1994) stated that a primary reason for the decline of grassland birds is habitat loss and fragmentation (which increases patch edge). Many grassland bird species are area sensitive, meaning that grassland patch size plays a role in occurrence, density, and nesting success (Herkert 1994, Winter and Faaborg 1999, Ribic and Sample 2001, Bakker et. al. 2002). A second reason for grassland bird decline is that remaining blocks of native prairie are being further degraded by unnatural disturbance regimes and the invasion of woody and exotic plant species (Bakker 2003, Lloyd and

Martin 2005). A third cause of decline for grassland birds comes at the landscape level. Ribic and Sample (2001), Bakker et. al. (2002), and Winter et. al. (2006) found that composition of the landscape surrounding a grassland patch also influenced grassland bird density and occurrence. Landscape composition can play a role in how an edge affects grassland birds, since adjoining lands can create either hard (very different, i.e. woods, row crops) or soft (similar, i.e. grassland on a different management regime) edges which can negatively influence grassland bird probability of occurrence (Bakker 2000) and productivity (Berman 2007). The loss of grassland obligate species is a problem that will only get worse if proper action is not taken to counteract the loss and degradation of vital grassland habitat.

Grassland Loss

Grasslands, both tall and mixed-grass, are being urbanized or converted to cropland (row crop agriculture) at an accelerated rate (Samson and Knopf 1994 & 1996, Higgins et. al. 2002a). Nationwide, these losses total 99.9% for tall-grass and 70-80% for mixed-grass prairies (Johnson 2006). This conversion has left grasslands of the Great Plains as one of the most endangered ecosystems in North America (Samson et. al. 2004). The tall-grass prairie is the most reduced with only one tenth of one percent remaining in some states and provinces (Samson and Knopf 1994, Higgins et. al. 2002b), leaving remaining areas of tall-grass prairie very fragmented with vast areas of agriculture surrounding them (Samson and Knopf 1994, 1996).

In eastern South Dakota, there has been an increase in development of farm ground on marginal grassland soil due to current farm policy and economics (Samson and

Knopf 1994, Checkett 2008). These grassland conversion rates range from 20% to over 90% for some counties in eastern South Dakota (Peterson 1995). In South Dakota, 47,167 acres of grassland were converted to cropland with some grassland dominated counties converting over 2,000 acres (810 hectares) of grassland to cropland in 2006 alone (U.S. Department of Agriculture Farm Service Agency, Brookings County Office, Brookings, SD). In the past 20 years, approximately 20% (1.4 million ha) of South Dakota's remaining range and grassland has been converted to cropland (Higgins et. al. 2002b). Remaining blocks of grassland are being invaded by exotic species, woody shrubs, man made shelter belts and roads, causing further fragmentation and increasing the effect of edges (Bakker et. al. 2002).

The northern Great Plains ecosystem has been greatly changed from endless miles of grasslands to large patches of cropland with small isolated grassland islands within them (Bakker et. al. 2002). As grasslands recede across the Great Plains, grassland bird populations continue to decline. As early as 1915, travelers across the area noticed declines in grassland obligate species. Bailey (1915) noticed a decline of chestnut-collared longspurs and burrowing owls (*Athene cunicularia*), and noted many species that were once prevalent all across the area nesting in small grassland "islands" due to breaking of native prairie. Costello (1969) noted a similar decline in bird species that utilize the grasslands of the Great Plains since his earlier trips in the 1940's. The correlation between grassland bird decline and the loss of native grassland has been supported by research from other areas experiencing similar patterns. In Illinois, where the average size of more than 80% of the remaining grasslands patches is less than 10

hectares (Herkert 1994), the grassland bird decline has been far greater with some species declining as much as 92.6% (Herkert et. al. 1996). Herkert et. al. (1996), Higgins et. al. (2002b), and Renfrew (2002) have linked grassland obligate species decline to continued loss of grassland habitat to row crop agriculture across the Great Plains. When comparing a managed wildlife area to a corn field, Arndt and Townsend (1982) found a greater abundance and diversity of birds in and around the grass covered wildlife area. Best et. al. (1991) found that birds trying to nest in cropped fields had only a 22% nest success rate, with most (54%) being lost to predators. With South Dakota converting more and more grasslands to cropland, grassland bird numbers have declined (Sauer et. al. 2008), and it may be only a matter of time until we see losses similar to the surrounding areas.

Loss of grasslands to agriculture not only affects grassland bird species but also causes change in other animal populations. Stephens (2008) showed that areas of large intact grasslands were required to obtain high nesting success rates needed to support the North American duck population. Daley (1992) showed that loss of grassland habitat has reduced the expansion and further isolated black-tailed prairie dog (*Cynomys ludovicianus*) colonies causing reduced gene flow and resulting in population declines. Tscharntke et. al. (2002) showed that polyphagous butterfly species richness decreased as grasslands were removed and fragmentation increased. Loss of grasslands to cropland can lead to increased soil erosion. This increased erosion leads to waterways polluted by sediments, fertilizers, pesticides and higher levels of siltation in lakes and reservoirs, which can have negative effects on fish and other aquatic life (Clark et. al. 1985). It is important that while South Dakota still has 75.7% of its 36.7 million acres of native

mixed-grass prairies left (DeJong 2001, Higgins et. al. 2002b) that we survey and preserve the appropriate amount and types to maintain grassland biodiversity.

Grassland Fragmentation and Edge Effect

As grasslands become more fragmented, there are more and smaller grassland patches with an increased amount of edge. This fragmentation isolates grasslands from other patches of suitable habitat (Wilcox and Murphy 1985). Grasslands can be fragmented by roads, cropland, urban areas, farms, and non-native woody species used to create windbreaks and shelterbelts.

Woody edges supply travel corridors and cover for mammalian predators, such as striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), and opossums (*Didelphis marsupialis*) that can have a negative effect on nesting success of grassland birds extending well into the interior of the grassland (Winter et. al. 2000). Johnson and Temple (1990) found that bobolink (*Dolichonix oryzivorus)* and western meadowlark (*Sturnella neglecta)* nests located within 45m of wooded edges had low success. Smaller grassland patch size causes grassland birds to be more susceptible to predation by forcing them to nest closer to the woodlands and other edges (Mankin and Warner 1992). Wooded edges may also supply perching habitat for avian predators and parasitic species like the brown-headed cowbird (*Molothrus ater*). Cowbirds have been documented to parasitize nests of over 220 species, including grassland obligates (Friedman 1963, Lowther 1993, Berman 2007). Parasitism leads to lower reproductive success for grassland bird species and ultimately an increase in parasitic species (Peterson 1995, Winter et. al. 2006, Berman 2007). There has been an increase of 3.3% for brown-headed

cowbirds in South Dakota since 1980, while nation wide they have declined 0.7% for the same time period (Sauer et. al. 2008). Brown-headed cowbirds have also expanded their range in the past 20 years, while ranges of most other species have declined (Sauer et. al. 2004). The range expansion for brown-headed cowbirds has been more prevalent in eastern South Dakota (Peterson 1995) due to greater fragmentation of the grasslands in this region. Other bird species that have shown positive population trends with increased prairie fragmentation include many woodland, edge, and habitat generalist species, such as the American crow (*Corvus brachyrhynchos*) and European starling (*Sturnus vulgaris*) (Chilson 1968, Sauer et. al. 2008), which can displace, disturb, destroy, or predate grassland birds or their nests.

The effects of prairie fragmentation can vary depending on the type of edge that borders a grassland patch. “Hard” edges are different from the grassland patch (i.e. crop land, wooded, urban area) and have higher rates of predation and nest parasitism when compared to “soft” or similar edges (i.e. grassland with differing management) (Winter et. al. 2000, Heske et. al. 2001). Small patches (<64ha) tend to have a greater edge effect this is due to the lack of internal grassland habitat, thus making the entire patch an edge (Pasitschniak-Arts et. al. 1998). Grazing can also play a role in the effect edges have on a grassland patch. Grassland birds nesting near edges in heavily grazed patches may have nesting success similar to birds in the interior (Renfrew et. al. 2005). This effect on nesting success is most likely due to the change in the local vegetation structure caused by the grazing, allowing predators easier access to the entire patch (Renfrew et. al. 2005).

Grassland Patch Size

Optimum and minimum area requirements which are directly related to grassland patch size may affect the occupation, density, and nesting success of numerous grassland bird species (Johnson and Temple 1990, Herkert 1994, Vickery et. al. 1994, Winter and Faaborg 1999, Bakker et al. 2002). Species classified as area-sensitive are showing the greatest declines as grassland patches become smaller and more fragmented in eastern South Dakota (Bakker 2000, Sauer et. al 2008). Patch size is positively correlated with occurrence of grasshopper sparrows, bobolinks, Le Conte's sparrows, Baird's sparrows and savannah sparrows (Herkert 1994, Johnson and Igl, 2001, Bakker et. al 2002, DeJong et. al. 2004, Ribic et. al. 2009b). With grassland patches becoming smaller, there is a decline in many of these species both in South Dakota and nation-wide (Peterson 1995, Samson and Knopf 1996).

Area sensitivity may vary between regions, habitat types, surrounding landscape or even study areas (Bakker et. al. 2002). Minimum area requirement for upland sandpipers (*Bartramia longicauda*) have been shown to be 614ha in South Dakota (Bakker 2000) but only 200ha in Maine (Vickery et. al. 1994). Area requirements also vary between different grassland species (Herkert 1994, Vickery et. al. 1994, Winter and Faaborg 1999). Initial findings by Ribic et. al. (2009a) showed a negative correlation between grassland bird occurrence, density and nesting success and prairie fragmentation (patch size reduction), but research on this topic is still in its infancy.

Grassland Patch Degradation

Wiens (1969, 1974), Cody (1985), Renken and Dinsmore (1987), Herkert (1994), and Bakker et. al. (2002) found that local vegetation structure affects habitat use by grassland birds. Problems with invasive plant species and how they negatively affect breeding bird habitat have been well documented (Bragg and Steuter 1995, Lesica and DeLuca 1996). However, little has been done to evaluate how these exotic plant species affect habitat quality for grassland birds in other areas of their life cycle. The few studies that were conducted on exotic plant species and habitat quality for grassland birds have shown that grassland bird numbers are lower in grasslands dominated by exotic species (Wilson and Belcher 1989, Pampush and Anthony 1993, Mermoz and Reboreda 1998, Lloyd and Martin 2005). Scheiman et. al. (2003) found that savannah and grasshopper sparrow densities were lower in areas that had higher amounts of leafy spurge (*Euphorbia esula*) when compared to fields that had lower amounts of the exotic forb.

South Dakota has numerous publically and privately owned grasslands in both the eastern and western portions of the state. Many grasslands have been invaded by exotic species such as Kentucky bluegrass (*Poa pratensis*), crested wheatgrass (*Agropyron desertorum*), brome species (*Bromus spp.*), leafy spurge, Canada thistle (*Cirsium arvense*), and yellow sweet clover (*Melilotus officinalis*). The changes these exotic plant species make to the grasslands may negatively affect grassland bird species. Lloyd and Martin (2005) found that chestnut-collared longspurs in Montana had lower nest success when nesting in monocultures of Asian crested wheatgrass (exotic species) (*Agropyron cristatum*) than in habitat containing natural vegetation. In Wisconsin, Ribic et. al.

(2009a) found that grasshopper sparrows had higher densities in native prairie remnants with greater native plant coverage than in CRP fields or hay fields containing greater amounts of exotic species.

Woody vegetation not only poses a problem with grassland fragmentation and edge effect but can also degrade the interior habitat. In some cases, grasslands have been transformed into shrub land by the invasion of woody species such as eastern red cedar (*Juniperus virginiana*) and western snowberry (*Symphoricarpos occidentalis*). The invasion of these and other woody species can bring an increased number of predators and nest parasites to the grassland which can decrease the occurrence, density and nesting success of several grassland bird species (Bakker 2003). Coppedge et. al. (2001) reported that encroaching woody vegetation on native prairies can supply habitat for some neo-tropical migrants, but it can diminish habitat for grassland obligate species.

Landscape Effects

As the decline of grasslands continues, there is a change in the landscape as a whole. Grassland patches become smaller and further isolated and the amount of prairie surrounding these grasslands also changes. As grasslands are converted to row crops and woodlands, the landscape once covered in grassland habitat has been transformed into areas dominated by fields of monotypic vegetation and increasing patch edge. This transformation can have both positive and negative effects on the avian community. Pearson et. al. (1996) found that increasing spatial heterogeneity can increase habitat types and seral stages leading to a greater diversity of bird species; but species that are area sensitive may see a decline in numbers due to the creation of small patches.

However, some area sensitive species like western meadowlarks may utilize smaller patches if the surrounding landscape includes large amounts of grassland (Frawley and Best 1991).

Studies that compare grassland bird density, occurrence and nesting success with amount of grassland in the surrounding landscape are few. Recent research has shown that when patch edge and size are removed, other factors such as surrounding landscape composition become influential in explaining bird density and occurrence (Best et. al. 2001, Johnson and Igl 2001, Sample 2001, Bakker et. al. 2002, Fletcher and Koford 2002). Ribic et. al. (2009b) reported evidence that occupancy rates of grassland birds are affected by landscape level variables. Ribic and Sample (2001) found that landscape variables had more of an effect on bobolink and eastern meadowlark (*Strurnella magna*) densities in south-central Wisconsin than local variables did. Veech (2006) discovered that landscapes with large grassland bird numbers contained more grassland than those with declining populations in the Midwest and Great Plains ecoregions. Cunningham and Johnson (2006) and Renfrew and Ribic (2008) found that models containing patch and landscape variables were best at explaining the densities of grassland birds.

Landscape composition requirements can vary among regions, study areas, and between species. Winter et. al. (2006) found that as the surrounding landscape increased in shrubs and trees, the density of clay-colored sparrows (*Spizella pallida*) increased, but savannah sparrow and bobolink (grassland obligates) densities decreased. Landscape composition also plays a role in how edges affect occurrence, density, and nesting success of grassland birds because as grasslands are removed there is an increase in

“hard” edge surrounding the remaining grassland patches (Winter et. al. 2000, Grant et. al. 2004).

Grassland habitat once dominated the Great Plains of South Dakota, but current land use practices have led to the breaking of this prairie and great changes within this ecosystem. Grassland conversion leads to fewer and smaller patches that have a negative impact on grassland bird occurrence and density. Also, the degradation of these patches by woody and exotic species lower the quality of habitat within a grassland and decrease grassland bird density and occurrence rates. With current tends in grassland loss is important that research be conducted to establish guidelines for land managers to aid in preservation of critical habitat which will help maintain grassland bird populations. This study will evaluate the habitat requirements of grassland obligate species and establish recommendations to help reduce the rate of grassland bird loss in the mixed-grass prairie of central and western South Dakota.

CHAPTER 2

STUDY AREA AND METHODS

Introduction

This study was conducted in the northern and central portions of west-central, central, and east-central South Dakota (2007-2008) (Figure 2-1). All surveys were conducted on grasslands (N=288) that were determined to be native (i.e. unbroken) sod. The surveyed areas were determined to be native sod if; (1) the history of the land was known by either the agency or private land owner and showed the land to be native sod or (2) if the field contained large rocks within the soil that would have been removed to protect farm equipment had the sod been broken. Fields not meeting these criteria were not surveyed.

Study Area

Study Area

South Dakota consists of 199,730km^2 divided approximately into two equal parts by the Missouri River that flows from north to south through the state. Mixed-grass prairie is the dominant vegetation type in both eastern and western South Dakota. The western portion of South Dakota is found within the northwestern Great Plains ecoregion (Bryce et. al. 1998) between 42° and 46° latitude and 98° and 104° longitude. Agriculture is limited in western South Dakota by low precipitation, low humidity, and extreme

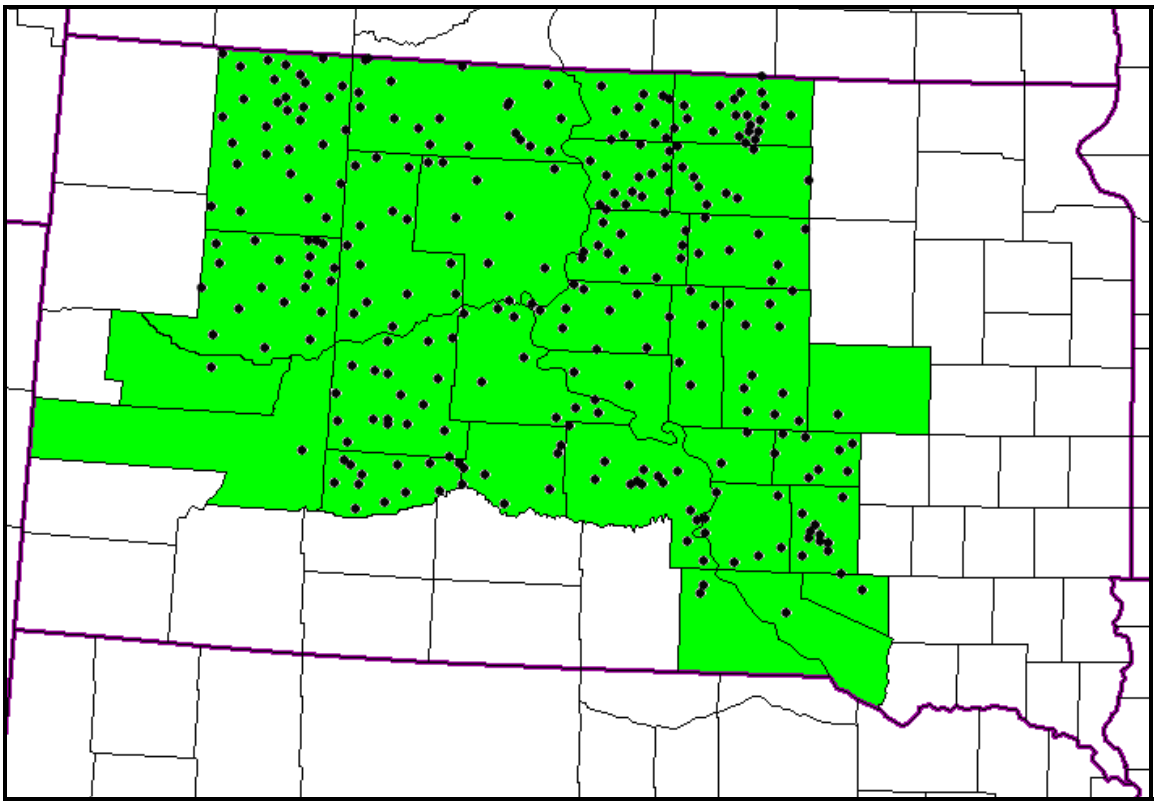

Figure 2-1. Map of South Dakota depicting the study area of this project, counties surveyed in summers 2007 and 2008 in green, with our 288 survey points marked by black dots.

temperatures; most land is used by ranchers for grazing of livestock. This lack of tillage agriculture in western South Dakota makes the northern mixed-grass prairie one of the most intact grasslands in North America (DeJong 2001). Eastern South Dakota is contained within the Eastern Prairie ecoregion and lies between 42° and 46° latitude and 96° and 106° longitude. This study was conducted in the portion of eastern South Dakota contained within the Missouri Coteau as referred to in the SDCWCP. The mixed-grass prairie is more fragmented in eastern South Dakota with agriculture being prevalent. The main crops of this area include wheat (*Triticum aestivum*), soybeans (*Glycine max*), and corn (*Zea mays*).

The study area consisted of the northern and central portions of west-central, central and east-central South Dakota. This area extended from approximately New Underwood east along I-90 to approximately Mt. Vernon and north to the North Dakota border. All counties were in this area except the southern portions of the southernmost counties and Gregory, Charles Mix, and Douglas counties which were located south of I-90 (Figure 2-1). This area included portions of both the northern and central portions of the mixed-grass sub-regions which are part of the Eastern Prairie and Great Plains ecoregions (SDCWCP). I surveyed grasslands in 29 counties within this area during the breeding seasons of 2007 and 2008 (Table 2-1).

Patch Definition

A patch was defined as the grassland area contiguous with the survey area that was in the same cover type, management practice, and condition (Bakker et al. 2002). For example, a patch boundary was delineated when idled (i.e., ungrazed before July 15 of

Table 2-1. South Dakota counties in which grasslands were surveyed for grassland birds of greatest conservation need in summers of 2007 - 2008.

2007 & 2008 Counties	
McPherson	Edmunds
Faulk	Hyde
Hand	Buffalo
Brule	Jerald
Aurora	Lyman
Hughes	Sully
Potter	Walworth
Campbell	Corson
Ziebach	Dewey
Haakon	Stanley
Jones	Jackson
Meade	Perkins
Douglas	
Counties added in 2008	
Beadle	Charles Mix
Gregory	Pennington

the survey year) grassland met pasture land where cattle had been or were currently grazing. Seasonal, semi-permanent, and permanent wetlands or waterways ≥400m wide whose borders dissect the grassland were also used to delineate grassland patch boundaries. Permanent wetlands and waterways <400m wide were not used to delineate patch boundaries, but were subtracted from total grassland patch area. Temporary and seasonal wetlands were considered part of the grassland patch area because they were grassy during most of the breeding season. However, temporary and seasonal wetlands that contained water at the time of the survey were noted and subtracted from the total patch area as they did not supply habitat for the grassland obligate species. Shelterbelts or windbreaks ≥20m wide and extending across ≥90% of a grassland patch and highways or maintained gravel roads that traverse through the grasslands were considered to be barriers that define patch boundaries. Creek bottoms and river valleys were not considered boundaries unless they met the standards for at least one of the above criteria. Minimum maintenance roads and fence lines bordering grasslands of the same cover type and condition were not considered to be patch boundaries, but were noted. Prairie dog towns were considered to be a patch boundary if the vegetative structure of the patch differed considerably from that of the town. Large mud/clay flats that were found in the western portion of the study area were treated the same as wetlands (i.e. used to delineate patch boundaries when they were ≥400m and subtracted from total patch area when they were ≤400m in size).

Site Selection

All sites were selected using a stratified random design. Surveyed grasslands were equally distributed between the northern and central portions of the mixed-grass sub-region of the Eastern Prairie and Great Plains steppe ecoregions of South Dakota (SDCWCP) and throughout all the counties within the survey area (Figure 2-1). Survey sites were selected to include both public and private grasslands that encompassed a wide variety of management practices (i.e., pastures in different grazing regimes, idle, non-native invaded prairie, and grasslands containing prairie dog towns), slopes and varied in size and surrounding landscape composition. This stratification was done to ensure that as much natural variation of the study area was included as possible. Sites were selected by the availability and accessibility of native sod within the area and relation to previous sites. All sites were placed at a distance of ≥ 2km apart to assure survey points were independent. Site selection was done using maps from state and federal agencies showing the location of native sod, public walk-in maps, the predetermined criteria for selecting native sod, and by talking with local landowners. A new set of survey sites were chosen each year to obtain a larger sample over a greater geographic area (Meentemeyer 1989).

Methods

Preseason Training

Pre-survey training was completed by all technicians to minimize variation among observers (Reynolds et. al. 1980). Practice counts were conducted in late April and early May to standardize methodological protocol and help surveyors gain proficiency in

identification of grassland bird species and their songs and calls. Tape recordings of songs and calls and Thayer Birding Software (2007), which contains photographs and recordings of calls and songs, were used to help gain proficiency in recognition and identification of each species. Technicians gained aptitude in the use of vegetation measuring equipment and in identification of common plant species. Technicians performed vegetation measurements that were compared for accuracy, in an attempt to minimize sampling bias.

Bird Counts

Bird surveys were conducted from 29 May – 9 July, 2007, and 27 May – 10 July, 2008 which are within the guidelines of Wakeley (1987) and Ralph et. al. (1993). Bird surveys began at sunrise and ended by 10am (Emlen 1971, Wakely 1987, Ralph et. al. 1993). Grasslands were surveyed using fixed-width belt transects that were 200m long and 100m wide (50m on each side of the observer) (Wakeley 1987), because beyond 50m the detection probabilities of some grassland bird species declines rapidly (Diefenbach et. al. 2003). During 2007, only a single survey was conducted per grassland patch. In 2008, a second transect was included in patches large enough to encompass two transects (Klute et. al. 1997). The second survey was added to obtain a better estimate of bird density and was not used to calculate occurrence data. The second transect was placed ≥100m from the edge of the first. Transects were placed at least 30m from maintained roads, permanent and semi-permanent wetlands, rivers, lakes, shelterbelts, and other boundaries to minimize edge effect (Emlen 1971, Stewart and Kantrud 1972, Arnold and Higgins 1986, Wakeley 1987). Grasslands were surveyed only if they were large enough

to contain the entire transect(s) and the aforementioned buffer (Bakker et. al. 2002). All technicians carried an electronic device (mp3 player, cell phone, IPod) containing recorded songs and calls of the target species during surveys to help identify species if questions arose. Bird surveyors walked the transects at a slow and steady pace (approx. 1 km/hr) stopping frequently to identify and record birds species by sight, sound, or both (Ralph et. al. 1993, and Bakker et. al. 2002). All birds located within the transect boundaries were counted and recorded; movements of the birds were noted to help prevent double counting. Birds flying overhead or outside transect boundaries were noted but were not used in data analysis (Ralph et. al. 1993). Patches were systematically searched (walk-about) to determine the presence of other SoGCN or Level I & II priority bird species using theses patches but not located within the transects. Any nests found incidentally were noted but not monitored. Surveys were not conducted when weather conditions were unfavorable: if winds were ≥ 15 km/hr, if temperatures were $< 7^{o}$ C or $> 24^{o}$ C, if there was moderate or heavy rain, or if there was a heavy fog that limited visibility (Mikol 1980, Ralph et. al. 1993, and Klute et. al. 1997). In both years, grassland surveys started in the southern portion of the study area and moved north throughout the survey period to follow the migration (Bakker and Higgins 2003).

Vegetation Measurements

I quantified seven vegetation characteristics in each grassland at 25m intervals along the bird survey transect. These variables included visual obstruction (VO), litter depth (LD), tallest forb (TLf), tallest grass (TLg), tallest shrub (TLs), effective leaf height (ELH), and percent coverage readings for grass (PCg), forb (PCf), shrub (PCs), thatch

(PCt), bare ground (PCbg), “other” (PCo) (large rocks, manure from livestock, items not normally found in grasslands, etc..), native species (PCn), introduced grass (PCig), introduced forb (PCif), and total introduced species (PCti) (Table 2-2). The starting and ending points for each transect were marked on a Garmin GPS. Visual obstruction was measured using a Robel pole placed directly on the transect line. A measurement was taken in each of the four cardinal directions at a height of one meter, a distance of four meters, and to an obstruction of 100%, and then recorded to the nearest 0.25dm (Robel et. al. 1970 and Higgins and Barker 1982). Litter depth was measured at the four points corresponding to Robel measurements. To measure litter depth, a millimeter ruler was placed into the litter until it made contact with the soil and read to the nearest millimeter (Bakker et. al. 2002). Tallest forb, tallest grass and tallest woody plant were all measured by identifying the tallest individual of the respective plant type within the 4m circle of the Robel pole and then measuring its height to the nearest 0.25dm using a decimeter stick (Higgins and Barker 1982). Effective leaf height was measured by sliding a ruler horizontally down the Robel pole until it made contact with the first leaves of the plants or grasses below and recorded to the nearest 0.25dm (Higgins and Barker 1982). A $1m^2$ frame was used to estimate percent cover (using the Daubenmire cover classes) (class 0 = (0), class 1 (>0-5), class 2 = (>5-25) class 3 = (>25-50) class 4 = (>50-75), class 5 = (>75-95), and class 6 = (>95-100)) of grass, forbs, thatch, bare ground, “other”, woody plants and native vs. introduced species at every survey station along the bird transect (Daubenmire 1959). Each technician was provided with a copy of Grassland Plants of South Dakota and the Northern Great Plains (Johnson and Larson 1999) to help facilitate

Table 2-2. Vegetation variables measured for each surveyed grassland during summers 2007 and 2008 in central and western South Dakota and their corresponding code used in data analysis.

Variable	Code
Visual Obstruction (Robel)	VO
Litter Depth	LD
Tallest Forb	TLf
Tallest Grass	TLg
Tallest Shrub	TLs
Effective Leaf Height	ELH
Percent Coverage Grass	PCg
Percent Coverage Forb	PCf
Percent Coverage Shrub	PCs
Percent Coverage Thatch (Litter)	PCt
Percent Coverage Bare Ground	PCbg
Percent Coverage "Other"	PCo
Percent Coverage Native Species	PCn
Percent Coverage Introduced Grass	PCig
Percent Coverage Introduced Forb	PCif
Percent Coverage Total Introduced Species	PCti

plant identification and determination of native or introduced plant species. All sites were classified to a general habitat class based on current management practice. Slope was estimated and placed into a general class (none, moderate, steep) for each transect within the grassland.

Landscape Variables

Estimation of local patch and landscape variables was completed to further assess spatial characteristics of patches not quantified by local vegetation attributes (Table 2-3, 2-4). Patch area was calculated using Arc GIS software and the 2005 National Agriculture Imagery Programs (NAIP) imagery (aerial photos) from the South Dakota Department of Environment and Natural Resources Geologic Survey (SDDENR). The NAIP imagery was loaded into the Arc GIS program, a polygon was created to encompass the entire patch according to our definition, and the area of this polygon was calculated within Arc GIS. Survey areas were ground truthed to help validate the NAIP imagery and patch edges. Proportion of the patch edge surrounded by woody vegetation was calculated by dividing woody patch edge by total patch edge as determined by ground truthing in the field. The proportion of grassland surrounding survey sites was calculated for concentric rings of 400m, 800m, 1600m, and 3200m from the center of the bird survey transects using information from ground truthing and the use of the Multi-Resolution Land Characteristic Consortiums (MRLC) National Land Cover Database (NLCD) (2001) to assess whether bird presence was related to grassland composition and abundance in the surrounding landscape.

Table 2-3. Patch and landscape variables measured for each surveyed grassland during summers 2007 and 2008 in central and western South Dakota and their corresponding code used in data analysis.

Variable	Code
Patch Area (log transformed)	LPA
Percent Woody Edge	PWE
Percent Grass within 400m	PG400
Percent Grass within 800m	PG800m
Percent Grass within 1600m	PG1600m
Percent Grass within 3200m	PG3200m

Table 2-4. Independent variables measured for each surveyed grassland to evaluate bird occurrence and density during the summers 2007 and 2008 in central and western South Dakota.

Measurement	Units	Variable Type
Visual Obstruction	0.25 Decimeters	Continuous
Litter Depth	Millimeters	Continuous
Tallest Plant Type	0.25 Decimeters	Continuous
Effective Leaf Height	0.25 Decimeters	Continuous
Percent Coverage Frame	Percent	Categorical
Management Type	Grazed, Grazed Spring, Grazed Last Year, Idle, Burned	Categorical
Patch Area	Hectares	Continuous
Slope	None, Moderate, Steep	Categorical
Woody Edge	Percent	Continuous
Surrounding Grassland	Percent	Continuous

Data Analyses

Grassland bird densities and average occurrence rates for all species were calculated from survey data. Occurrence rate was calculated as number of grasslands in which a given species was observed, compared to total number of grassland patches surveyed, and was recorded as percent occurrence. I recorded these measurements for both the transect and the walk-about but walk-about value was not used in analysis. Density was calculated by dividing the number of individuals of a given species by the area of the transect (2 ha) and multiplying by 50 to yield number of birds per 100 ha. Density was calculated for both territorial males and total number of birds for each given species.

Since patch area was not normally distributed, I log transformed the data and used this value in model development. A priori models established from the literature were used with complete linear (Galton 1877) and logistic regression (Hosmer and Lemeshow 1989) to develop models to evaluate the influence of local, patch and landscape attributes on density and occurrence of grassland bird species. In the first set of candidate models for each species, only local (vegetation structure and composition) variables were used to develop the models. Only patch level (patch area and amount of woody edge) variables were used in development of the second set of candidate models. In the third set of candidate models, only landscape level (amount of surrounding grassland) variables were included in the development process. In a fourth set of candidate models, uncorrelated ($|r| < 0.5$) (Fletcher and Koford 2002), local and patch variables were used in combination to develop the models. The fifth set of candidate models were developed by using

uncorrelated ($|r| < 0.5$) (Fletcher and Koford 2002), local and landscape variables. In the final set (sixth) of candidate models, local, patch, and landscape variables that were uncorrelated ($|r| < 0.5$) (Fletcher and Koford 2002) were used in model development. I used Akaike's information criterion (AIC) (Akaike 1969, Liberton et. al. 1992, and Burnham and Anderson 1998) as a basis for model selection. Variables considered to be "best" from all previous model sets were used in development of final models. I considered the model that yielded the smallest AIC value to be the most parsimonious and the best approximation for the information in the data set (Burnham and Anderson 1998). Since it is the relative change in AIC between models and not the AIC value that is important, Burnham and Anderson (1998) suggested reporting the change in AIC (ΔAIC) rather than it's actual value to show support for developed models. Both AIC and ΔAIC are reported when comparing any two developed models in this document. I considered any model with a ΔAIC of ≤ 2, when compared to the "best" model to be a competitive alternative (Burnham and Anderson 1998). All calculations and models were performed or developed using Systat software (Systat 2007).

CHAPTER 3

RESULTS

Study Sites

I surveyed 292 grassland patches over 2 field seasons. Four surveys were too close to a previous survey point and were removed to avoid pseudo-replication and to assure that all points were independent (Hurlbert 1984). Therefore, the number of grasslands used in analysis was 288 (Appendix B). The average patch size was 907.4ha with a range of 10.5ha-12,852.2ha (Table 3-1).

Vegetation

There was a large variation in local, patch and landscape variables (Table 3-1). Visual obstruction (Robel) readings had a mean of 1.4dm (0.0dm - 5.0dm). Litter depth had a mean of 13.5mm (0.0mm - 63.3mm). Ground cover according to the daubenmire class method for surveyed grasslands was as follows, mean grass 55.5% (5.3% - 94.7%), mean thatch 17.5% (0.0% - 58.1%), mean bare-ground 7.9% (0.0% - 59.4%), mean introduced grass species 36.0% (0.0% - 85.0%), and mean total introduced species 41.5% (0.0% - 98.2%). Amount of woody edge had a mean of 6.4% (0.0% to 75.0%). The amount of grass in the concentric rings (400m, 800m, 1600, 3200m) ranged from 0.0% - 100% for all buffer sizes, but each had a different mean (Table 3-1). It will be noted as to what management type is related to the preferred habitat structure for each species occurrence and density in the discussion section.

[B] See appendix B for list of surveyed grasslands and their locations.

Table 3-1. Mean, minimum, maximum, and standard error for independent variables collected from surveyed grasslands (N=288) during summers of 2007 and 2008, used to develop density and occurrence models for grassland obligate species in central and western South Dakota.

Variable	Mean	Minimum	Maximum	±SE
Robel (dm)	1.4	0.0	5.0	±0.1
Tall Grass (dm)	7.8	3.3	13.3	±0.1
Tall Forb (dm)	5.1	0.3	11.5	±0.1
Tall Shrub (dm)	2.0	0.0	13.1	±0.2
Litter Depth (mm)	13.5	0.0	63.3	±0.8
Leaf Height (dm)	2.9	0.7	8.6	±0.1
PC Grass (%)	55.5	5.3	94.7	±0.8
PC Forb (%)	19.0	0.0	64.4	±0.8
PC Shrub (%)	1.5	0.0	74.7	±0.3
PC Thatch (%)	17.5	0.0	58.1	±0.7
PC Bare-ground (%)	7.9	0.0	59.4	±0.6
PC Other (%)	1.6	0.0	16.4	±0.1
PC Native Species (%)	31.2	0.0	94.7	±1.4
PC Introduced Grass Species (%)	36.0	0.0	85.0	±1.3
PC Introduced Forb Species (%)	6.2	0.0	59.2	±0.5
PC Total Introduced Species (%)	41.5	0.0	98.2	±1.4
Patch Area (Ha)	907.4	10.5	12,852.2	±104.0

Table 3-1 Continued

Variable	Mean	Minimum	Maximum	±SE
Woody Edge (%)	6.4	0.0	75.0	±0.6
Amount of Grass 400m (%)	74.5	0.0	100.0	±2.0
Amount of Grass 800m (%)	71.1	0.0	100.0	±2.0
Amount of Grass 1600m (%)	68.1	0.0	100.0	±2.0
Amount of Grass 3200m (%)	66.0	0.0	100.0	±2.0

Grassland Obligate Species Transect Occurrence

I had 638 total bird occurrences of the 10 study species within the transects of the surveyed grasslands (N=288). Baird' Sparrows were found in 5 (2%), chestnut-collared longspurs were found in 54 (19%), lark buntings were found in 74 (26%) and Sprague's pipits were found in 2 (1.0%) of the 288 bird transects (Table 3-2). Grasshopper sparrows, lark buntings and western meadowlarks made up over 73% of all bird occurrences within the transects. Grasshopper sparrows (N=203) were the most commonly occurring bird in transects followed by western meadowlarks (N = 191) and lark buntings (N = 74). The remaining portion of grassland bird occurrences (27%) were largely accounted for by chestnut-collared longspurs (N=54) and bobolinks (N=52) (Table 3-2).

Grassland Obligate Species Walk-about Occurrence

There were 918 occurrences of the 10 study species within the walk-abouts of the surveyed grasslands. I found Baird's sparrows in 11 (4%), chestnut-collared longspurs in 67 (23%), lark buntings in 113 (39%) and Sprague's pipits in 5 (2%) grasslands (Table 3-3). Eighty one percent of 918 walk-about occurrences were accounted for by western meadowlarks (N = 278), grasshopper sparrows (N = 240), lark buntings (N = 113) and bobolinks (N = 109). Two other species made up 15% of the total walk-about occurrences, savannah sparrows (N = 68) and chestnut-collared longspurs (N = 67). The remaining 4% of walk-about occurrences were made up of Dickcissels (N = 27), Baird's sparrows (N = 11), and Sprague's Pipits (N = 5) (Table 3-3). The most commonly detected bird species in walk-abouts were western meadowlarks (N=278), grasshopper

Table 3-2. Number of occurrences, percent occurrence and percent composition of total grassland bird occurrences (N=638) for each study species, within the transects of the surveyed grasslands (N=288) in central and western South Dakota during summer 2007 and 2008.

Species	# of Occurrences	% Transect Occurrences	% Composition of Occurrences
Baird's Sparrow	5	2%	1%
Bobolink	52	18%	8%
Chestnut-Collared Longspur	54	19%	8%
Dickcissel	12	4%	2%
Grasshopper Sparrow	203	70%	32%
Lark Bunting	74	26%	12%
Le Conte's Sparrow	0	0%	0%
Savannah Sparrow	46	16%	7%
Sprague's Pipit	2	1%	0%
Western Meadowlark	191	66%	30%
Total	638	N/A	100%

Table 3-3. Number of occurrences, percent occurrence and percent composition of total grassland bird occurrences (N=918) for each species within the walk-about of the surveyed grasslands (N=288) in central and western South Dakota during summer 2007 and 2008.

Species	# of Occurrences	% Walk-about Occurrence	% Composition of Occurrences
Baird's Sparrow	11	4%	1%
Bobolink	109	38%	12%
Chestnut-Collared Longspur	67	23%	7%
Dickcissel	27	9%	3%
Grasshopper Sparrow	240	83%	26%
Lark Bunting	113	39%	12%
Le Conte's Sparrow	0	0%	0%
Savannah Sparrow	68	24%	7%
Sprague's Pipit	5	2%	1%
Western Meadowlark	278	97%	30%
Total	918	N/A	100%

sparrows (N = 240), lark buntings (N = 113), and bobolinks (N = 109). The walk-about increased the number of all focus species detections except the Le Conte's sparrow (Table 3-4) and also increased the number of detections for non-target species.

Grassland Obligate Species Occurrence Models

Habitat models were created using male transect occurrence data for each grassland bird species that was present in more than one transect. To avoid including grasslands that would never be occupied by a selected species, regardless of habitat quality, I reduced the number of grasslands used in analysis to include only survey points that were within the selected species distribution (Bakker et. al. 2002). Species with reduced sample sizes included Baird's sparrows (N=182), savannah sparrows (N=131), and Sprague's pipits (N=199). The Le Conte's sparrow had no occurrences within the transects and therefore no model could be created for this species.

Baird's Sparrow

Baird's sparrow occurrence was positively associated with grass height, amount of forb in the patch, amount of woody edge around the patch and amount of surrounding grassland up to 800m, and negatively associated with shrub height, litter depth and amount of "other" material covering the ground of a grassland (Table 3-5). Three of the four competitive models were found to contain variables from all three spatial scales (local, patch and landscape), while the final model contained only local and landscape level variables. Averages of measured variables for grasslands occupied by Baird's sparrows are listed in (Table 3-6).

Table 3-4. Number of transects and walk-abouts in which a species was detected, and number of increased detections due to the walk-about for each species in the surveyed grasslands (N=288) in central and western South Dakota during summer 2007 and 2008.

Species	# of Transect Detections	# of Walk-about Detections	# of Increased Detections
Baird's Sparrow	5	11	6
Bobolink	52	109	57
Chestnut-Collared Longspur	54	67	13
Dickcissel	12	27	15
Grasshopper Sparrow	203	240	37
Lark Bunting	74	113	39
Le Conte's Sparrow	0	0	0
Savannah Sparrow	46	68	22
Sprague's Pipit	2	5	3
Western Meadowlark	191	278	87
Total	638	918	280

Table 3-5. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for Baird's sparrow transect occurrence (N=5) in surveyed grasslands (N=182) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Baird's Sparrow Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local, Patch and Landscape	+TLg –TLs +PCf –PCo +PWE +PG400m	37.7	0.0
Local, Patch and Landscape	+TLg –TLs –LD +PCf –PCo +PWE +PG400m	39.0	+1.3
Local, Patch and Landscape	+TLg +PCf –PCo +PWE +PG800m	39.0	+1.3
Local and Landscape	+TLg –TLs +PCf –PCo +PG400m	39.4	+1.7
Local and Patch	+TLG –TLs –LD +PCf –PCo +PWE	40.0	+2.3
Local and Patch	+TLg –TLs +PCf –PCo +PWE	40.0	+2.3
Local and Landscape	+TLg –TLs –LD +PCf –PCo +PG400m	40.3	+2.6
Local	+TLg –TLs +PCf –PCo	40.6	+2.9
Local	+TLg –TLs –LD +PCf –PCo	40.9	+3.2
Patch	+PWE	46.5	+8.8
Patch	+PWE +LPA	48.5	+10.8
Landscape	+PG400m	49.1	+11.4
Landscape	+PG800m	49.4	+11.7

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-6. List of measured variables means (±SE) and ranges for grasslands occupied by Baird's sparrows (N=5) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	1.6 (±0.5)	0.0	2.9
Tall Grass (dm)	10.1 (±0.7)	7.8	12.0
Tallest Forb (dm)	5.2 (±0.6)	3.9	6.8
Tallest Shrub (dm)	0.5 (±0.2)	0.0	0.9
Litter Depth (mm)	16.8 (± 4.3)	1.6	28.2
Leaf Height (dm)	2.9 (±0.4)	2.6	4.3
PC Grass (%)	60.8 (±7.0)	40.6	84.2
PC Forb (%)	29.3 (±3.9)	18.9	38.3
PC Shrub (%)	0.7 (±0.4)	0.0	1.7
PC Thatch (%)	23.1 (±3.2)	11.9	28.9
PC Bare Ground (%)	3.6 (±1.7)	0.0	9.7
PC Other (%)	0.2 (±0.1)	0.0	0.6
PC Native (%)	36.6 (±10.8)	3.9	61.7
PC Intro Grass (%)	40.0 (±12.5)	0.8	65.6
PC Intro Forb (%)	4.8 (±1.8)	0.0	9.4
PC Total Intro (%)	41.8 (±12.5)	0.8	65.6
Patch Area (ha)	390.4 (±170.0)	43.1	966.2
% Woody Edge	16.0 (±9.1)	0.0	50.0

Table 3-6 Continued Variable Means for Baird's Sparrow

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	85.8 (±6.2)	65.0	97.0
% Grass 800m	80.2 (±5.8)	62.0	98.0
% Grass 1600m	76.0 (±6.9)	59.0	95.0
% Grass 3200m	67.0 (±8.8)	34.0	84.0

Bobolink

Bobolink occurrence was positively associated with visual obstruction (Robel) and percent of introduced grass within the patch and negatively associated with the amount of bare ground and grass cover, amount of woody edge surrounding the grassland and the amount of grassland surrounding the patch up to 1600m (Table 3-7). Four of the eight competitive models for bobolinks contained both local and landscape level variables, while three contained only local level variables and one contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by bobolinks are listed in (Table 3-8).

Chestnut-Collared Longspur

The models for chestnut-collared longspur occurrence indicated a positive association with amount of shrub within the grassland and percent of grassland surrounding the patch up to 1600m and a negative association to visual obstruction, percent ground cover of introduced forbs and amount of woody edge surrounding the grassland patch (Table 3-9). Probability of occurrence for chestnut-collared longspurs was reduced from 20% to 10% with an increase in woody edge from 0 to 3.5%, and the presence of any woody edge indicated a probability of occurrence less than 30% (Figure 3-1). Two of the top four competitive models contained both local and patch level variables, while the other two contained variables associated with all three spatial scales. Averages of measured variables for grassland occupied by chestnut-collared longspurs are listed in (Table 3-10).

Table 3-7. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for bobolink transect occurrence (N=52) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Bobolink Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	+VO –PCg –PCbg +PCig –PG1600m	202.4	0.0
Local and Landscape	+VO –PCbg +PCig –PG1600m	202.9	+0.5
Local and Landscape	+VO +PCig –PC1600m	203.0	+0.6
Local and Landscape	+VO +PCig –PG800m	203.1	+0.7
Local	+VO –PCg –PCbg –PCig	203.3	+0.9
Local	+VO –PCg –PCig	203.9	+1.5
Local	+VO –PCbg +PCig	204.3	+1.9
Local, Patch and Landscape	+VO –PCg –PCbg +PCig –PWE –PG1600m	204.4	+2.0
Local and Patch	+VO –PCg –PCbg +PCig –LPA	204.7	+2.3
Local, Patch and Landscape	+VO +PCig –PWE –PG1600m	204.9	+2.5
Local and Patch	+VO–PCbg +PCig –LPA	205.5	+3.1
Landscape	–PG1600m	249.3	+46.9
Landscape	–PG800m	250.6	+48.2
Patch	–LPA	256.7	+54.3
Patch	+PWE –LPA	258.7	+56.3

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-8. List of measured variables means (±SE) and ranges for grasslands occupied by bobolinks (N=52) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	2.3 (±0.1)	0.0	5.0
Tall Grass (dm)	8.6 (±0.2)	3.5	11.3
Tallest Forb (dm)	5.2 (±0.4)	0.3	11.0
Tallest Shrub (dm)	2.6 (±0.5)	0.0	12.6
Litter Depth (mm)	20.8 (±2.1)	0.1	57.8
Leaf Height (dm)	3.8 (±0.2)	1.5	6.4
PC Grass (%)	61.3 (±2.1)	5.3	85.3
PC Forb (%)	14.6 (±2.0)	0.0	64.4
PC Shrub (%)	1.5 (±0.4)	0.0	18.1
PC Thatch (%)	21.4 (±1.3)	3.6	45.8
PC Bare Ground (%)	2.3 (±0.5)	0.0	15.3
PC Other (%)	0.6 (±0.2)	0.0	5.8
PC Native (%)	12.9 (±2.1)	0.0	64.4
PC Intro Grass (%)	56.1 (±2.5)	5.3	85.0
PC Intro Forb (%)	6.6 (±1.4)	0.0	43.3
PC Total Intro (%)	61.2 (±2.5)	5.3	98.2
Patch Area (ha)	260.4 (±64.2)	15.9	2658.7
% Woody Edge	8.3 (±1.7)	0.0	70.0

Table 3-8 Continued Variable Means for Bobolink

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	56.5 (±4.7)	0.0	95.0
% Grass 800m	51.7 (±4.4)	0.0	98.0
% Grass 1600m	48.8 (±4.3)	0.0	98.0
% Grass 3200m	48.2 (±4.1)	1.0	96.0

Table 3-9. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for Chestnut-collared longspur transect occurrence (N=54) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Chestnut-Collared Longspur Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Patch	–VO –PCif –PWE	204.7	0.0
Local, Patch and Landscape	–VO –PCif –PWE +PG400m	206.6	+1.9
Local and Patch	–VO –PCif +PCs –PWE	206.6	+1.9
Local, Patch and Landscape	–VO –PCif –PWE +PG1600m	206.7	+2.0
Local	–VO –PCif	232.4	+27.7
Local	–VO –PCg	232.5	+27.8
Local and Landscape	–VO –PCif +PG1600m	233.3	+28.6
Local and Landscape	–VO –PCif +PG800m	233.7	+29.0
Patch	–PWE	253.2	+48.5
Patch	–PWE +LPA	254.6	+49.9
Landscape	+PG160000m	274.6	+69.9
Landscape	+PG400m	275.5	+70.8

*** ΔAIC is change in AIC when current model is compared to the best model.**

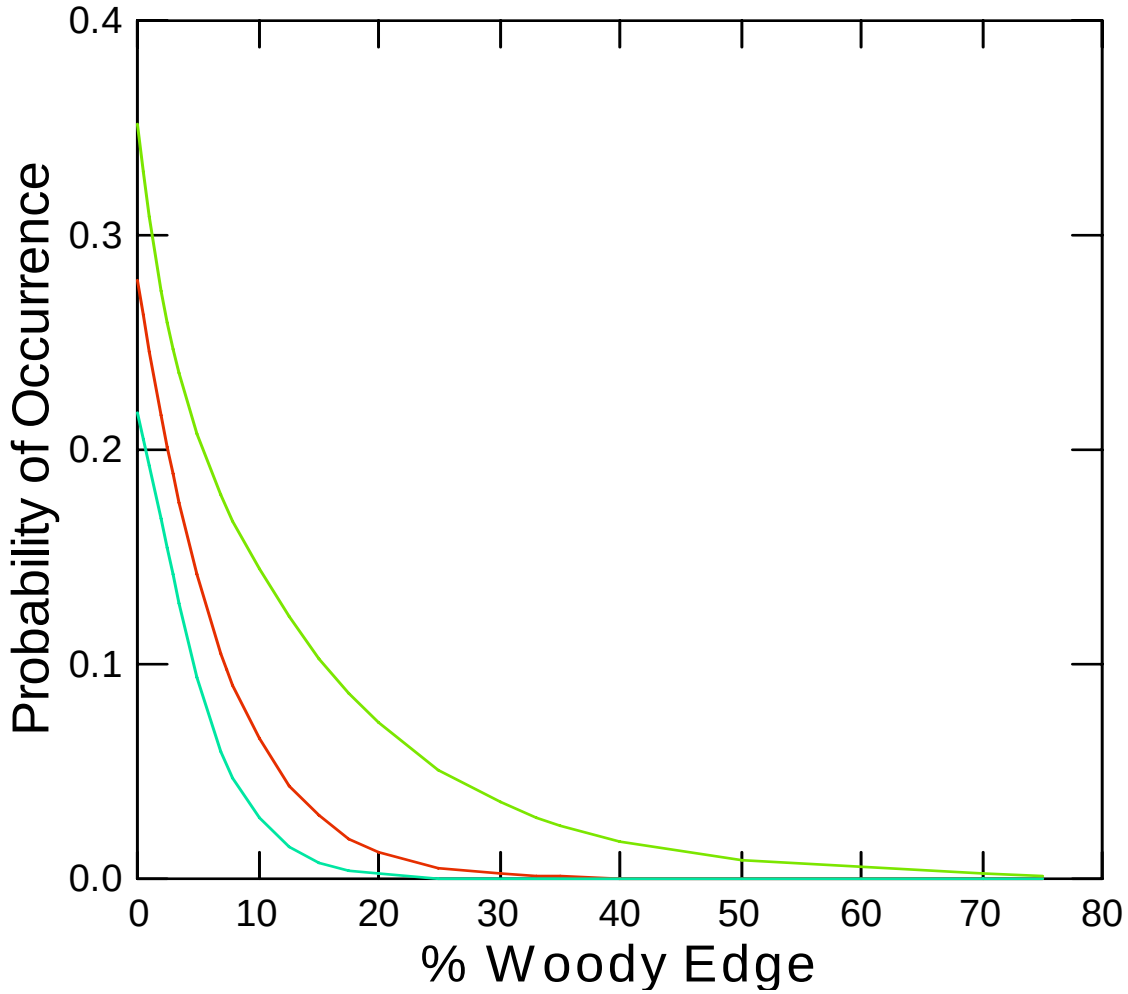

Figure 3-1. Probability of detecting chestnut-collared longspurs in grasslands (N=288) with increasing percentages woody edge in western and central South Dakota for summers 2007 and 2008. Green and blue lines indicate 95% confidence intervals.

Table 3-10. List of measured variables means (±SE) and ranges for grasslands occupied by chestnut-collared longspurs (N=54) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	0.6 (±0.1)	0.0	1.9
Tall Grass (dm)	7.4 (±0.2)	3.3	10.6
Tallest Forb (dm)	4.2 (±0.2)	1.5	6.8
Tallest Shrub (dm)	1.7 (±0.3)	0.0	7.6
Litter Depth (mm)	5.2 (±0.8)	0.0	31.1
Leaf Height (dm)	2.3 (±0.1)	0.7	4.6
PC Grass (%)	53.6 (±1.7)	32.8	85.0
PC Forb (%)	20.4 (±1.5)	1.7	46.1
PC Shrub (%)	1.3 (±0.3)	0.0	13.1
PC Thatch (%)	14.2 (±1.6)	0.0	45.8
PC Bare Ground (%)	11.0 (±1.4)	0.0	47.5
PC Other (%)	2.4(±0.3)	0.0	10.0
PC Native (%)	44.3 (±3.5)	2.5	82.5
PC Intro Grass (%)	22.8 (±2.7)	0.0	75.0
PC Intro Forb (%)	3.4 (±0.6)	0.0	21.1
PC Total Intro (%)	26.1 (±2.9)	0.8	85.0
Patch Area (ha)	1125.2 (±240.3)	17.7	10835.2
% Woody Edge	1.2 (±0.4)	0.0	15.0

Table 3-10 Continued Variable Means for Chestnut-Collared Longspurs

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	83.0 (±3.0)	0.0	100.0
% Grass 800m	79.2 (±3.2)	1.0	100.0
% Grass 1600m	77.1 (±2.9)	8.0	99.0
% Grass 3200m	73.6 (±2.6)	17.0	98.0

Dickcissel

Dickcissel occurrence was positively associated with litter depth and effective leaf height and was negatively associated with patch area (Table 3-11). Eight of the 18 competitive models contained only local level variables, while three contained only patch level variables, four contained only landscape level variables and three contained local and patch level variables. Averages of measured variables for grasslands occupied by dickcissels are listed in (Table 3-12).

Grasshopper Sparrow

Grasshopper sparrow occurrence was positively associated with the amount of thatch covering the ground and amount of grassland habitat within 400m of the survey point, and had a negative association with shrub height, litter depth, and the amount of woody edge surrounding the patch (Table 3-13). Probability of occurrence for the grasshopper sparrow was greater than 75% when no woody edge was present, but fell below 15% when woody edge occupied over 75% of the patch (Figure 3-2). Grasshopper sparrow probability of occurrence was greater than 70% when the surrounding landscape contained 75% grassland habitat within 400m (Figure 3-3). The two competitive models contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by grasshopper sparrows are listed in (Table 3-14).

Lark Bunting

Lark bunting occurrence was positively associated with amount of bare ground and forb within a grassland patch and also with the amount of grassland surrounding that patch within 3200m, and was negatively associated with visual obstruction, amount of

Table 3-11. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for dickcissel transect occurrence (N=12) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Dickcissel Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Patch	–LPA	102.4	0.0
Local	+ELH	103.2	+0.8
Local	+LD	103.3	+0.9
Local	+VO	103.4	+1.0
Landscape	–PG1600m	103.5	+1.1
Landscape	–PG3200m	103.5	+1.1
Patch	+PWE	103.6	+1.2
Local	+PCg	103.6	+1.2
Local	+PCig	103.7	+1.3
Landscape	–PG800m	103.7	+1.3
Local	–PCf	103.8	+1.4
Local	–PCs	103.8	+1.4
Landscape	–PG400m	103.8	+1.4
Local	–PCbg	103.8	+1.4
Local and Patch	–LPA +LD	104.1	+1.7
Local and Patch	–LPA +ELH	104.2	+1.8
Local and Patch	+VO –LPA	104.4	+2.0

Table 3-11 Dickcissel Occurrence Continued

Model Set	Model	AIC	*ΔAIC
Patch	+PWE –LPA	104.4	+2.0
Local and Landscape	+LD –PG1600	104.9	+2.5
Local and Landscape	+LD –PG800m	105.0	+2.6
Local, Patch and Landscape	+ELH +PWE –PG1600m	107.0	+4.6
Local, Patch and Landscape	+ELH +PWE +PG400m	107.1	+4.7

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-12. List of measured variables means (±SE) and ranges for grasslands occupied by dickcissels (N=12) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	1.5 (±0.2)	0.3	2.9
Tall Grass (dm)	8.5 (±0.4)	6.9	10.8
Tallest Forb (dm)	5.6 (±0.5)	1.6	7.7
Tallest Shrub (dm)	0.8 (±0.5)	0.0	4.8
Litter Depth (mm)	17.0 (±3.56)	2.7	37.1
Leaf Height (dm)	3.2 (±0.3)	1.5	4.4
PC Grass (%)	56.8 (±3.7)	26.1	75.0
PC Forb (%)	18.8 (±2.8)	5.8	32.5
PC Shrub (%)	1.4 (±0.8)	0.0	8.6
PC Thatch (%)	15.6 (±2.60)	2.5	26.9
PC Bare Ground (%)	7.8 (±3.0)	0.0	36.9
PC Other (%)	1.6 (±0.7)	0.0	6.7
PC Native (%)	32.6 (±8.0)	1.7	81.3
PC Intro Grass (%)	38.2 (±6.4)	3.8	64.2
PC Intro Forb (%)	6.9 (±2.3)	0.8	27.2
PC Total Intro (%)	42.4 (±6.1)	7.2	63.1
Patch Area (ha)	408.8 (±158.0)	20.8	1719.2
% Woody Edge	7.6 (±2.8)	0.0	30.0

Table 3-12 Continued Variable Means for Dickcissel

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	73.8 (±6.7)	22.0	100.0
% Grass 800m	68.7 (±6.8)	27.0	97.0
% Grass 1600m	63.7 (±7.3)	19.0	95.0
% Grass 3200m	62.3 (±6.5)	10.0	86.0

Table 3-13. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for grasshopper sparrow transect occurrence (N=203) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Grasshopper Sparrow Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local, Patch and Landscape	–TLs +PCt –LD –PWE +PG400m	319.3	0.0
Local, Patch and Landscape	–TLs +PCt –LD –PWE +PG800m	321.9	+2.6
Local and Landscape	–TLs +PCt –LD +PG400m	322.6	+3.3
Local and Landscape	–TLs +PCt –LD +PG800m	325.2	+5.9
Local and Patch	–TLs +PCt –LD –PWE +LPA	332.7	+13.4
Local and Patch	–TLs –VO –PWE	333.4	+14.1
Landscape	+PG400m	334.4	+15.1
Landscape	+PG800m	336.8	+17.5
Patch	–PWE +LPA	340.2	+20.9
Local	–VO –TLs	341.4	+22.1
Local	–TLs +PCt –LD	341.6	+22.3
Patch	–PWE	341.9	+22.6

*** ΔAIC is change in AIC when current model is compared to the best model.**

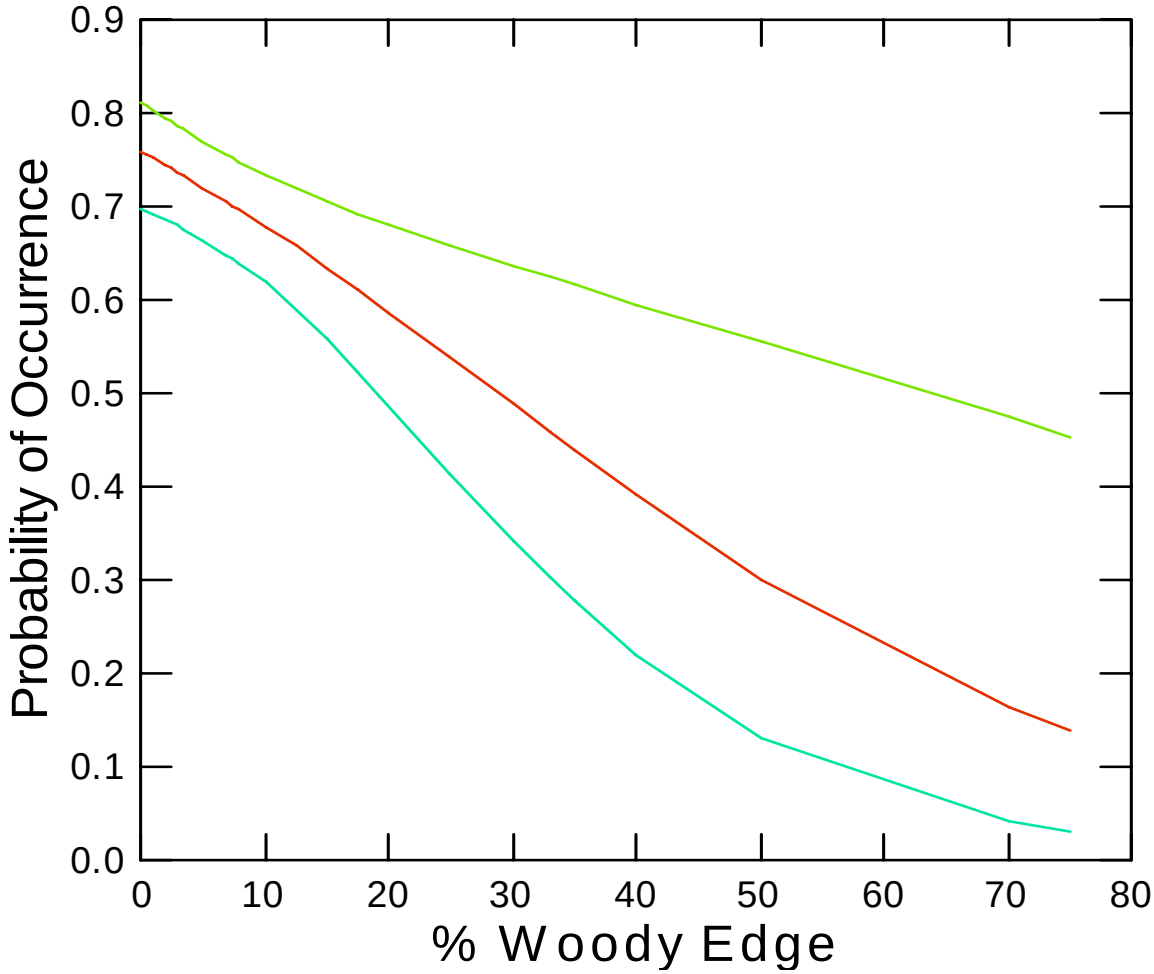

Figure 3-2. Probability of detecting grasshopper sparrows in grasslands (N=288) with increasing percentages of woody edge in western and central South Dakota for summers 2007 and 2008. Green and blue lines indicate 95% confidence intervals.

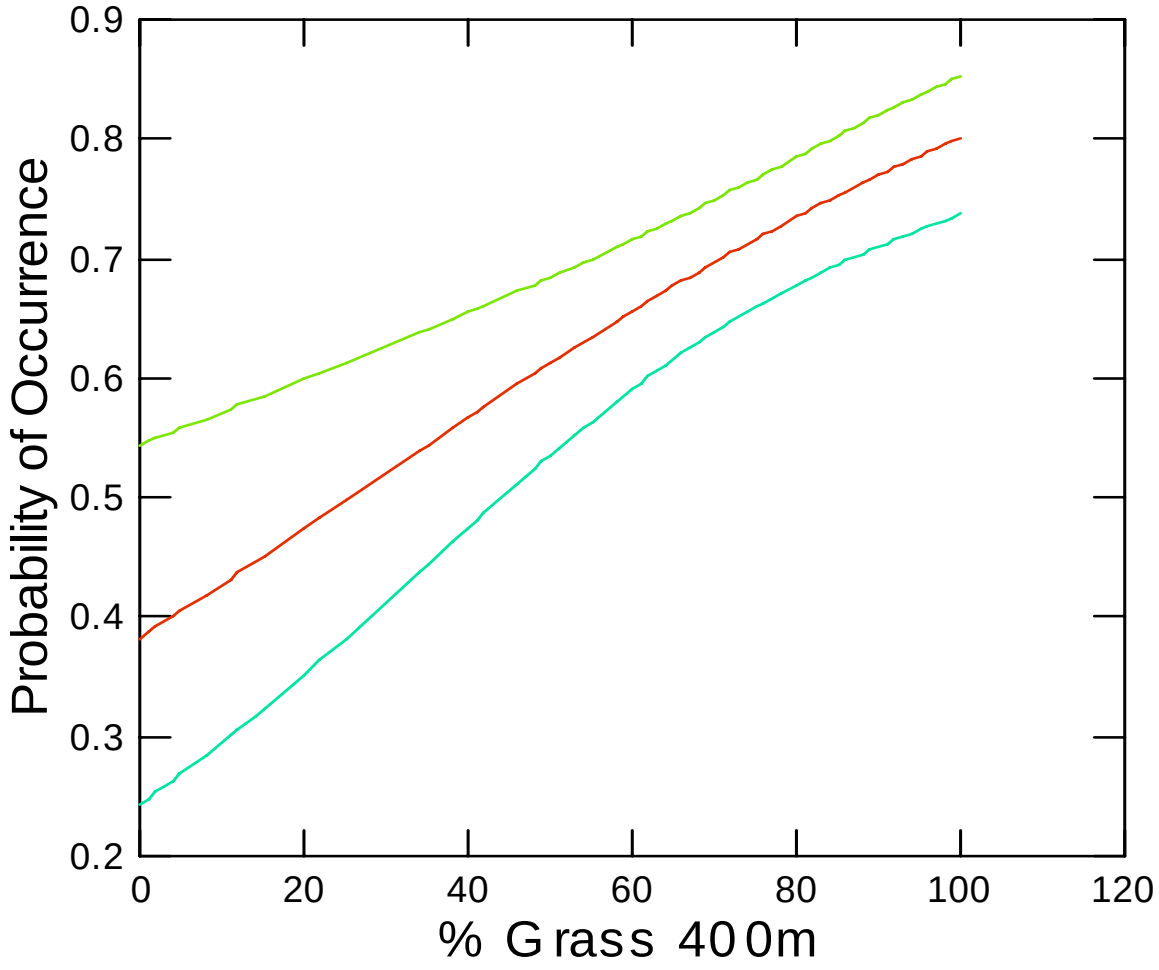

Figure 3-3. Probability of detecting grasshopper sparrows in grasslands (N=288) with increasing percentages of grassland habitat within 400m of the survey point western and central South Dakota for summers 2007 and 2008. Green and blue lines indicate 95% confidence intervals.

Table 3-14. List of measured variables means (±SE) and ranges for grasslands occupied by grasshopper sparrows (N=203) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	1.3 (±0.1)	0.0	5.0
Tall Grass (dm)	7.8 (±0.1)	3.5	13.3
Tallest Forb (dm)	5.1 (±0.1)	0.7	11.0
Tallest Shrub (dm)	1.6 (±0.2)	0.0	10.5
Litter Depth (mm)	12.2 (±0.9)	0.0	54.9
Leaf Height (dm)	2.8 (±0.1)	0.9	8.6
PC Grass (%)	55.0 (±1.0)	19.7	94.7
PC Forb (%)	20.0 (±0.8)	0.8	62.2
PC Shrub (%)	1.5 (±0.4)	0.0	74.7
PC Thatch (%)	17.6 (±0.9)	0.0	58.1
PC Bare Ground (%)	7.8 (±0.6)	0.0	48.3
PC Other (%)	1.7 (±0.2)	0.0	16.4
PC Native (%)	32.5 (±1.7)	0.0	94.7
PC Intro Grass (%)	34.1 (±1.5)	0.0	82.8
PC Intro Forb (%)	6.4 (±0.6)	0.0	43.3
PC Total Intro (%)	39.4 (±1.6)	0.8	98.2
Patch Area (ha)	1018.6 (±132.1)	10.5	12852.2
% Woody Edge	4.9 (±0.7)	0.0	75.0

Table 3-14 Continued Variable Means for Grasshopper Sparrow

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	79.5 (±1.7)	0.0	100.0
% Grass 800m	75.8 (±1.8)	0.0	100.0
% Grass 1600m	72.1 (±1.8)	1.0	100.0
% Grass 3200m	69.0 (±1.7)	1.0	100.0

introduced grass and amount of "other" material within the patch (Table 3-15). Probability of occurrence for lark buntings was less than two percent when the surrounding landscape contained only one percent grass within 3200m, but increased to 50% when grassland habitat occupied 99% of the surrounding landscape (Figure 3.4). Three of the five competitive models contained variables from both local and landscape spatial scales while the remaining two contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by lark buntings are listed in (Table 3-16).

Savannah Sparrow

Savannah sparrow occurrence was positively associated with visual obstruction, litter depth, amount of thatch covering the ground, and the amount of grass within 3200m, and was negatively associated with amount of bare ground (Table 3-17). Six of the seven competitive models contained variables from local and landscape level, while one contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by savannah sparrows are listed in (Table 3-18).

Sprague's Pipit

Sprague's pipit occurrence was positively associated with the amount of grass surrounding the patch up to 3200m, and was negatively associated with forb height, shrub height, amount of bare ground, amount of introduced grass coverage within the grassland and amount of woody edge surrounding the grassland patch (Table 3-19). It is important to note that I had only two Sprague's pipit transect occurrences which may affect the accuracy of the developed model. Six of the eight competitive models for the Sprague's

Table 3-15. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for lark bunting transect occurrence (N=74) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Lark Bunting Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	–VO +PCf +PCbg –PCo +PG3200m	261.5	0.0
Local and Landscape	–VO +PCf +PCbg –PCo +PG1600m	262.0	+0.5
Local and Landscape	–VO +PCf +PCbg –PCo –PCig +PG3200m	262.7	+1.2
Local, Patch and Landscape	–VO +PCf +PCbg –PCo +PWE +PG3200m	263.0	+1.5
Local, Patch and Landscape	–VO +PCf +PCbg –PCo +PWE +PG1600m	263.4	+1.9
Local	–VO +PCf –PCig +PCbg –PCo	268.9	+7.4
Local and Patch	–VO +PCf –PCig +PCbg –PCo +LPA	269.6	+8.1
Local and Patch	–VO +PCf –PCig +PCbg –PCo +PWE	270.5	+9.0
Local	–VO +PCf –PCig +PCbg	273.3	+11.8
Landscape	+PG3200m	294.7	+33.2
Landscape	+PG1600m	295.8	+34.3
Patch	+LPA	318.9	+57.4
Patch	+PWE +LPA	320.8	+59.3

*** ΔAIC is change in AIC when current model is compared to the best model.**

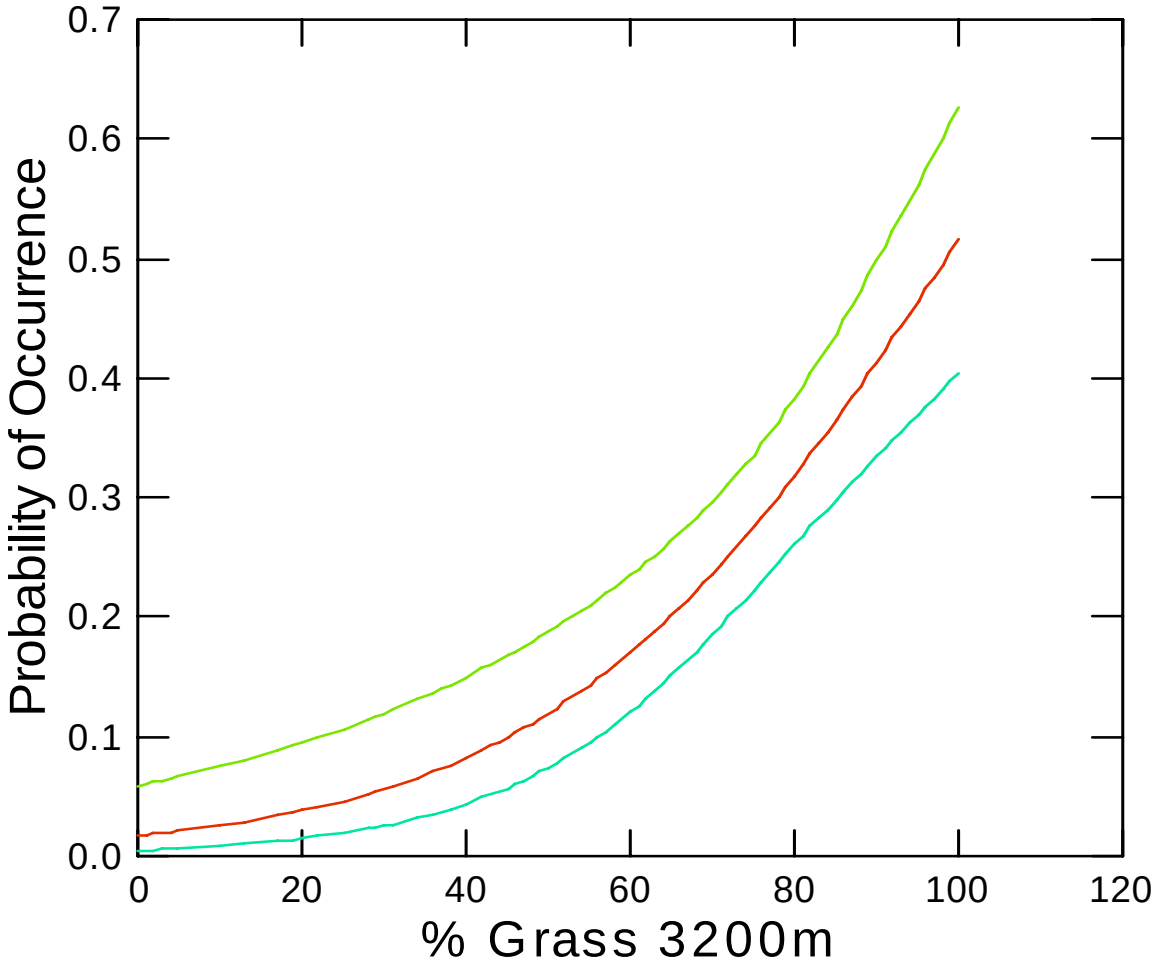

Figure 3-4. Probability of detecting lark buntings in grasslands (N=288) with increasing percentages of grassland habitat within 3200m of the survey point in western and central South Dakota for summers 2007 and 2008. Green and blue lines indicate 95% confidence intervals.

Table 3-16. List of measured variables means (±SE) and ranges for grasslands occupied by lark buntings (N=74) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	0.8 (±0.1)	0.0	3.6
Tall Grass (dm)	7.2 (±0.2)	3.5	10.4
Tallest Forb (dm)	4.8 (±0.2)	1.6	8.4
Tallest Shrub (dm)	1.6 (±0.2)	0.0	8.6
Litter Depth (mm)	8.2 (±1.2)	0.0	44.9
Leaf Height (dm)	2.6 (±0.1)	1.0	5.3
PC Grass (%)	50.8 (±1.6)	19.7	81.7
PC Forb (%)	23.7 (±1.4)	5.3	62.2
PC Shrub (%)	1.4 (±0.3)	0.0	8.6
PC Thatch (%)	12.4 (±1.3)	0.0	53.9
PC Bare Ground (%)	14.2 (±1.5)	0.0	59.4
PC Other (%)	1.6 (±0.2)	0.0	8.9
PC Native (%)	41.9 (±2.5)	1.7	82.5
PC Intro Grass (%)	23.4 (±2.0)	0.0	70.0
PC Intro Forb (%)	6.0 (±0.9)	0.0	40.6
PC Total Intro (%)	29.9 (±2.3)	0.0	70.0
Patch Area (ha)	1569.6 (±294.7)	13.4	10931.7
% Woody Edge	5.7 (±1.1)	0.0	40.0

Table 3-16 Continued Variable Means for Lark Bunting

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	88.8 (±1.8)	12.0	100.0
% Grass 800m	85.1 (±2.0)	18.0	100.0
% Grass 1600m	83.4 (±1.9)	30.0	100.0
% Grass 3200m	80.8 (±1.9)	36.0	99.0

Table 3-17. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for savannah sparrow transect occurrence (N=46) in surveyed grasslands (N=131) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Savannah Sparrow Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	+LD +PCt +PG3200m	153.7	0.0
Local and Landscape	+PCt –PCbg +PG3200m	154.3	+0.6
Local and Landscape	+VO +PCt –PCbg +PG3200m	154.5	+0.8
Local and Landscape	–PCs +PCt –PCbg +PG3200m	154.7	+1.0
Local and Landscape	+TLf +PCt +PG3200m	154.7	+1.0
Local and Landscape	+LD +PCt + PG1600m	155.4	+1.7
Local, Patch and Landscape	+LD +PCt –PWE +PG3200m	155.7	+2.0
Local	+LD +PCt	156.2	+2.5
Local, Patch and Landscape	+PCt –PCbg –PWE +PG3200m	156.2	+2.5
Local	+TLf +PCt	156.3	+2.6
Local and Patch	+TLf +PCt –LPA	156.9	+3.2
Local and Patch	+LD +PCt –PWE	157.4	+3.7
Landscape	+PG3200m	164.0	+10.3
Patch	–LPA	164.7	+11.0
Landscape	+PG1600m	165.2	+11.5
Patch	–PWE –LPA	166.1	+12.4

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-18. List of measured variables means (±SE) and ranges for grasslands occupied by savannah sparrows (N=46) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	2.0 (±0.2)	0.1	4.8
Tall Grass (dm)	8.5 (±0.3)	3.3	11.7
Tallest Forb (dm)	5.6 (±0.3)	1.5	11.4
Tallest Shrub (dm)	2.0 (±0.5)	0.0	13.1
Litter Depth (mm)	24.0 (±2.4)	0.2	63.3
Leaf Height (dm)	3.4 (±0.2)	0.9	6.0
PC Grass (%)	55.4 (±1.8)	30.3	81.7
PC Forb (%)	17.8 (±1.9)	0.0	53.1
PC Shrub (%)	0.8 (±0.2)	0.0	8.6
PC Thatch (%)	27.4 (±1.9)	4.4	54.2
PC Bare Ground (%)	1.8 (±0.4)	0.0	10.6
PC Other (%)	1.6 (±0.4)	0.0	10.9
PC Native (%)	18.4 (±2.8)	0.0	75.0
PC Intro Grass (%)	46.1 (±2.8)	5.8	70.0
PC Intro Forb (%)	7.0 (±1.4)	0.0	34.2
PC Total Intro (%)	52.2 (±2.9)	5.8	98.2
Patch Area (ha)	278.7 (±64.4)	11.2	2048.5
% Woody Edge	6.3 (±1.7)	0.0	70.0

Table 3-18 Continued Variable Means for Savannah Sparrow

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	64.0 (±4.4)	0.0	95.0
% Grass 800m	60.3 (±4.2)	1.0	98.0
% Grass 1600m	59.1 (±3.9)	0.0	95.0
% Grass 3200m	57.2 (±3.6)	1.0	97.0

Table 3-19. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for Sprague's pipit transect occurrence (N=2) in surveyed grasslands (N=199) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Sprague's Pipit Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	–TLf –TLs –PCbg +PG3200m	16.9	0.0
Local, Patch and Landscape	–TLf –TLs –PCbg –PWE +PG3200m	18.3	+1.4
Local and Landscape	–TLf –TLs –PCbg –PCig +PG3200m	18.5	+1.6
Local and Landscape	–TLf –TLs –PCbg +PG400m	18.6	+1.6
Local, Patch and Landscape	–TLf –TLs –PCbg –PWE +PG400m	18.6	+1.7
Local and Landscape	–TLf –TLs –PCbg +PG1600m	18.7	+1.8
Local and Landscape	–TLf –TLs –PCbg –PCt +PG3200m	18.9	+2.0
Local and Landscape	–TLf -TLs –PCs –PCbg +PG3200m	18.9	+2.0
Local and Patch	–TLf –TLs –PCbg –PWE	19.1	+2.2
Local	–TLf –TLs –PCbg	19.2	+2.3
Local and Patch	–TLs –PCbg –PWE	20.2	+3.3
Local	–TLf –TLs –PCbg –PCt	20.9	+4.0
Patch	–PWE	24.1	+7.2
Patch	–PWE –LPA	25.5	+8.6
Landscape	+PG1600m	26.0	+9.1
Landscape	+PG3200m	26.0	+9.1

*** ΔAIC is change in AIC when current model is compared to the best model.**

pipit contained variables from local and landscape levels, while two contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by Sprague's pipits are listed in (Table 3-20).

Western Meadowlark

Western meadowlark occurrence was negatively associated with grass height, litter depth, amount of bare ground, amount of introduced grass within the patch, amount of woody edge surrounding the grassland and amount of grassland in the surrounding landscape up to 3200m (Figure 3-21). Probability of occurrence for western meadowlarks was greater than 70% when woody edge was absent from a patch, but decreased to less than 20% when woody species occupied 70% of the patch edge (Figure 3.5). Five of the 10 competitive models included both local and patch level variables, while five models contained variables from all three spatial scales. Averages of measured variables for grasslands occupied by western meadowlarks are listed in (Table 3-22).

Table 3-20. List of measured variables means (±SE) and ranges for grasslands occupied by Sprague's pipits (N=2) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction (dm)	0.7 (n/a)	0.6	0.9
Tall Grass (dm)	6.9 (n/a)	6.6	7.3
Tallest Forb (dm)	3.3 (n/a)	3.1	3.5
Tallest Shrub (dm)	0.0 (n/a)	0.0	0.0
Litter Depth (mm)	19.0 (n/a)	13.1	24.8
Leaf Height (dm)	1.9 (n/a)	1.3	2.4
PC Grass (%)	51.5 (n/a)	40.6	62.5
PC Forb (%)	13.3 (n/a)	9.4	17.2
PC Shrub (%)	0.0 (n/a)	0.0	0.0
PC Thatch (%)	29.0 (n/a)	20.0	37.8
PC Bare Ground (%)	0.4 (n/a)	0.3	0.6
PC Other (%)	3.3 (n/a)	2.8	3.9
PC Native (%)	27.6 (n/a)	24.2	31.1
PC Intro Grass (%)	33.9 (n/a)	19.2	48.6
PC Intro Forb (%)	3.5 (n/a)	0.0	6.9
PC Total Intro (%)	34.7 (n/a)	19.2	50.3
Patch Area (ha)	288.8 (n/a)	117.3	460.3
% Woody Edge	0.0 (n/a)	0.0	0.0

Table 3-20 Continued Variable Means for Sprague's Pipit

Measured Variable	Mean (±SE)	Minimum	Maximum
% Grass 400m	88.0 (n/a)	82.0	93.0
% Grass 800m	86.0 (n/a)	77.0	94.0
% Grass 1600m	84.0 (n/a)	83.0	85.0
% Grass 3200m	81.0 (n/a)	79.0	83.0

Table 3-21. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for western meadowlark transect occurrence (N=191) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Western Meadowlark Occurrence			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Patch	–TLg –LD –PCig –PWE	349.7	0.0
Local, Patch and Landscape	–TLg –LD –PCig –PWE –PG3200m	349.8	+0.1
Local, Patch and Landscape	–TLg +PCbg –PCig –PWE –PG3200m	350.1	+0.4
Local and Patch	–TLg +PCbg –PCig –PWE	350.4	+0.7
Local and Patch	–TLg –LD –PCg –PCig –PWE	350.4	+0.7
Local, Patch and Landscape	–TLg –LD –PCig –PWE –PG1600m	350.7	+1.0
Local, Patch and Landscape	–TLg –LD –PCg –PCig –PWE –PG3200m	350.8	+1.1
Local and Patch	–TLg –LD –PCig –PWE –LPA	351.4	+1.7
Local and Patch	–VO –PCg –PCs –PCt –PWE	351.6	+1.9
Local, Patch and Landscape	–TLg –LD –PCig –PWE –PG400m	352.2	+2.5
Local	–TLg –LD –PCig	354.0	+4.3
Local	–TLg –LD –PCg –PCig	354.7	+5.0
Local and Landscape	–TLg –LD –PCig –PG3200m	355.2	+5.5
Local and Landscape	–TLg –LD –PCig –PG1600m	355.8	+6.1
Patch	–PWE +LPA	361.7	+12.0

Table 3-21 Western Meadowlark Occurrence Continued

Model Set	Model	AIC	ΔAIC
Patch	–PWE	363.7	+14.0
Landscape	+PG400m	369.8	+20.1
Landscape	+PG800m	369.8	+20.1

*** ΔAIC is change in AIC when current model is compared to the best model.**

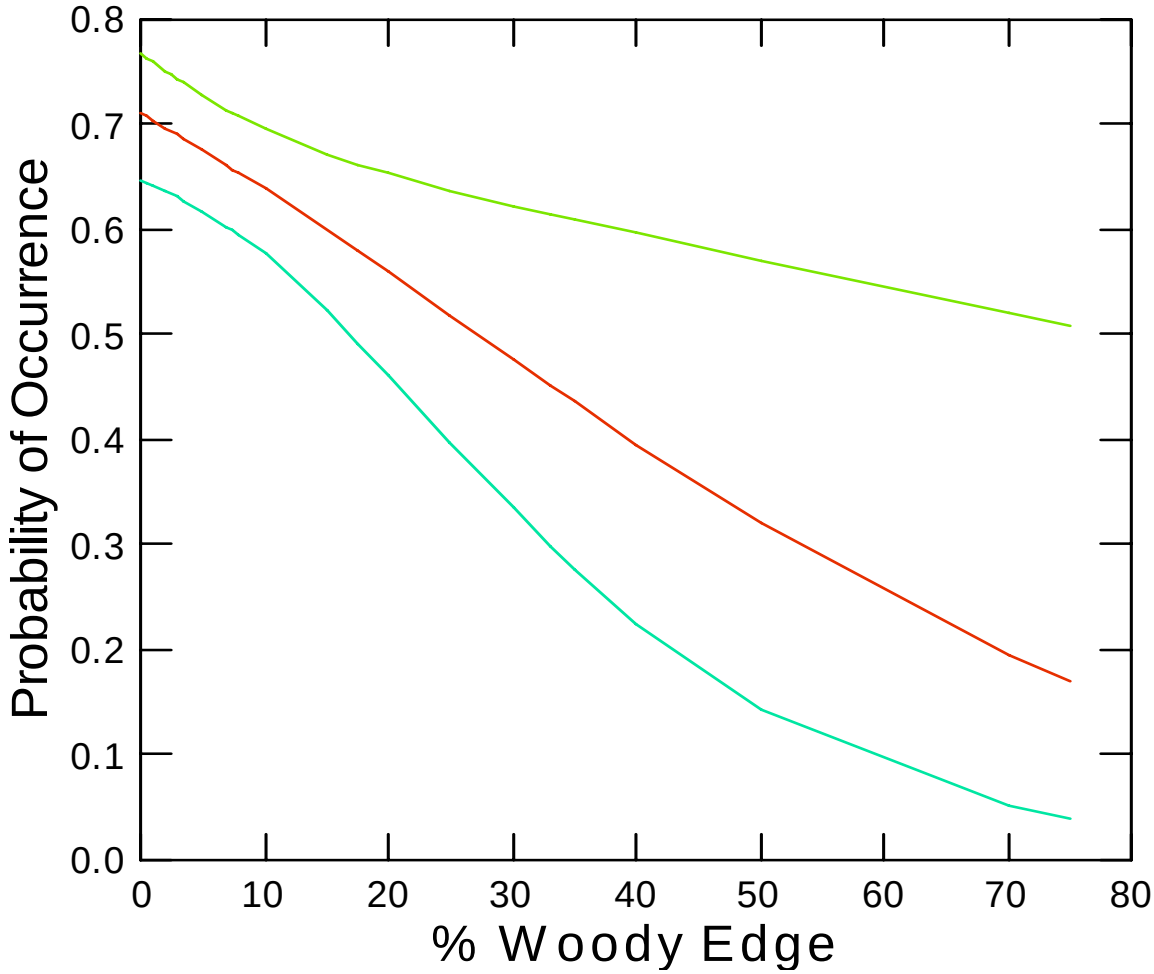

Figure 3-5. Probability of detecting western meadowlarks in grasslands (N=288) with increasing percentages of woody edge in western and central South Dakota for summers 2007 and 2008. Green and blue lines indicate 95% confidence intervals.

Table 3-22. List of measured variables means (±SE) and ranges for grasslands occupied by western meadowlarks (N=191) in central and western South Dakota for summers 2007 and 2008.

Measured Variable	Mean (±SE)	Minimum	Maximum
Visual Obstruction	1.2 (±0.1)	0.0	4.7
Tall Grass	7.6 (±0.1)	3.5	13.3
Tallest Forb	4.9 (±0.1)	0.3	11.5
Tallest Shrub	1.7 (±0.2)	0.0	9.5
Litter Depth	11.4 (±0.9)	0.0	57.8
Leaf Height	2.9 (±0.1)	0.9	6.4
PC Grass (%)	53.8 (±0.9)	19.7	85.3
PC Forb (%)	20.3 (±0.9)	0.8	61.9
PC Shrub (%)	1.4 (±0.2)	0.0	18.1
PC Thatch (%)	16.4 (±0.9)	0.0	53.9
PC Bare Ground (%)	9.1 (±0.8)	0.0	59.4
PC Other (%)	1.7 (±0.2)	0.0	16.4
PC Native (%)	33.6 (±1.8)	0.0	89.7
PC Intro Grass (%)	32.9 (±1.6)	0.0	85.0
PC Intro Forb (%)	6.5 (±0.6)	0.0	59.2
PC Total Intro (%)	38.8 (±1.6)	0.0	88.1
Patch Area	1056.4 (±143.4)	13.4	12852.2
% Woody Edge	5.0 (±0.6)	0.0	40.0

Table 3-22 Continued Variable Means for Western Meadowlarks

Measured Variables	Mean (±SE)	Minimum	Maximum
% Grass 400m	76.4 (±2.1)	0.0	100.0
% Grass 800m	73.0 (±2.1)	0.0	100.0
% Grass 1600m	69.7 (±2.1)	0.0	100.0
% Grass 3200m	67.0 (±2.0)	1.0	99.0

Grassland Obligate Species Male Density

Nine of the 10 focus bird species had densities greater than zero. For these nine species I calculated average densities for territorial males only and reported them as the number of territorial males per 100ha. Bird densities exhibited a wide variation across our study area. Average densities ranged from 50.0 males per 100ha for Sprague's pipits to 123.2 males per 100ha for chestnut-collared longspurs (Table 3-23). For SoGCN, average densities were: Baird's sparrow (80.0 males per 100ha), chestnut-collared longspur (123.2 males per 100ha), lark bunting (90.7 males per 100ha) and Sprague's pipit (50.0 males per 100ha) (Table 3-23).

Grassland Obligate Species Male Density Models

Habitat models were created from transect density data for all focus grassland bird species using only grasslands that were located within the given species range (Bakker et. al. 2002). The species with reduced sample sizes include the Baird's sparrow (N=182), savannah sparrow (N=131), and Sprague's pipit (N=199).

Baird's Sparrow

Baird's sparrow male density was positively associated with grass height, amount of forb cover within the grassland, amount of woody edge bordering the patch, and amount of grassland habitat in the surrounding landscape within 800m, and was negatively associated with shrub height (Table 3-24). Four of the 13 competitive models included variables from local and patch levels while nine had contained variables from all three spatial scales.

Table 3-23. Number of grasslands in which a given species was recorded, average male density, and standard error for the average male density for each study specie of grassland bird within the transects of the grasslands surveyed (N=288) in central and western South Dakota for summer 2007 and 2008.

Species	# of Records	Average Male Density	±SE Male Density
Baird's Sparrow	5	80.0	±12.3
Bobolink	51	85.3	±6.0
Chestnut-Collared Longspur	54	123.2	±10.0
Dickcissel	12	70.8	±13.0
Grasshopper Sparrow	202	106.7	±4.0
Lark Bunting	70	90.7	±6.2
Le Conte's Sparrow	0	0.0	±0.0
Savannah Sparrow	46	79.4	±6.5
Sprague's Pipit	2	50.0	±0.0
Western Meadowlark	188	89.9	±3.5

Table 3-24. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for Baird's sparrow male density (N=5) in surveyed grasslands (N=182) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Baird's Sparrow Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local, Patch and Landscape	+TLg –TLs +PWE +PG800m	1463.4	0.0
Local, Patch and Landscape	+TLg –TLs +PCf +PWE +PG800m	1463.7	+0.3
Local and Patch	+TLg –TLs +PCf +PWE	1463.8	+0.4
Local and Patch	+TLg +PCf +PWE	1463.8	+0.4
Local, Patch and Landscape	+TLg –TLs +PWE +PG400m	1463.8	+0.4
Local, Patch and Landscape	+TLg –TLs +PCf +PWE +PG400m	1464.0	+0.6
Local, Patch and Landscape	+TLg +PCf +PWE +PG400m	1464.2	+0.8
Local, Patch and Landscape	+TLg –TLs +PWE +PG1600m	1464.3	+0.9
Local, Patch and Landscape	+TLg +PCf +PWE +PG800m	1464.4	+1.0
Local, Patch and Landscape	+TLg –TLs +PCf +PWE +PG1600m	1464.4	+1.0
Local, Patch and Landscape	+TLg +PCf +PWE +PG1600m	1464.7	+1.3
Local and Patch	+TLg –TLS +PWE	1464.7	+1.3
Local and Patch	+TLg +PWE	1465.3	+1.9

Table 3-24 Baird's Sparrow Male Density Continued

Model Set	Model	AIC	ΔAIC
Local	+TLg +PCf	1467.8	+4.4
Local	+TLg –TLs +PCf	1467.9	+4.5
Local and Landscape	+TLg –TLs +PG800m	1468.3	+4.9
Local and Landscape	+TLg –TLs +PG400m	1468.4	+5.0
Patch	+PWE	1469.0	+5.6
Patch	+PWE +LPA	1470.9	+7.5
Landscape	+PG400m	1474.3	+10.9
Landscape	+PG800m	1474.4	+11.0

*** ΔAIC is change in AIC when current model is compared to the best model.**

Bobolink

Bobolink male density was positively associated with visual obstruction, and the amount of introduced grass within the surveyed patch, and was negatively associated with forb height and amount of grassland surrounding the patch up to 3200m (Table 3-25). Of the six competitive models one included local level variables only, one contained local and patch level variables and four had local landscape level variables.

Chestnut-Collared Longspur

Chestnut-collared longspur male density was positively associated with amount of grass cover and bare ground within a grassland, and was negatively associated with litter depth, amount of total introduced plant species within the patch and amount of woody edge surrounding the grassland (Table 3-26). Seven of the 12 competitive models were found to contain both local and patch level variables, while five contained variables from all three spatial scales.

Dickcissel

Dickcissel male density was positively associated with grass height and negatively associated with shrub height and amount of total introduced plant species cover within the grassland patch (Table 3-27). Six of the 13 competitive models contained only local level variables, while three had local and patch level variables and four had variables from all three spatial scales.

Grasshopper Sparrow

Grasshopper sparrow male density was positively associated with grass height, the amount of forb and thatch coverage in the grassland, patch size, and to amount of

Table 3-25. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for bobolink male density (N=51) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Bobolink Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	+VO –TLf +PCig –PG1600m	2830.5	0.0
Local and Landscape	+VO –TLf +PCig –PG3200m	2831.0	+0.5
Local	+VO –TLf +PCig	2831.2	+0.7
Local and Landscape	+VO –TLf +PCig –PG800m	2831.6	+1.1
Local, Patch and Landscape	+VO –TLf +PCig –PWE –PG1600m	2832.1	+1.6
Local and Landscape	+VO –TLf +PCbg +PCig –PG1600m	2832.5	+2.0
Local, Patch and Landscape	+VO –TLf +PCig –PWE –PG3200m	2832.7	+2.2
Local and Patch	+VO –TLf +PCig –PWE	2833.1	+2.6
Local and Patch	+VO –TLf +PCig –LPA	2833.1	+2.6
Local	+VO –TLf –PCbg –PCig	2833.2	+2.7
Landscape	–PG1600m	2876.2	+45.7
Landscape	–PG3200m	2879.3	+48.8
Patch	–LPA	2890.8	+60.3
Patch	–PWE –LPA	2892.8	+62.3

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-26. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for chestnut-collared longspur male density (N=54) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Chestnut-Collared Longspur Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Patch	–LD –PCti –PWE	3120.0	0.0
Local and Patch	–LD +PCg –PCti –PWE	3120.0	+0.0
Local and Patch	–LD +PCg +PCbg –PCti –PWE	3120.2	+0.2
Local and Patch	–VO +PCg +PCbg –PCig –PWE	3121.5	+1.5
Local, Patch and Landscape	–LD +PCg +PCbg –PCti –PWE –PG800m	3121.7	+1.7
Local and Patch	–LD –PCti –ELH –PWE	3121.7	+1.7
Local, Patch and Landscape	–LD –PCti –PWE –PG800m	3121.7	+1.7
Local and Patch	–LD –PCti –PWE –LPA	3121.7	+1.7
Local, Patch and Landscape	–LD –PCti –PWE –PG400m	3121.8	+1.8
Local and Patch	–LD +PCg –PCti –PWE –LPA	3121.8	+1.8
Local, Patch and Landscape	–LD –PCti –PWE –PG3200m	3121.9	+1.9
Local, Patch and Landscape	–LD –PCti –PWE –PG1600m	3122.0	+2.0
Local	–LD –PCti	3126.3	+6.3
Local	–LD –PCti +PCg	3126.9	+6.9
Local and Landscape	–LD –PCti +PG1600m	3128.1	+8.1

Table 3-26 Chestnut-Collared Longspur Male Density Continued

Model Set	Model	AIC	ΔAIC
Local and Landscape	–LD –PCti +PG400m	3128.3	+8.3
Local and Landscape	–LD –PCti +PG800m	3128.3	+8.3
Patch	–PWE +LPA	3146.4	+26.4
Patch	–PWE	3146.4	+26.4
Landscape	+PG1600m	3151.6	+31.6
Landscape	+PG800m	3152.7	+32.7

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-27. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for dickcissel male density (N=12) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Dickcissel Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local	+TLg –TLs	2439.9	0.0
Local	+TLg –TLs –PCti	2440.5	+0.6
Local	–TLs	2441.2	+1.3
Local	+TLg +TLf –TLs	2441.4	+1.5
Local	+TLg –TLs +LD	2441.6	+1.7
Local and Patch	+TLg –TLs +PWE	2441.6	+1.7
Local	+TLg	2441.8	+1.9
Local and Patch	+TLg –TLs –LPA	2441.8	+1.9
Local and Patch	+TLg –TLs –PCti –LPA	2441.9	+2.0
Local and Landscape	+TLg –TLs +PG400m	2441.9	+2.0
Local and Landscape	+TLg –TLs +PG800m	2441.9	+2.0
Local and Landscape	+TLg –TLs –PG1600m	2441.9	+2.0
Local and Landscape	+TLg –TLs –PG3200m	2441.9	+2.0
Patch	–LPA	2443.5	+3.6
Local, Patch and Landscape	+TLg –TLs +PWE +PG400m	2443.5	+3.6
Local, Patch and Landscape	+TLg –TLs +PWE +PG800m	2443.5	+3.6

Table 3-27 Dickcissel Male Density Continued

Model Set	Model	AIC	ΔAIC
Patch	+PWE	2443.6	+3.7
Landscape	–PG1600m	2443.7	+3.8
Landscape	–PG3200m	2443.7	+3.8

*** ΔAIC is change in AIC when current model is compared to the best model.**

grassland surrounding the patch up to 800m, and was negatively associated with shrub height, amount of bare ground, amount of introduced forb within the patch, and amount of patch edge occupied by woody species (Table 3-28). One of the eight competitive models contained local and patch level variables, while two contained local and landscape level variables and five contained variables from all three spatial scales.

Lark Bunting

Lark bunting male density was positively associated with amount of forb and bare ground located within the grassland, amount of grassland habitat in the surrounding landscape up to 3200m, and was negatively associated with visual obstruction, and the amount of introduced grass and total introduced species within the patch (Table 3-29). Four of the five competitive models contained variables from both local and landscape levels and one contained variables from all three spatial scales.

Savannah Sparrow

Savannah sparrow male density was positively associated with visual obstruction, amount of thatch covering the ground, amount of forb cover within the grassland and amount of grassland surrounding the patch within 3200m, and was negatively associated with the amount of grass within the patch and amount of the patch edge occupied by woody plant species (Table 3-30). Two of the three competitive models contained variables from both the local and landscape levels, and one contained variables from all three spatial scales.

Sprague's Pipit

Sprague's pipit male density was positively associated with the amount of thatch

Table 3-28. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for grasshopper sparrow male density (N=202) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Grasshopper Sparrow Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local, Patch and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif –PWE +LPA +PG400m	3221.5	0.0
Local, Patch and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif –PWE +PG800m	3221.7	+0.2
Local, Patch and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif –PWE +PG400m	3221.7	+0.2
Local, Patch and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif +LPA +PG400m	3221.8	+0.3
Local, Patch and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif –PWE +PG1600m	3222.6	+1.1
Local and Patch	+TLg –TLs +PCf +PCt –PCbg –PCif –PWE +LPA	3222.7	+1.2
Local and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif +PG800m	3222.8	+1.3
Local and Landscape	+TLg –TLs +PCf +PCt –PCbg –PCif +PG400m	3222.9	+1.4
Local and Patch	+TLg –TLs +PCf +PCt –PCbg –PCif +LPA	3224.0	+2.5
Local	+TLg –TLs +PCf +PCt –PCbg –PCif	3229.9	+8.4
Local	+TLg –TLs +PCf +PCt –PCbg –PCti	3232.5	+11.0
Landscape	+PG400m	3248.8	+27.3
Landscape	+PG800m	3249.1	+27.6

Table 3-28 Grasshopper Sparrow Male Density Continued

Model Set	Model	AIC	ΔAIC
Patch	–PWE +LPA	3249.4	+27.9
Patch	–PWE	3249.5	+28.0

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-29. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for lark bunting male density (N=70) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Lark Bunting Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	–VO +PCf +PCbg +PG3200m	2987.5	0.0
Local and Landscape	–VO +PCf +PCbg –PCig +PG3200m	2988.0	+0.5
Local and Landscape	+PCf +PCbg –PCti +PG3200m	2989.4	+1.9
Local, Patch and Landscape	–VO +PCf +PCbg +PWE +PG3200m	2989.5	+2.0
Local and Landscape	–VO +PCf +PCbg +PG1600m	2989.5	+2.0
Local, Patch and Landscape	–VO +PCf +PCbg –PCig +PWE +PG3200m	2990.0	+2.5
Local	–VO +PCf +PCbg –PCig	2991.3	+3.8
Local	–VO +PCf +PCbg	2992.0	+4.5
Local and Patch	–VO +PCf +PCbg –PCig +LPA	2993.3	+5.8
Local and Patch	–VO +PCf +PCbg –PCig –PWE	2993.3	+5.8
Landscape	+PG3200m	3008.1	+20.6
Landscape	+PG1600m	3011.2	+23.7
Patch	+LPA	3026.3	+38.8
Patch	–PWE +LPA	3028.2	+40.7

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-30. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for savannah sparrow male density (N=46) in surveyed grasslands (N=131) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Savannah Sparrow Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Landscape	+VO –PCg +PCt +PG3200m	1352.9	0.0
Local and Landscape	+VO +PCf +PCt +PG3200m	1353.8	+0.9
Local, Patch and Landscape	+VO –PCg +PCt –PWE +PG3200m	1354.3	+1.4
Local, Patch and Landscape	+VO +PCf +PCt –PWE +PG3200m	1355.3	+2.4
Local	+LD +PCf +PCt	1356.3	+3.4
Local	+VO +PCf +PCt	1356.6	+3.7
Local and Patch	+LD +PCf +PCt –LPA	1357.0	+4.1
Local and Patch	+LD +PCf +PCt –PWE –LPA	1357.0	+4.1
Landscape	+PG3200m	1369.7	+16.8
Landscape	+PG1600m	1371.5	+18.6
Patch	–LPA	1371.8	+18.9
Patch	–PWE –LPA	1371.9	+19.0

*** ΔAIC is change in AIC when current model is compared to the best model.**

covering the ground, and was negatively associated with forb height and amount of bare ground (Table 3-31). These models have low statistical power because there were only two recorded observations for Sprague's pipits. Fourteen of the 24 competitive models contained only local level variables, while three contained local and patch level variables and seven contained local and landscape level variables.

Western Meadowlark

Western meadowlark male density was positively associated with amount of forb cover in a grassland, patch size, and amount of surrounding grassland in the landscape within 400m, and negatively associated with grass and shrub height and amount of woody edge surrounding the grassland patch (Table 3-32). Three of the four competitive models for the western meadowlark included variables from the local and patch levels, and one contained variables from all three spatial scales.

Table 3-31. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for Sprague's pipit male density (N=2) in surveyed grasslands (N=199) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Sprague's Pipit Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local	–TLf +PCt	1207.3	0.0
Local	+PCt	1207.5	+0.2
Local	–TLf –PCbg	1207.7	+0.4
Local	–TLs +PCt	1208.1	+0.8
Local	–TLf	1208.2	+0.9
Local	–TLf +PCt –PCbg	1208.5	+1.2
Local and Landscape	–TLf +PCt +PG3200m	1208.5	+1.2
Local and Landscape	–TLf +PCt +PG1600m	1208.5	+1.2
Local and Landscape	–TLf +PCt +PG800m	1208.6	+1.3
Local and Landscape	–TLf –PCbg +PG3200m	1208.7	+1.4
Local and Landscape	–TLs –PCt +PG3200m	1208.8	+1.5
Local and Landscape	–TLf +PCt +PG400m	1208.8	+1.5
Local and Landscape	–TLf –PCbg +PG1600m	1208.8	+1.5
Local	–TLs	1208.8	+1.5
Local	–TLf –TLs	1208.8	+1.5
Local and Patch	–TLf +PCt –PWE	1208.9	+1.6
Local	–PCbg	1209.0	+1.7

Table 3-31 Sprague's Pipit Male Density Continued

Model Set	Model	AIC	ΔAIC
Local and Patch	–TLf –PCbg –PWE	1209.1	+1.8
Local	–TLf –TLs +PCt –PCbg	1209.1	+1.8
Local	–ELH	1209.1	+1.8
Local	–TLf –PCg +PCt	1209.2	+1.9
Local	–TLf +PCt –PCif	1209.2	+1.9
Local	–VO –TLf +PCt	1209.2	+1.9
Local and Patch	–TLf +PCt –LPA	1209.2	+1.9
Patch	–PWE	1209.7	+2.4
Landscape	+PG1600m	1210.0	+2.7
Landscape	+PG3200m	1210.0	+2.7
Patch	–LPA	1210.1	+2.8
Local, Patch and Landscape	–TLf +PCt –PWE +PG3200m	1210.1	+2.8
Local, Patch and Landscape	–TLf +PCt –PWE +PG1600m	1210.2	+2.9
Local, Patch and Landscape	–TLf –PCbg –PWE +PG3200m	1210.2	+2.9

*** ΔAIC is change in AIC when current model is compared to the best model.**

Table 3-32. List of all competitive models (ΔAIC ≤ 2), and the two best models from all six model sets, listed with AIC and ΔAIC, for western meadowlark male density (N=188) in surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008. Models arranged in ascending order of ΔAIC.

Western Meadowlark Male Density			
Model Set	**Model**	**AIC**	***ΔAIC**
Local and Patch	–TLg –TLs +PCf +LPA	3129.0	+0.0
Local and Patch	–TLg –TLs +PCf –PWE +LPA	3129.7	+0.7
Local, Patch and Landscape	–TLg –TLs +PCf +LPA +PG400m	3130.8	+1.8
Local and Patch	–TLg –TLs +PCf –PCig +LPA	3131.0	+2.0
Local, Patch and Landscape	–TLg –TLs +PCf –PWE +LPA +PG400m	3131.6	+2.6
Local	–TLg –TLs +PCf	3131.8	+2.8
Local and Landscape	–TLg –TLs +PCf +PG400m	3132.0	+3.0
Local and Landscape	–TLg –TLs +PCf +PG800m	3132.3	+3.3
Local	–VO –TLs +PCf	3132.6	+3.6
Patch	–PWE +LPA	3147.2	+18.2
Patch	+LPA	3147.3	+18.3
Landscape	+PG1600m	3149.9	+20.9
Landscape	+PG400m	3150.1	+21.1

*** ΔAIC is change in AIC when current model is compared to the best model.**

CHAPTER 4

DISCUSSION OF STUDY RESULTS

Discussion

Grassland Bird Distributions

Due to the large scale of my study, some of the grassland bird species were not detected in all portions of the study area. Therefore, I used only grassland patches that fell within the documented distributions of the focal species (Tallman et. al. 2002, Sauer et. al. 2008). All distributions documented in this study[C] were consistent with those listed by the SDOU (Tallman et. al. 2002) and the North American Breeding Bird Survey (BBS) (Sauer et. al. 2008). I found that Baird's sparrows and Sprague's Pipits had distributions concentrated in the northern portion of the study area. Lark buntings were more prominent in western South Dakota and savannah sparrows were more common in eastern South Dakota. The savannah sparrow was the only species for which I recorded occurrences outside of its reported distribution (N=9). All occurrences out of the established distribution were located in a county bordering the Missouri river, in close proximity to the reported distribution, and those grasslands had habitat characteristics similar to those selected by the savannah sparrow in eastern South Dakota (Bakker et. al. 2002), indicating that savannah sparrows may be expanding its range (Sauer et. al. 2008). Dechant et. al. (1999b) and Sauer et. al. (2008) found that savannah sparrow abundance was higher in eastern South Dakota and increased farther east of the Missouri river.

[C] See appendix C for individual species distribution maps.

Abundance of lark buntings was greater in western South Dakota and began to diminish east of the Missouri river (Sauer et. al. 2008) coinciding with my findings.

Walk-about vs. Transect Occurrence

The combined use of transect and walk-about occurrences for grassland bird distributions significantly increased detections of focus species over transect occurrence alone. The walk-about increased the number of study species occurrences by 280 over the course of two field seasons. All species except the Le Conte's sparrow had an increase in individual occurrences. The Baird's sparrow and Sprague's pipit, both SoGCN, had occurrences that nearly doubled due to the walk-about. I found that the walk-about was an effective way to increase the detection rate of species within a grassland. These results are expected as the more area sampled the more species will be detected (Horn et. al 2000, Johnson 2001). Even though these detections cannot be used in analysis due to issues with passive sampling (Connor and McCoy 1979, Horn et. al. 2000, Ribic et. al. 2009), this information is useful for distributional studies.

Variables Associated with Grassland Bird Occurrence

Baird's Sparrow

Baird's sparrows selected for moderately grazed pastures in mixed-grass prairie that had large amounts of surrounding grasslands and higher percentages of woody edge. Similar results were reported in Saskatchewan and Colorado (Dale 1983, Jones and Green 1998). My results indicate no effect of exotic plant species on Baird's sparrow occurrence. Similarly, Davis et. al. (1999) found that Baird's sparrows responded more strongly to local vegetation structure than the composition of the plant community in

Saskatchewan. Baird's sparrow occurrence was positively associated with the amount of edge occupied by woody species and the amount of grass within 400m of the surveyed patch. Although there is little information on area and landscape requirements for Baird's sparrows, McMaster and Davis (1998) found they were more likely to occur in grassland patches surrounded by grassland than by cropland, woodland or wetland in Saskatchewan. The positive association of Baird's sparrow occurrence to woody edge contradicts the literature. This result may be due to the fragmented landscape of eastern South Dakota where half of the Baird's sparrow's occurrences were recorded. Much of the preferred habitat (idled grassland) was located on WPAs or GPAs which tended to be bordered by woody vegetation. It is also possible the association with woody edge is due in part to the low number of occurrences I had for the Baird's sparrow. Low occurrences may give high influential power to some variables that would not be as powerful in a data set with a greater number of occurrences, therefore inflating the importance of woody edge when idled grassland is the key variable selected for by the Baird's sparrow.

Bobolink

Bobolinks selected for lightly grazed or idle grasslands within mixed-grass prairie that had high vegetation density, little bare ground, and increasing coverage of introduced grass which occurred largely in WPA's and GPA's within my study area. Dejong (2001) found similar results for visual obstruction in western South Dakota, while Sample (1989), Herkert (1994), and Dechant (1999a) found similar results for the negative association to bare ground in areas of mixed-grass prairie. Madden (1996) found similar trends for the increasing amount of exotic grass in North Dakota. Selection of exotic over

native grass is likely a function of the ability of many introduced species to grow in thick densities within this region thus creating preferred habitat for the bobolink. Bobolinks have been documented to use hay lands suggesting a preference for cool season grasses, which many exotic grass species are (Koford 1999). Contrary to Helzer and Jelinski (1999), I found bobolinks to be negatively associated with amount of grass within the landscape up to 1600m. Bobolinks selected for grassland with high visual obstruction readings, which tend to occur as small islands of idle habitat within agricultural or grazing dominated landscapes of eastern South Dakota, while larger grasslands of western South Dakota were out of their range of distribution.

Chestnut-Collared Longspur

Chestnut-collared longspurs selected grasslands that had heavy to extreme grazing rates, had reduced amounts of introduced forb coverage, little to no woody edge and large amounts of grassland in the landscape. In western South Dakota, DeJong et. al. (2005) found similar results where chestnut-collared longspurs were negatively associated with visual obstruction and vegetation height, indicating their preference for grasslands with short sparse vegetation. Schneider (1998) found that longspurs selected grasslands dominated solely by native grass in North Dakota, supporting the negative association to introduced forb cover found in this study. Selection of grasslands with lower amounts of woody edge was reported by Arnold and Higgins (1986) in North Dakota, supporting my findings. Probability of occurrence never exceeded 30% with the inclusion of any amount of woody edge, indicating that fragmentation of grasslands by woody species, in any amount drastically alters the occurrence rates of chestnut-collared longspurs in South

Dakota. Maher (1974) and Davis and Duncan (1999) in Saskatchewan reported that chestnut-collared longspurs had a preference for native grasslands, showing many of the same associations as this study. These birds select habitats with little introduced forb and woody edge and prefer grasslands with large amounts of grass in the surrounding landscape. The combination of their preference for native sod grasslands and their high sensitivity to fragmentation may be the primary factors contributing to the rapid population declines exhibited by the chestnut-collared longspur in South Dakota (Sauer et. al. 2008). This also makes them susceptible to further declines as grasslands diminish within the state.

Dickcissel

Dickcissels selected grasslands that were idle or grazed moderately within mixed-grass prairie. These grasslands had high vegetation density with increasing grass coverage, and were relatively small in size. Winter et. al. (2000) in Missouri, Bakker et. al. (2002) and Dejong et. al. (2004) in South Dakota found similar results with dickcissels occurrence increasing as vegetation height and density increased. Patterson and Best (1996) found dickcissel occurrence in Iowa to be associated with increasing forb cover, as forbs tend to supply nesting sites and contain more invertebrates.

In developing models for dickcissels, there was little change in AIC between the candidate models. Of 22 candidate models generated, 18 had a change in AIC of two or less, making selection of the best model difficult. These issues may be related to the distribution of the dickcissel. Both Tallman et. al. (2002) and Sauer et. al. (2008) list the distribution as state-wide, but I found dickcissels favored the eastern half of the state. The

inclusion of the western South Dakota occurrences may be the underlying cause of the model development issues, but I found no reason to remove them based on the literature.

Dickcissels were negatively associated to patch area and amount of grassland habitat in the landscape. It is likely that in eastern South Dakota dickcissels selected habitat found in small patches of highly fragmented landscapes which seems to be well tolerated by this species (Herkert et. al. 1993, Winter 1998), while the larger grasslands of western South Dakota were located out of their range. Bakker (2000) found opposing results, finding dickcissels to be positively associated to patch size in eastern South Dakota.

Grasshopper Sparrow

Grasshopper sparrows selected open grasslands that were grazed moderately on a consistent basis, had very little woody edge and large amounts of surrounding grassland in the landscape. Bakker (2000) in eastern South Dakota and Grant et. al. (2004) in the northern mixed-grass prairie also found that grasshopper sparrows avoid grasslands with tall vegetation, and had higher occurrence rates in grasslands that were more open. Bakker et. al. (2002) in eastern South Dakota found that grasshopper sparrows had greater occurrence rates in grassland patches with large amounts of grassland in the surrounding landscape, adding support to my findings of a greater probability of occurrence in grassland-dominated landscapes. Bakker et. al. (2002) and Grant et. al. (2004) also showed the negative effect of increasing woody edge on grasshopper sparrow occurrence supporting my results of increased probability of occurrence in grasslands with little edge occupied by woody species. As grasslands become more fragmented and

woody edge increases in South Dakota, I would expect to see the occurrence rates of grasshopper sparrows to continue to decline. Litter depth has conflicting influences depending on the study. Fletcher and Koford (2002) showed the same negative effect as I found, while Bakker (2000) showed that litter depth had a positive effect on grasshopper sparrow occurrence. Litter accumulates faster in areas where there is more precipitation so the opposing results may be a function of local climate rather than an actual difference in litter depth selection by this species. Grasshopper sparrows were the most common grassland bird in the survey transect and thusly inhabited a wide variety of grassland habitats.

Lark Bunting

Lark buntings selected moderately to heavily grazed pastures of mixed-grass prairie in western South Dakota that had low vegetation density, increasing bare ground and large amounts of surrounding grassland habitat. Creighton (1974) reported similar results as lark bunting occurrence increased with higher amounts of bare ground and decreasing visual obstruction, indicating the lark buntings' preference for low to moderate vegetation height in Colorado. Johnsgard (1979) reported similar findings showing that lark bunting occurrence was positively associated with the amount of forb within grasslands, as lark buntings use forbs and shrubs for perching and nesting habitat in Nebraska. Johnson (1993) reported lark buntings had a positive association to amount of grassland in the surrounding landscape in the Great Plains, which coincides with my finding of increasing probability of occurrence for lark buntings with greater grassland habitat in the landscape, indicating that they may be sensitive to changes in landscape

composition. It is critical to preserve remaining intact grassland habitats of South Dakota because as grasslands become more fragmented (up to 3200m from occupied grassland) occurrence rates of savannah sparrows decline quickly. DeJong (2001) reported results opposing mine, showing a preference of lark buntings for moderately sized grasslands in western South Dakota. Dejong (2001) hypothesized that lark buntings selecting smaller grasslands may have an increased threat of nest parasitism. There have been few studies other than Dejong (2001) conducted on lark buntings in South Dakota, this study provides critical knowledge for management of this species.

Savannah Sparrow

Savannah sparrows selected grasslands in eastern South Dakota that were lightly grazed or left idle, had little bare ground and large amounts of grassland in the surrounding landscape. Similar results for increasing litter depth, thatch coverage and decreasing bare ground on savannah sparrow occurrence were reported by Fletcher and Koford (2002) in Iowa and Swanson (2002) in the Great Plains, who noted that savannah sparrows require a well developed litter layer. Contrary to Swanson (2002), I found that savannah sparrows were positively associated with visual obstruction and vegetation height. This finding may be due to most grasslands containing the desired litter level in eastern South Dakota are patches that have been idle for many years, and are selected for because of the litter depth and not the high visual obstruction reading. Herkert et. al. (1994) reported that savannah sparrows were highly sensitive to habitat fragmentation in Illinois, showing it to be positively associated with the amount of grass within the surrounding landscape.

Sprague's Pipit

Sprague's pipits selected moderately to heavily grazed pastures in mixed-grass prairie that had short vegetation, little bare ground and large amounts of surrounding grassland. Sutter and Bingham (1996), Davis and Duncan (1999), and Grant et. al. (2004) found that Sprague's pipits' occurrence was higher in grasslands of North Dakota and Saskatchewan that had low to moderate vegetation height and density. Pylypec (1991) in Canada and Madden (1996) in North Dakota observed that most of the studies on Sprague's pipits were conducted in large grasslands where occurrences tended to be greater which supports my findings that Sprague's pipits were positively associated to amount of grassland in the surrounding landscape. My models were consistent with the literature but the small number of occurrences on which they were based lowers the statistical power of these models, and warrants caution when incorporating these results into a management plan.

Western Meadowlark

Western meadowlarks were found in grasslands that had low vegetation height, little woody edge, little to no introduced grass and large amounts of grassland surrounding the patch. Similarly, Madden (1996) in North Dakota, Patterson and Best (1996) in Iowa , and DeJong (2001) in western South Dakota found that western meadowlarks selected a wide variety of habitats, but avoided patches with tall or thick vegetation and thick layers of litter. This avoidance of tall and thick vegetation is evident in their selection against introduced grass. Many survey sites dominated by smooth brome (*Bromus inermis*) and Kentucky bluegrass were thick, dense grasslands. Johnson

(1997), Bakker et. al. (2002), and Grant et. al. (2004) found a negative association between amount of woody edge and occurrence rates of western meadowlarks in mixed-grass prairie, supporting my results of decreased probability of occurrence with even small amounts of woody edge. The negative association of meadowlarks to amount of surrounding grassland opposes the findings of Herkert et. al. (1993) who found meadowlarks in Illinois to be moderately sensitive to habitat fragmentation. This association may be due to meadowlarks being habitat generalists that select grasslands primarily by local structure and by patch and landscape characteristics on a secondary basis.

Variables Associated with Grassland Male Density

Baird's Sparrow

Baird's sparrows had higher densities in grasslands that had tall grass, increased amounts of woody edge and more grassland habitat in the surrounding landscape. Top candidate models for density are very similar to those of the Baird's sparrow occurrence. Dechant (1998b) found similar result in mixed grass prairie showing that Baird's sparrow densities were higher in areas with moderate vegetation height, low visual obstruction, decreased shrub cover and height and increasing amounts of grass and forb. Baird's sparrow association with grassland surrounded by large amounts of other grassland is further supported by the results of McMaster and Davis (1998) in Saskatchewan. Contrary to my results Dechant (1998b) showed Baird's sparrow density to be negatively associated to woody plants both within the grassland and along the patch edge. The positive association to woody edge may be a function of the grasslands being selected for

by the Baird's sparrows occurring in WPA's and GPA's that usually have shelterbelts surrounding them.

Bobolink

Bobolinks had higher densities in grasslands that had thick stands of introduced grass and were located in highly fragmented landscapes. Models for bobolink density share many variables (positive to visual obstruction and introduced grass, negative to surrounding grassland) with the top candidate models for bobolink occurrence. Fritcher (1998) and DeJong et. al. (2004) in western South Dakota found results similar to mine reporting that bobolink densities were higher in grasslands with higher visual obstruction measurements, while Gavin (1992) in the Midwest found similar results recording lower densities of bobolinks in grasslands with large amounts of shrubs. My results of increased densities with decreasing frequency of native grasses were supported by Madden (1996) in North Dakota. O'Leary and Nyberg (2000) found results that oppose mine as they reported bobolink density to be positively associated with increasing patch size and amount of surrounding grass in Illinois. The negative association of bobolinks to amount of surrounding grassland in the landscape may be a result of grassland with suitable vegetation structure occurring as small isolated islands within the landscape that is highly fragmented.

Chestnut-Collared Longspur

Chestnut-collard longspurs had higher densities in heavily grazed grasslands that had little to no litter depth, lower amounts of woody edge and reduced coverage by introduced plant species. Chestnut-collared longspur male density shared common trends

(negative to introduced plant species and woody edge) with the top candidate models of longspur occurrence, but also contained differences (negative to litter depth, positive to both grass coverage and within the surrounding landscape). Fritcher (1998) found similar results in western South Dakota, showing that chestnut-collared longspurs selected for grasslands that had little to no litter. Schneider (1998) and Dechant (1998c) reported higher densities of longspurs in North Dakota grasslands with greater native grass coverage, supporting my findings. Dechant (1998c) reported that chestnut-collared longspurs were highly associated with native sod prairies, supporting my results, as true native prairie has very little coverage of introduced plant species and little to no woody edge. This makes this species very susceptible to habitat fragmentation and encroachment of exotic plant species.

Dickcissel

Dickcissels had higher densities in idle to moderately grazed pastures with tall grass, short shrubs and large amounts of surrounding grassland. Dickcissel occurrence and density models had almost no overlap in selected variables. Occurrence was positively associated with increasing visual obstruction and negatively to grassland patch size, while dickcissel density was positively associated with grass height and amount of surrounding grass. Skinner (1975) in North Dakota, Fritcher (1998) and Dejong (2001) in western South Dakota, found similar results showing that densities of dickcissels increased as vegetation height and visual obstruction increased. In Iowa, lower dickcissel density was associated with increasing shrub height and coverage (Best et. al. 1981). Similar to my results, Swengel (1996) reported that densities of dickcissels increased as

amount of surrounding grassland increased in Missouri. However, Winter and Faaborg (1999) reported that densities of dickcissels were not affected by amount of surrounding prairie but productivity was, as dickcissel nests located closer than 50m to a patch edge were more likely to be parasitized when compared to those further from the edge in Missouri.

Grasshopper Sparrow

Grasshopper sparrows had higher densities in grasslands that had large patch areas, little woody edge, very little introduced forb coverage and high amounts of grassland habitat in the surrounding landscape. Light to moderate grazing keeps grasslands more open (low visual obstruction) while still maintaining vegetation height. Models for grasshopper sparrow density and occurrence had some overlapping variables (negative to tall shrub and woody edge, positive to amount of thatch and surrounding grass) but also contained variables unique to each. Grasshopper sparrow occurrence was negatively associated to litter depth while grasshopper sparrow density was positively associated with grass height and negative to introduced forb, which are all characteristics of open grasslands. Fritcher (1998) reported similar result in western South Dakota showing increased densities with increasing vegetation height. Similar to my results, Rotenberry and Weins (1980) found grasshopper sparrow density increased with greater amounts of thatch coverage and decreased with increasing bare ground and shrub height across the central Great Plains. Greater amounts of forb cover may increase densities of grasshopper sparrows by supplying singing and displaying sites, but at a certain point may create monotypic stands of dense vegetation that will lower densities, as was the

case with introduced forb species like yellow sweet-clover in this study. Negative effects of woody species on grasshopper sparrow density were also shown by Arnold and Higgins (1986) in North Dakota and Bakker et. al. (2002) in eastern South Dakota mixed-grass prairie. Similar to my results, O'Leary and Nyberg (2000) found grasshopper sparrows to be moderately sensitive to landscape fragmentation, preferring areas with large amounts of surrounding grassland over areas with little or no surrounding grassland in Illinois. Bakker et. al. (2002) in eastern South Dakota and DeJong et. al. (2005) in western South Dakota and other studies (see Ribic et. al. 2009) report area sensitivity by the grasshopper sparrow nearly range wide.

Lark Bunting

Lark buntings had higher densities in moderately to heavily grazed pastures with low vegetation density, and large amounts of grassland surrounding the patch. Models for lark bunting occurrence and density were identical, containing all of the same variables and associations. Creighton (1974) found results similar to mine, reporting that lark bunting densities were greater in areas with moderate vegetation height and thickness, and with areas of bare ground in Colorado. Shane (2000) noted that in Kansas densities were higher in areas with greater amounts of forb cover, tall grass and scattered shrubs, as this vegetation may be used for nesting. Lark bunting's positive association with greater amount of grassland within the landscape was supported by Johnson and Igl (2001) who reported lark buntings being positively associated with large areas of contiguous grassland.

Savannah Sparrow

Savannah sparrows had higher densities in grasslands of eastern South Dakota that were left idle and had high vegetation density and large amounts of grassland in the surrounding landscape. Savannah sparrow density and occurrence models had many of the same associations (positive to thatch coverage, and amount of surrounding grass), but also contained variables specific to each (positive to litter depth for occurrence and positive to visual obstruction in density). Litter depth and visual obstruction are highly correlated showing the models are more similar than they appear. I had similar results to Schneider (1998) who found savannah sparrows had higher densities in grasslands with greater visual obstruction readings in North Dakota, and with Swanson (2002) who found densities were greater in the northern mixed grass prairie for grasslands with a well developed litter layer that covered much of the grassland. Herkert et. al. (1993) in Illinois categorized the savannah sparrow as sensitive to habitat fragmentation, indicating that densities would be higher in large patches and with more grassland in the surrounding landscape, supporting my results.

Sprague's Pipit

Sprague's pipits had higher densities in grasslands that are moderately to heavily grazed, in mixed-grass prairie of South Dakota that had high thatch coverage and large amounts of surrounding grassland. Sprague's pipit occurrence and density models contained the same variables and associations. Results showing the negative affect of vegetation height on density of Sprague's pipits were also reported by Dechant (1998a) in the northern mixed-grass prairie. Davis and Duncan (1999) reported that Sprague's pipits

had higher densities in southern Saskatchewan in grasslands with moderate vegetation density and thatch coverage, supporting my results. Pylypec (1991) and Madden (1996) showed a positive relationship between Sprague's pipit densities and both grassland patch size and amount of surrounding grassland in the landscape of North Dakota, which is consistent with my results.

Western Meadowlark

Western Meadowlarks had high densities in grasslands that were under many different management regimes with short vegetation and a large patch sizes. Western meadowlark density and occurrence models had one similar trend (negative to vegetation height), but also had many differences (negative to woody edge and positive to surrounding grass for occurrence and positive to forb coverage and patch size for density). This association to patch size may be a function of the large territory size (2-7ha) (Schaeff and Picman 1988) of the western meadowlark and although they can occur in many different types of grassland there densities will be greater in larger patches where less territorial overlap would occur. Similarly, Bakker et. al. (2002) found western meadowlark densities were higher in larger patches than in smaller ones in eastern South Dakota, and that occurrence was not related to patch size. DeJong (2001) and Bakker et. al. (2002) found similar results reporting higher densities of meadowlarks as vegetation height decreased in western and eastern South Dakota, respectively. Increasing density with greater thatch coverage was reported by Knick and Rotenberry (1995) in New Mexico. Western meadowlarks are habitat generalist capable of using a diversity of habitats; this was evident in the numerous variables recorded in my competitive models.

Summary

Occurrence and density of grassland obligate bird species is influenced by numerous characteristics at multiple levels. At the local level grassland bird species require a wide variety of vegetation structure and composition. Introduced plant species whether forb, grass or both had a negative effect on four of ten focus species. However, for bobolinks it was a positively associated with both density and occurrence. Management practices within the state can be conducive to establishing the diverse habitat requirements of grassland birds in South Dakota.

At the patch level, multiple species occurrences and densities were negatively affected by increasing presence of patch edge surrounded by woody species. Woody edge creates corridors for mammalian predators and perches for avian and nest predators (Winter et. al. 2000). Some species like Baird's sparrows had higher densities and occurrences with increasing woody edge which may have been a secondary effect of the chosen habitat. Patch area was not used in any species occurrence models but was used in development of density models for some species. Densities of grasshopper sparrows and western meadowlarks were positively associated with patch area while others species were not, which is consistent with the literature.

Increasing amounts of grassland at the landscape scale positively influenced the occurrence and/or densities of all species except the bobolink. This negative association of bobolinks to surrounding grassland may be a secondary effect of the chosen patch and not the primary reason for this species selecting a grassland. There was variability not only in the type of association (+ or -) the landscape variable had but also at what

distance this effect remained. Baird's sparrows and grasshopper sparrows showed positive associations at the 400m or 800m levels while bobolinks, chestnut-collared longspurs, lark buntings, savannah sparrows and Sprague's pipits were influenced at or up to the 1600m or 3200m levels. By surveying some of the most intact grasslands in the US, this study may give insight into how birds will respond to newly fragmented areas, and how to mitigate the effects of this fragmentation through preservation of key habitats.

The numerous positive associations to patch area and amount of grassland habitat in the surrounding landscape show the importance of maintaining vast expanses of grassland to sustain current grassland bird diversity and density. Reduced patch size and grassland habitat within the landscape have been shown to have negative affects on grassland bird density, occurrence, productivity and many key ecological processes that could influence grassland bird species (Ribic et. al. 2009b). The importance of including grassland patch size and landscape variables into models explaining grassland bird density and occurrence has been reported by numerous studies including Frawley and Best (1991), Herkert et. al. (1994), Bakker et. al. (2002), DeJong et. al. (2004), Cunningham and Johnson (2006), Renfrew and Ribic (2008) and others reported in Ribic et al (2009b).

Areas of Concern

I was able to develop models for all grassland obligate species observed, although Baird's sparrow, dickcissels and Sprague's pipit occurrence rates were low. Caution should be used when implementing developed models for these species. Le Conte's sparrows were not observed in the study area and a more intensive search of eastern

South Dakota from the east edge of my study area to the Minnesota border would be required to locate this species and develop appropriate habitat models and distribution maps.

I used aerial photography and ground truthed maps to calculate the size of a grassland patch. I used the most recent (2005) aerial photographs available, but changes to the habitat mosaic occurring in a single year can be significant. The results for landscape variables are likely to be biased to some degree as the most recent NLCD available for use was from 2001, and the changes to the landscape in 7 years can vary from substantial in some areas, to very minimal in others. I was able to mitigate some of theses discrepancies by using ground truthing maps constructed during bird surveys.

CHAPTER 5

MANAGEMENT IMPLICATIONS AND FUTURE STUDY RECOMMENDATIONS

Management Implications

It is important that managers develop conservation plans for grassland birds that include multiple scales including patch and landscape. The importance of patch area and grassland habitat in the surrounding landscape is shown by at least one of the top candidate models for all species occurrence and density containing one or more of these variables. This fact has major management implications as patch size and amount of grassland in the landscape will likely decline as habitat fragmentation continues across the Great Plains region and in South Dakota.

Grassland bird species respond on a species by species basis to vegetation structure. In the top candidate models for each species at least one within patch variable was associated with bird density and occurrence. There was a great diversity within the selected variables and the combination in which they were selected for among all study species. This finding indicates the importance of local vegetation structure and composition on grassland birds, but also shows how diverse vegetation must be to support grassland bird species. It is important to preserve as much native prairie as possible under varying management practices in all parts of the state if we wish to preserve habitat suitable for the conservation of these species. The selected grassland and management practices used within them should favor removal and control of exotic plant

species, while promoting the growth and reestablishment of native plants as four of the nine species studied were negatively impacted by increasing exotic plant coverage.

Preserved grasslands should be large enough to allow for a majority of the grassland birds, especially area sensitive species to occupy them. For grasslands in South Dakota patches should be (≥250-1600ha) to fulfill this requirement. Larger patches have been shown to increase daily nest survival and decrease nest parasitism rates for grassland nesting birds (Berman 2007). Preservation of smaller patches can be effective if these small patches are in areas with large amounts of grass in the surrounding landscape. Patches ranging from 12-25ha that had 80-100% grassland habitat in the landscape had occurrence rates and densities of western meadowlarks, grasshopper sparrows, and lark buntings similar to patches that were 300ha+.

Patches should contain little to no edge occupied by woody species as these supply travel corridors and cover for mammalian predators and perching sites for avian and nest predators which negatively impact grassland bird species (Winter et. al. 2000). Bakker (2000) found that in eastern South Dakota patches should contain less than 2% woody edge to mitigate these negative effects. Probability of occurrence for grasshopper sparrows and western meadowlarks were highest when there was less than one percent woody edge and declined drastically as woody edge increased. Chestnut-collared longspurs were most susceptible to increases in woody edge and probability of occurrence never exceeded 30% when any amount of woody edge was present. I would suggest that no woody edge be present in preserved grassland to ensure the preservation

of species like the chestnut-collared longspur that are highly affected by any increase in woody edge.

Preserved grasslands should be located in landscapes with large amounts of surrounding grassland as six of the nine species were positively associated with increasing amount grassland habitat in landscape. Probability of occurrence for the grasshopper sparrow was lower in landscapes with little surrounding grassland habitat than in those with large amounts. Lark buntings were highly susceptible to decreasing grassland in the landscape and required greater than 95% surrounding grassland habitat to obtain a probability of occurrence greater than 50%. The extent at which the surrounding grassland plays a role can range from 400m up 3200m and possibly more. These large areas of grass dominated landscapes supply many benefits such as reduced nest predation and lower competition with edge and generalist bird species, and benefit grassland birds more than single large patches isolated from other grassland. Preservation of these large tracts of grassland is vital to the conservation of not only landscape sensitive species but all grassland obligates as this is the habitat they have evolved in.

My findings show the need to manage these birds based on data and information collected within the intended management area and not from surrounding areas when possible. When compared to models from the literature my results contained some similar variables and trends but were distinct in others. Johnson and Igl (2001) and Bakker et. al. (2002) indicated that results from one study area may not apply to other areas because the habitat requirements of grassland birds may vary with species distribution, vegetation structure, and landscape composition. This difference between study areas is evident

when comparing results from my study of central and western South Dakota showing grasshopper sparrow occurrence to be negatively associated with litter depth while Bakker (2000) showed a positive association in eastern South Dakota. Although this study was conducted in a largely unfragmented area on native sod grasslands, the results may provide insight on how to manage grasslands in areas that are becoming or already are highly fragmented. This insight could help mitigate the effects of this habitat destruction, preserving grassland bird densities and diversities.

Managers need to look at more than just local patch characteristics and undertake a management plan that incorporates a multiple scale approach, including variables from local, patch and landscape scales. Managers need to manage vegetation on a species by species method, as the variation in local habitat characteristics vary greatly by species and lumping them together under one management scheme could be detrimental to some, while benefiting others. Patch and landscape habitat characteristics should be managed based on species that are most sensitive to fragmentation and landscape composition changes, to ensure all species are covered by the management plan.

Recommendations for Future Study

Restoration of grasslands through the Conservation Reserve Program (CRP) has been a well-established management tool in South Dakota and the Great Plains. CRP has been shown to supply many grassland obligate species with suitable breeding habitat in the Great Plains by Best et. al. (1997) and Koford (1999). However, CRP may not work in some areas like western South Dakota or for certain species such as the chestnut-collared longspur and Sprague's pipit which prefer native sod habitat. A study comparing

the occurrence, density and nesting success of the avian communities of South Dakota should be conducted to asses how effective CRP (restored grasslands) is in supplying suitable habitat when compared to native sod grasslands. This study should be conducted on restored grasslands of different ages to see if a certain time period is required for these grasslands to exhibit similar trends in avian community as native sod and if so how long does this take?

Bakker and Higgins *in press* reported that CRP and native sod grasslands are not equivalent habitats when considering grassland bird occurrence, density and productivity in eastern South Dakota and western Minnesota. If similar results are found for western South Dakota, a study looking at the amount of grassland in the surrounding landscape that is native vs. restored and its affect on grassland obligates should be conducted. This study would be time intensive as a GIS layer for native sod vs. restored grasslands does not yet exist for South Dakota, and all study sites would have to be ground truthed and digitized for analysis.

A more intensive study of species with low occurrences in this study should be conducted. This study should concentrate on grassland obligate species not looked at by this study such as the vesper and Henslow's sparrows and also Le Conte's sparrows, Baird's sparrows, Sprague's pipits and the dickcissel. Increasing the number of occurrences for these species would allow for development of more robust models and give managers a better idea on how to manage habitat for these species. When a new version of the NLCD is produced a reevaluation of the landscape variables from this study may be warranted to see if as habitat fragmentation increases, does amount of grass

in the surrounding landscape become an important predictor of occurrence and density for additional species. Inclusion of a larger buffer size (>3200m) should also be included as three species had densities and occurrences positively associated with landscape variables at 3200m, and these species may be affected by a larger level.

South Dakota contains more intact grassland than many of the surrounding states in the Great Plains region, such as Iowa which is estimated to have less than 0.1% of its original prairie cover remaining (Smith 1998). With these large amounts of grassland, South Dakota has a lower rate of grassland bird decline for most species than states with increased habitat loss and fragmentation (Sauer et. al. 2008). As conversion of native grassland increases in South Dakota grassland bird species that I found to be highly sensitive to habitat fragmentation, such as chestnut-collared longspurs, western meadowlarks and lark buntings have started to decline at greater rates (Sauer et. al. 2008).

Continued monitoring of grassland obligate species is needed. Native sod and CRP grasslands are being lost at an accelerated rate so it is imperative to monitor occurrence, densities and nesting success of these birds. In this continued monitoring and future research a walk-about surveying portions of the grassland not covered by transects should be included, to help locate additional species within grassland patches. By knowing what the grassland bird populations are doing and at what rate we can be ready to take more intensive actions to preserve these species for future generations, if our current actions do not help.

The results of this study show the importance of patch and landscape level variables on grassland bird occurrence and density. With these findings and current conversion rates of grasslands nation wide it is important that we act immediately to preserve as much native grassland as possible. As many of these species require large tracts of continuous grass to survive and breed. It is also important that we manage for individual species and create habitat that is suitable for each one. If action is not taken to preserve and manage these grasslands the loss of many grassland bird species is eminent.

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APPENDICES

Appendix A. Common and scientific names of bird species referred to in this document.

Species Common Name	Species Scientific Name
Northern Harrier	*Circus cyaneus*
Ring-necked Pheasant	*Phasianus colchicus*
Greater Prairie Chicken	*Tympanuchus cupido*
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Upland Sandpiper	*Bartramia longicauda*
Long-billed Curlew	*Numenius americanus*
Marbled Godwit	*Limosa fedoa*
Burrowing Owl	*Athene cunicularia*
Short-eared Owl	*Asio flammeus*
Horned Lark	*Eremophila alpestris*
American Crow	*Pica pica*
Sedge Wren	*Cistothorus platensis*
Sprague's Pipit	*Anthus spragueii*
European Starling	*Sturnus vulgaris*
Dickcissel	*Spiza americana*
Clay-colored Sparrow	*Spizella pallida*
Vesper Sparrow	*Pooecetes gramineus*
Lark Bunting	*Calamospiza melanocorys*
Savannah sparrow	*Passerculus sandwichensis*
Baird's Sparrow	*Ammodramus bairdii*
Henslow's Sparrow	*Ammodramus henslowii*
Grasshopper Sparrow	*Ammodramus savannarum*
Le Conte's Sparrow	*Ammodramus leconteii*
Chestnut-collared Longspur	*Calcarius ornatus*
Bobolink	*Dolichonyx oryzivorus*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Brown-headed Cowbird	*Molothrus ater*

Appendix B. Name, county and location (UTM) of all surveyed grasslands (N=288) in central and western South Dakota for summers 2007 and 2008.

Year	Name	County	UTM Zone	UTM East	UTM North
2007	Bobby Thorson #1	Haakon	14T	264748	4891203
2007	Leo Patton #1	Haakon	14T	291532	4917735
2007	Ralph Jones #1	Haakon	14T	326538	4874041
2007	Marie Lamn #1	Haakon	14T	291988	4890341
2007	Rudy Roth #1	Haakon	14T	283658	4892690
2007	Mark Nelson #1	Haakon	14T	303060	4890535
2007	William McDaniel #1	Haakon	14T	291650	4893193
2007	Larry Gabriel #1	Haakon	14T	262855	4906594
2007	Terry Hand #1	Haakon	14T	318871	4916085
2007	Nels Paulsen #1	Haakon	14T	326960	4939045
2007	Vincent Schofield #1	Haakon	14T	311703	4901444
2007	Jerry Nemes #1	Haakon	14T	323299	4887995
2007	Dave Stangle #1	Haakon	14T	272024	4921949
2007	Boyd Parsons Jr. #1	Haakon	14T	290981	4935918
2007	John Eisenbraun #1	Jackson	14T	291653	4848280
2007	Mark Williams #1	Jackson	14T	302725	4853920
2007	Mike Perault #1	Jackson	14T	322042	4855272
2007	Mark Reiman #1	Jackson	14T	332021	4870523
2007	Mike Perault #2	Jackson	14T	334094	4858382
2007	Larry Dolezal #1	Jackson	14T	316192	4869759
2007	Kelly Riggins #1	Jackson	14T	297911	4868388
2007	Gene Fortune #1	Jackson	14T	275312	4843993
2007	Justin Wheeler #1	Jackson	14T	278259	4862664
2007	Walk-in Area #1	Jackson	14T	271791	4867364
2007	Walk-in Area #2	Meade	13T	718557	4988916
2007	Walk-in Area #3	Meade	13T	722434	4988928
2007	Walk-in Area #4	Meade	13T	726270	4987519
2007	Walk-in Area #5	Meade	13T	720395	4979486
2007	Walk-in Area #6	Meade	13T	720119	4970086
2007	GPA? #1	Meade	13T	703775	4976002
2007	Walk-in Area #7	Meade	13T	719441	4963132
2007	Bob Collins #1	Meade	13T	734226	4975227
2007	Doug Hlavka #1	Meade	13T	729464	4950118
2007	SD School Land #1	Meade	13T	732828	4967398
2007	Mrs. Sandal #1	Meade	13T	724366	4935004
2007	Melven Arneson #1	Meade	13T	700394	4927992
2007	Walk-in Area #8	Meade	13T	689498	4985862
2007	Walk-in Area #9	Meade	13T	667592	4982034
2007	SD School Land #2	Meade	13T	670566	4971387
2007	Walk-in Area #10	Meade	13T	662553	4956870

Year	Name	County	UTM Zone	UTM East	UTM North
2007	SD School Land #3	Meade	13T	671030	4932290
2007	SD School Land #4	Meade	13T	671724	4913813
2007	SD School Land #5	Meade	13T	708736	4953507
2007	Dan Arenson #1	Meade	13T	695373	4960328
2007	SD School Land #6	Meade	13T	684275	4947390
2007	Walk-in Area #11	Ziebach	14T	266828	4987897
2007	Walk-in Area #12	Ziebach	14T	274266	4977175
2007	Walk-in Area #13	Ziebach	14T	273766	4998739
2007	Walk-in Area #14	Ziebach	14T	299639	5003109
2007	Walk-in Area #15	Ziebach	14T	300109	5031446
2007	Walk-in Area #16	Ziebach	14T	270903	5031697
2007	SD School Land #7	Ziebach	14T	300821	4961669
2007	Lake Owens GPA #1	Perkins	13T	703112	5037160
2007	Bester MU Walk-in #1	Perkins	13T	690632	5033416
2007	Walk-in Area #17	Perkins	13T	675088	5026632
2007	SD School Land #8	Perkins	13T	671201	5037989
2007	Walk-in Area #18	Perkins	13T	663390	5001789
2007	SD School Land #9	Perkins	13T	664459	5051138
2007	SD School Land #10	Perkins	13T	679628	5000477
2007	Walk-in Area #19	Perkins	13T	721052	5042146
2007	Walk-in Area #20	Perkins	13T	733223	5021382
2007	Beryl Veal #1	Perkins	13T	704618	5024158
2007	SD School Land #11	Perkins	13T	716102	5088702
2007	SD School Land #12	Perkins	13T	726610	5001968
2007	Walk-in Area #21	Perkins	13T	716152	5011429
2007	GRNG #1	Perkins	13T	696103	5083599
2007	Walk-in Area #22	Perkins	13T	699912	5058114
2007	Walk-in Area #23	Perkins	13T	732855	5051187
2007	GRNG #2	Perkins	13T	721987	5068068
2007	GRNG #3	Perkins	13T	707657	5053475
2007	GRNG #4	Perkins	13T	690795	5074631
2007	Walk-in Area #24	Perkins	13T	675189	5062268
2007	Walk-in Area #25	Perkins	13T	661221	5085553
2007	GRNG #5	Perkins	13T	671190	5079980
2007	GRNG #6	Perkins	13T	688938	5048208
2007	Walk-in Area #26	Corson	14T	276198	5090642
2007	SD School Land #13	Corson	14T	272529	5064131
2007	SD School Land #14	Corson	14T	288799	5078072
2007	Walk-in Area #27	Corson	14T	291594	5057852
2007	Karlen #1	Lyman	14T	453263	4869430
2007	FPNG Lookout North #1	Lyman	14T	392274	4892730
2007	Warren Hammerbeck #1	Lyman	14T	459889	4831448
2007	Evelan Haines #1	Lyman	14T	468950	4821081
2007	Carpenter GPA #1	Lyman	14T	464329	4843323

Year	Name	County	UTM Zone	UTM East	UTM North
2007	Jim Anderson #1	Lyman	14T	427246	4861819
2007	Negebauer GPA #1	Lyman	14T	460571	4847986
2007	FPNG Sletto Home #1	Jones	14T	388560	4881843
2007	FPNG Stockton North #1	Jones	14T	386536	4877117
2007	Buxcel GPA #1	Jones	14T	334541	4867552
2007	FPNG Bad River West #1	Stanley	14T	385448	4897055
2007	FPNG Williams North #1	Stanley	14T	408514	4900479
2007	Antelope Creek GPA #1	Stanley	14T	406665	4907160
2007	FPNG Mustang West #1	Stanley	14T	395863	4902759
2007	Robbins WPA #1	Hughes	14T	424686	4915380
2007	Hyde WPA #1	Hughes	14T	394377	4921502
2007	Siebrasse GPA #1	Potter	14T	396948	4984454
2007	Potts Damn GPA #1	Potter	14T	438512	4975210
2007	Walk-in Area #35	Potter	14T	409313	5010937
2007	Firesteel GPA #1	Dewey	14T	318964	5034532
2007	Isabel Lake GPA #1	Dewey	14T	310923	5034534
2007	Little Moreau GPA #1	Dewey	14T	337167	5025128
2007	Walk-in Area #28	Dewey	14T	380580	5033200
2007	Little Bend GPA #1	Sully	14T	370230	4958642
2007	Little Bend GPA #2	Sully	14T	374479	4955392
2007	Sutton Bay GPA #1	Sully	14T	392584	4969732
2007	Lombreacht GPA #1	Sully	14T	388895	4956296
2007	Cottonwood Lake GPA #1	Sully	14T	427385	4965369
2007	Walk-in Area #29	Corson	14T	377397	5042376
2007	Walk-in Area #30	Corson	14T	353451	5067127
2007	Walk-in Area #31	Corson	14T	358257	5051664
2007	Ray Johnson #1	Corson	14T	361049	5048206
2007	SD School Land #15	Corson	14T	327613	5087170
2007	Walk-in Area #32	Corson	14T	316566	5058769
2007	Walk-in Area #33	Corson	14T	274706	5089716
2007	Walk-in Area #34	Corson	14T	271222	5071823
2007	Liebelt WPA #1	Walworth	14T	429066	5019513
2007	SD School Land #16	Walworth	14T	413768	5020398
2007	BLM 1A WPA #1	Campbell	14T	425719	5067840
2007	Cooper WPA #1	Campbell	14T	434564	5059207
2007	Koss WPA #1	Brule	14T	511654	4829561
2007	Stanek WPA #1	Brule	14T	499235	4824212
2007	Boyer GPA #1	Brule	14T	469420	4836367
2007	Hoover GPA #1	Brule	14T	486100	4820206
2007	Kramer Slough GPA #1	Aurora	14T	526482	4835646
2007	Foster WPA #1	Aurora	14T	523150	4824923
2007	Humphery WPA #1	Aurora	14T	522855	4848002
2007	Lutz WPA #1	Aurora	14T	530095	4842657
2007	Maine WPA #1	Aurora	14T	532831	4836782

Year	Name	County	UTM Zone	UTM East	UTM North
2007	Schute WPA #1	Aurora	14T	527130	4838926
2007	Sorenson WPA #1	Aurora	14T	537330	4833090
2007	Horseshoe Lake GPA #1	Jerauld	14T	525203	4868002
2007	Winter WPA #1	Jerauld	14T	510298	4892017
2007	Zink WPA #1	Jerauld	14T	542340	4883511
2007	Jackson WPA #1	Jerauld	14T	547205	4872247
2007	Reimitz #1	Douglas	14T	557234	4807664
2007	Harter WPA #1	Hyde	14T	458285	4917036
2007	Curtis GPA #1	Hand	14T	490089	4903252
2007	Camp Dakota GPA #1	Hand	14T	492912	4922973
2007	VenJohn WPA #1	Hand	14T	478522	4961640
2007	Slunecka WPA #1	Hand	14T	488417	4950558
2007	Miller Dale WPA #1	Hand	14T	488343	4915691
2007	Spring Lake WPA #1	Hand	14T	505373	4902036
2007	Waldman WPA #1	Faulk	14T	477598	4990778
2007	Lane WPA #1	Faulk	14T	463605	5008089
2007	Schafer-Schafer-Hoffman WPA #1	McPherson	14T	492594	5077703
2007	Long Lake WPA #1	McPherson	14T	481103	5077560
2007	Eureka Demo WPA #1	McPherson	14T	450830	5070061
2007	Mehlhaff WPA #1	McPherson	14T	452289	5062903
2007	Haerter WPA #1	McPherson	14T	466790	5056341
2007	Newharth WPA #1	McPherson	14T	469910	5069892
2007	Adam-Ginger WPA #1	McPherson	14T	481237	5053891
2007	Perch Lake WPA #1	McPherson	14T	486635	5056702
2007	Hoffman-Gottleib WPA #1	McPherson	14T	494787	5071354
2007	Weisser WPA #1	McPherson	14T	485765	5064992
2007	Hettich WPA #1	Edmunds	14T	459651	5024948
2007	Dewald WPA #1	Edmunds	14T	457114	5030836
2007	Rieger WPA #1	Edmunds	14T	450220	5036152
2007	Bowdle Lake WPA #1	Edmunds	14T	447893	5047382
2007	Ryman WPA #1	Edmunds	14T	464262	5015245
2008	GPA? #2	Haakon	14T	270172	4880219
2008	GPA? #3	Haakon	14T	298484	4906524
2008	SD School Land #17	Haakon	14T	284181	4919893
2008	GPA? #4	Haakon	14T	312906	4936826
2008	SDSU Cottonwood #1	Jackson	14T	268982	4869945
2008	Buffalo Gap NG #1	Jackson	14T	276554	4857173
2008	Buffalo Gap NG #2	Jackson	14T	263776	4858184
2008	Buffalo Gap NG #3	Pennington	13T	726512	4874164
2008	GPA? #5	Ziebach	14T	281558	5036152
2008	CRST #1	Ziebach	14T	278595	4956583
2008	CRST #2	Ziebach	14T	324230	4979817
2008	CRST #3	Ziebach	14T	291918	5007140
2008	CRST #4	Ziebach	14T	271780	4950259

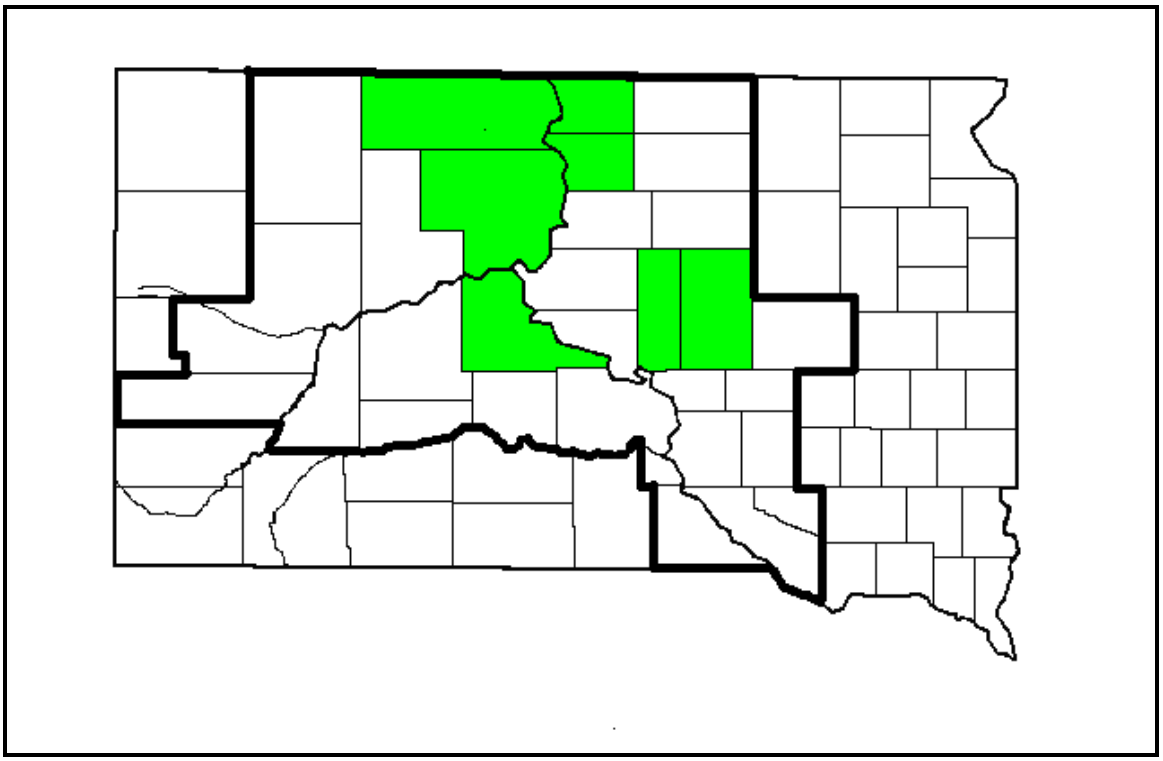
Year	Name	County	UTM Zone	UTM East	UTM North
2008	CRST #5	Ziebach	14T	293539	4943659
2008	CRST #6	Ziebach	14T	328100	4962502
2008	GRNG #7	Perkins	13T	698127	5064993
2008	GRNG #8	Perkins	13T	693762	5062555
2008	GRNG #9	Perkins	13T	704697	5078875
2008	GRNG #10	Perkins	13T	686478	5084941
2008	GRNG #11	Perkins	13T	728945	5075031
2008	Shade Hill #1	Perkins	13T	708085	5074500
2008	Shade Hill #2	Perkins	13T	708460	5061375
2008	Jim Anderson #2	Lyman	14T	433188	4861785
2008	Walk-in Area #35	Lyman	14T	445062	4862472
2008	Walk-in Area #36	Lyman	14T	442699	4866241
2008	Walk-in Area #37	Lyman	14T	430649	4863441
2008	Walk-in Area #38	Lyman	14T	433885	4869880
2008	Walk-in Area #39	Lyman	14T	407863	4863713
2008	Walk-in Area #40	Lyman	14T	412721	4873083
2008	Walk-in Area #41	Jones	14T	358120	4848660
2008	Raymond Roghair #1	Jones	14T	346583	4864210
2008	Walk-in Area #42	Jones	14T	382257	4857296
2008	GPA? #6	Stanley	14T	343533	4915159
2008	GPA? #7	Stanley	14T	365984	4929414
2008	BLM Land #1	Stanley	14T	360196	4951144
2008	BLM Land #2	Stanley	14T	350776	4955444
2008	Jeff Mortinson #1	Stanley	14T	332401	4952577
2008	Stan Chocholousek #1	Gregory	14T	467324	4802778
2008	Dale Pastian #1	Gregory	14T	469547	4807813
2008	Walk-in Area #43	Potter	14T	451811	4992783
2008	SD School Land #18	Potter	14T	451449	4985784
2008	SD School Land #19	Potter	14T	453383	5000728
2008	Walk-in Area #44	Potter	14T	408255	5004525
2008	SD School Land #21	Potter	14T	405755	4991526
2008	SD School Land #22	Potter	14T	411422	4987383
2008	SD School Land #23	Potter	14T	418130	4997831
2008	SD School Land #24	Potter	14T	420252	4978514
2008	SD School Land #25	Potter	14T	441669	5010500
2008	CRST #7	Dewey	14T	326126	5004472
2008	Private Land? #1	Dewey	14T	355842	5006412
2008	CRST #8	Dewey	14T	397227	4987519
2008	CRST #9	Dewey	14T	357424	4960224
2008	CRST #10	Dewey	14T	376571	4978291
2008	Private Land? #2	Dewey	14T	344950	4979785
2008	Walk-in Area #46	Sully	14T	446379	4953581
2008	Walk-in Area #47	Sully	14T	398362	4967809
2008	GPA? #8	Sully	14T	433593	4936213

Year	Name	County	UTM Zone	UTM East	UTM North
2008	Walk-in Area #48	Sully	14T	406198	4934465
2008	Walk-in Area #49	Sully	14T	386928	4945361
2008	SD School Land #26	Sully	14T	412834	4956434
2008	SD School Land #27	Corson	14T	311083	5044651
2008	SD School Land #28	Corson	14T	375241	5079067
2008	SD School Land #29	Corson	14T	382976	5060750
2008	GPA? #11	Corson	14T	354107	5068774
2008	GPA? #12	Corson	14T	366498	5044841
2008	Walk-in Area #50	Corson	14T	304566	5053042
2008	Walk-in Area #51	Corson	14T	332879	5043876
2008	Walk-in Area #52	Walworth	14T	442909	5044399
2008	SD School Land #30	Walworth	14T	433365	5031551
2008	SD School Land #31	Walworth	14T	426888	5030004
2008	Walk-in Area #53	Walworth	14T	420172	5013981
2008	Walk-in Area #54	Walworth	14T	405963	5014338
2008	Walk-in Area #55	Walworth	14T	427441	5047754
2008	Walk-in Area #56	Walworth	14T	441264	5035505
2008	Private Land? #3	Walworth	14T	443700	5021774
2008	Walk-in Area #57	Walworth	14T	423411	5022005
2008	SD School Land #32	Walworth	14T	399663	5038024
2008	Walk-in Area #58	Walworth	14T	408626	5030448
2008	Walk-in Area #59	Walworth	14T	410751	5049468
2008	SD School Land #33	Campbell	14T	404309	5079181
2008	Lloyd Grad #1	Campbell	14T	412733	5065765
2008	Gary Oster #1	Campbell	14T	442720	5072778
2008	Walk-in Area #60	Campbell	14T	417553	5052858
2008	Walk-in Area #61	Campbell	14T	438404	5074832
2008	WPA? #1	Campbell	14T	440799	5051721
2008	SD School Land #34	Campbell	14T	428375	5074950
2008	Private Land? #4	Brule	14T	509162	4857406
2008	Mr. Reur #1	Brule	14T	468825	4844163
2008	SD Waterfowl Refuge #1	Brule	14T	475285	4858748
2008	WPA? #2	Aurora	14T	532604	4833508
2008	Walk-in Area #62	Aurora	14T	544745	4858322
2008	Private Land? #5	Aurora	14T	545149	4816655
2008	GPA? 13	Aurora	14T	537294	4828160
2008	Freudenberg WPA #1	Jerauld	14T	549462	4887260
2008	Long Lake GPA #1	Jerauld	14T	522895	4890002
2008	Kraft WPA #1	Jerauld	14T	530591	4872801
2008	Walk-in Area #63	Jerauld	14T	506054	4880529
2008	Walk-in Area #64	Buffalo	14T	477322	4874226
2008	Mills WPA #1	Buffalo	14T	490584	4891914
2008	Sip #1	Charles-Mix	14T	515028	4793662
2008	Rezak Lake GPA #1	Hyde	14T	470632	4960544

Year	Name	County	UTM Zone	UTM East	UTM North
2008	SD School Land #35	Hyde	14T	456969	4968446
2008	Ken Branine #1	Hyde	14T	451915	4928834
2008	Jim Faulstich #1	Hyde	14T	464324	4949659
2008	Campbell WPA #1	Hand	14T	509360	4913612
2008	Walk-in Area #65	Hand	14T	506897	4950543
2008	Boomsma WPA #1	Hand	14T	518830	4898630
2008	Reinhardt GPA #1	Hand	14T	500783	4962346
2008	SD School Land #36	Hand	14T	513690	4969754
2008	Scatterwood GPA #1	Faulk	14T	519652	5003780
2008	Gherkin Refuge GPA #1	Faulk	14T	504597	4984325
2008	Sprague GPA #1	Faulk	14T	501535	4974636
2008	Walk-in Area #66	Faulk	14T	461223	4989226
2008	SD School Land #37	Faulk	14T	493203	5000622
2008	Sand Creek GPA #1	Beadle	14T	540705	4903392
2008	Schumacher GPA #1	McPherson	14T	477909	5074518
2008	Walk-in Area #67	McPherson	14T	509695	5066281
2008	Ordway P-13 #1	McPherson	14T	492501	5063101
2008	North Jackson GPA #1	McPherson	14T	445461	5057114
2008	Moscow GPA #1	McPherson	14T	479428	5065057
2008	DU Goebel North #1	McPherson	14T	492561	5086740
2008	Ordway P-5 #2	McPherson	14T	492132	5056981
2008	Ordway P-N6 #3	McPherson	14T	487713	5060069
2008	DU Goebel 10A #2	McPherson	14T	489147	5046644
2008	Anderson WPA #1	Edmunds	14T	481705	5019736
2008	Losee GPA #1	Edmunds	14T	475206	5022338
2008	Shaner GPA #1	Edmunds	14T	520765	5030851
2008	DU Goebel 26C #3	Edmunds	14T	490665	5051870
2008	DU Goebel 29C #4	Edmunds	14T	484493	5050584

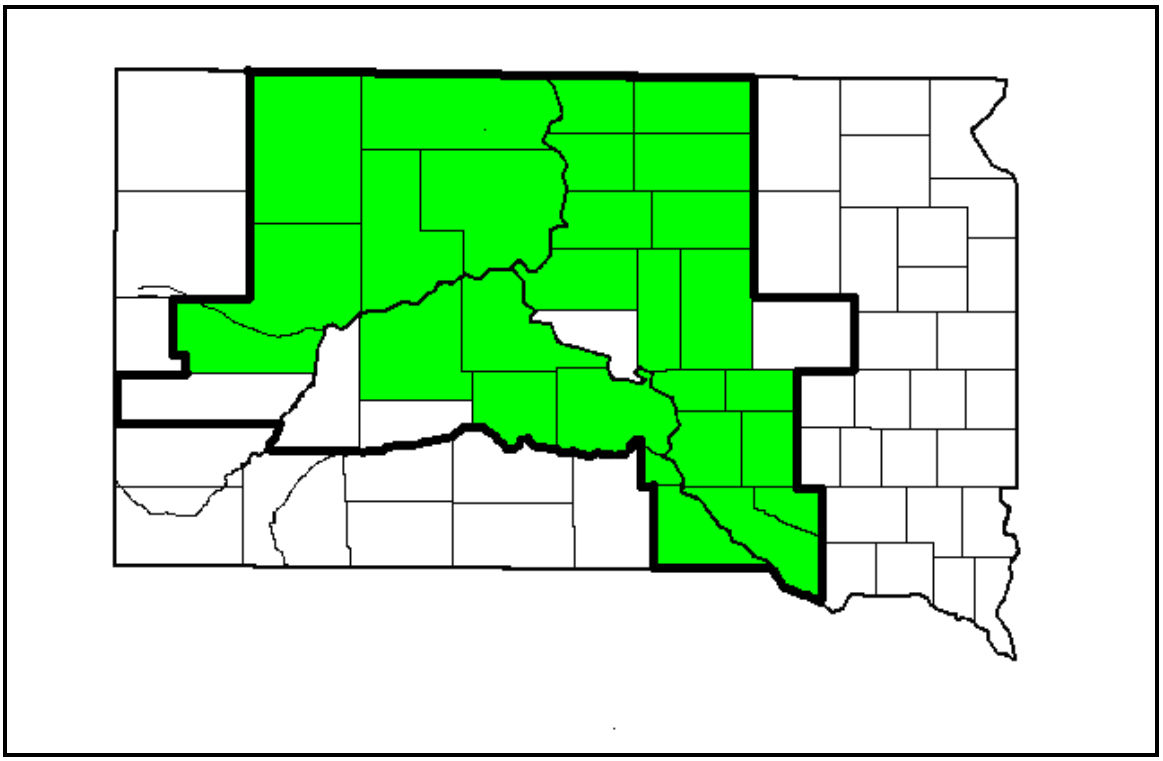
Appendix C. Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Baird's Sparrow</u>



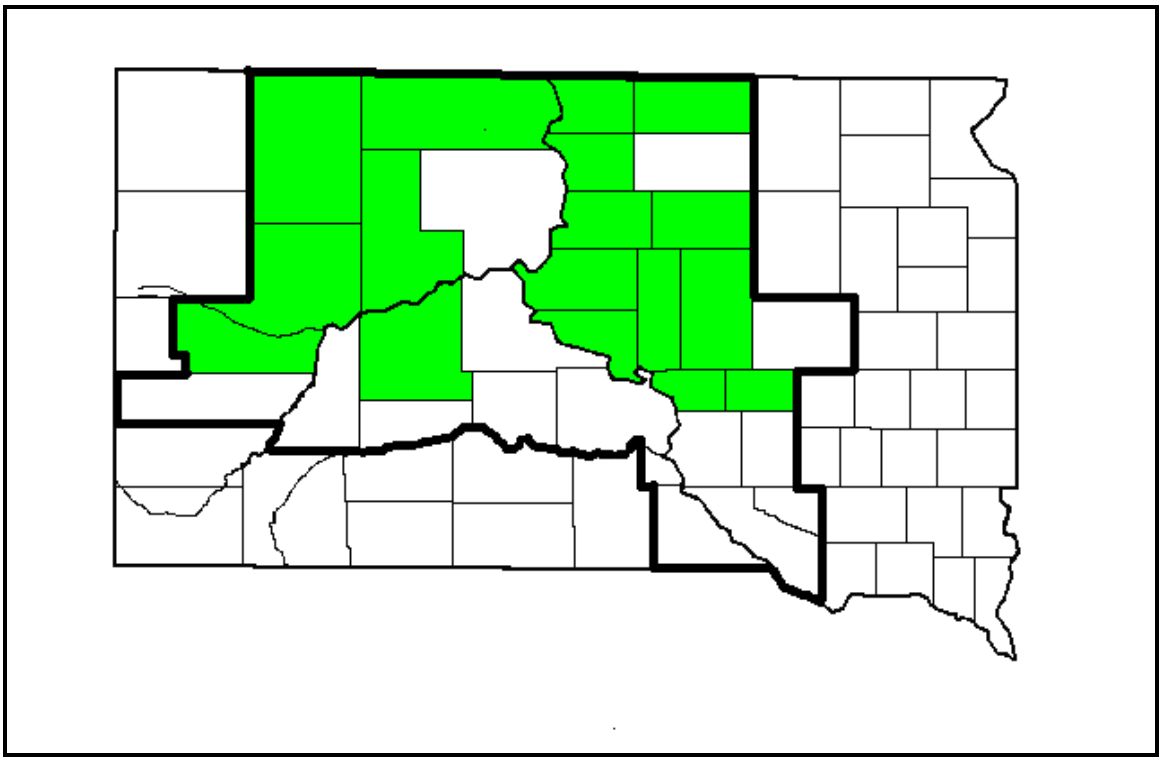
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Bobolink</u>



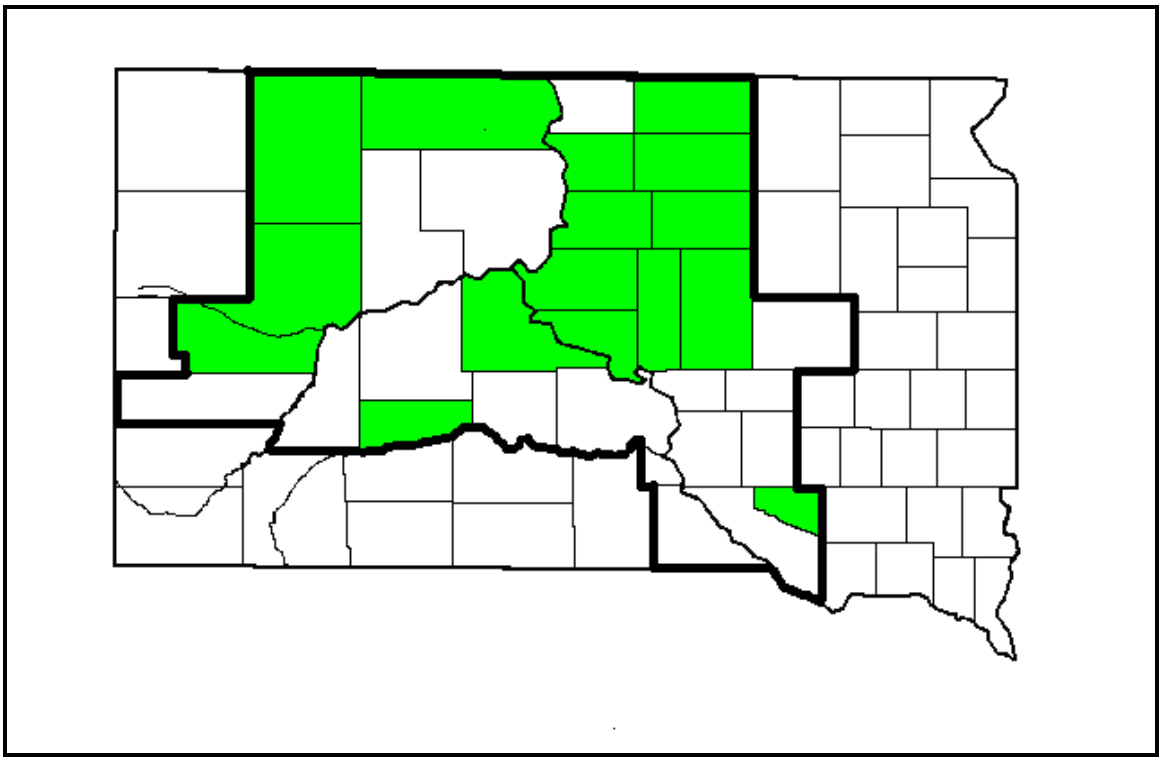
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Chestnut-Collared Longspur</u>



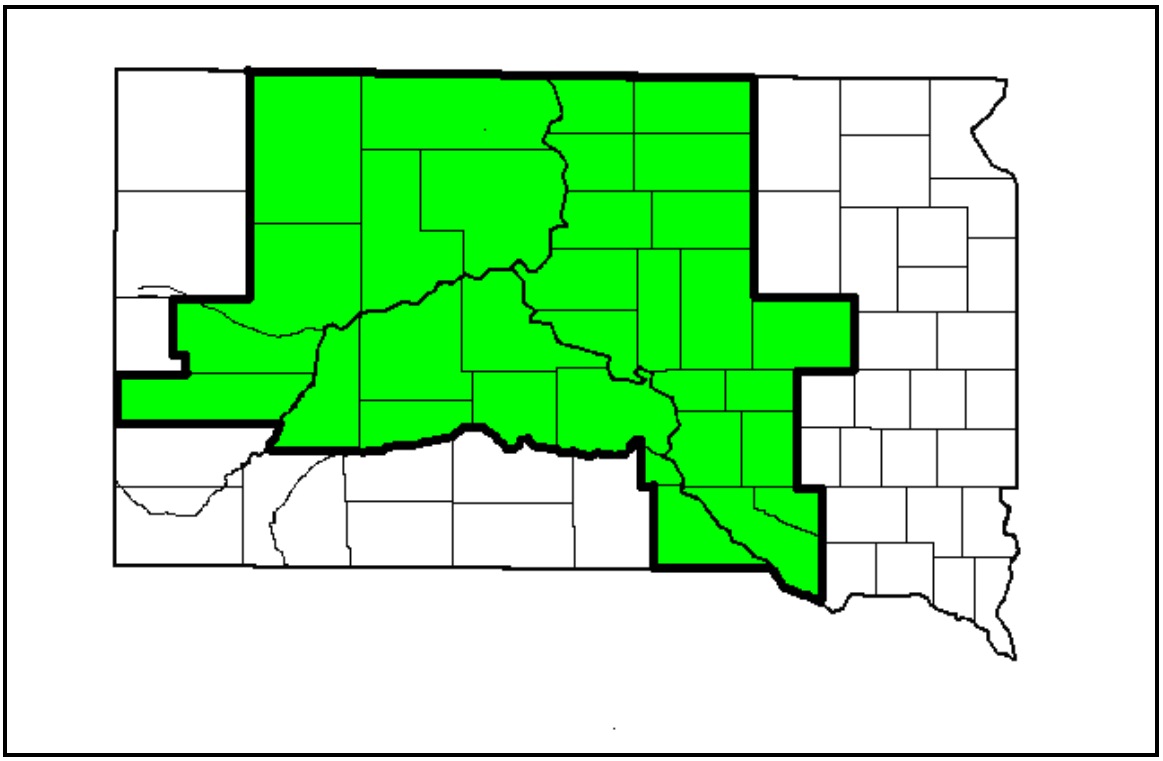
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Dickcissel</u>



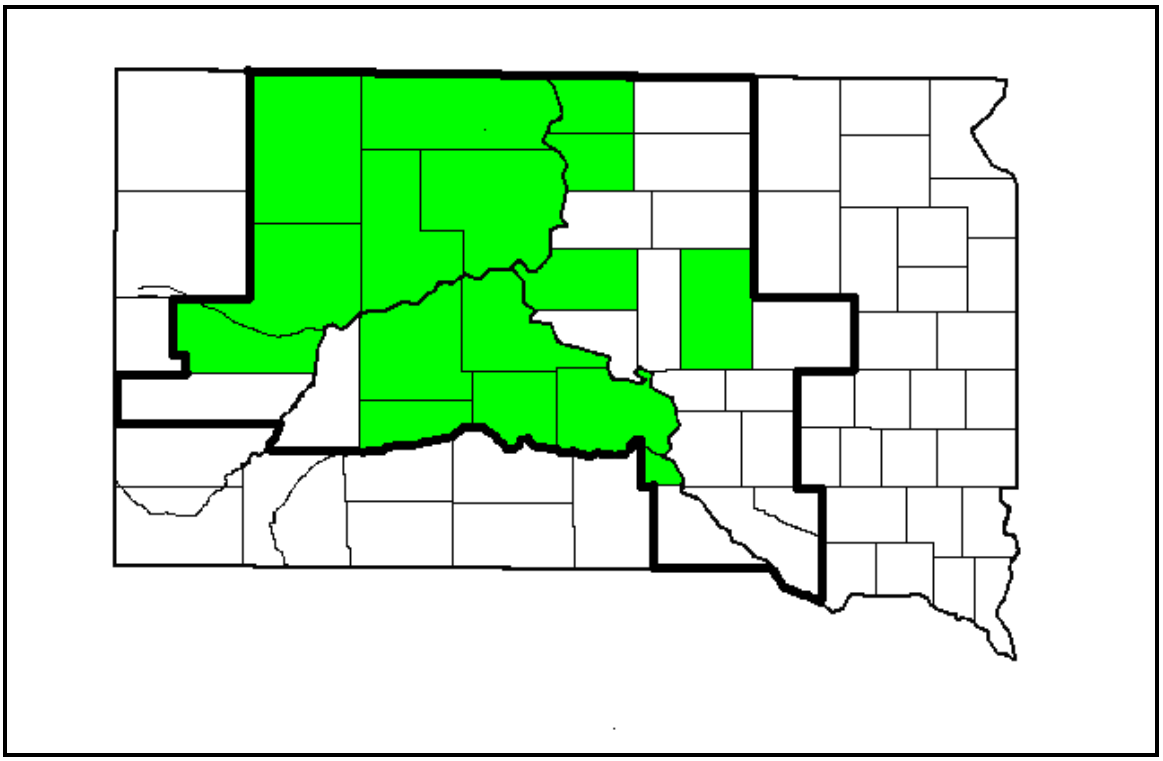
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Grasshopper Sparrow</u>



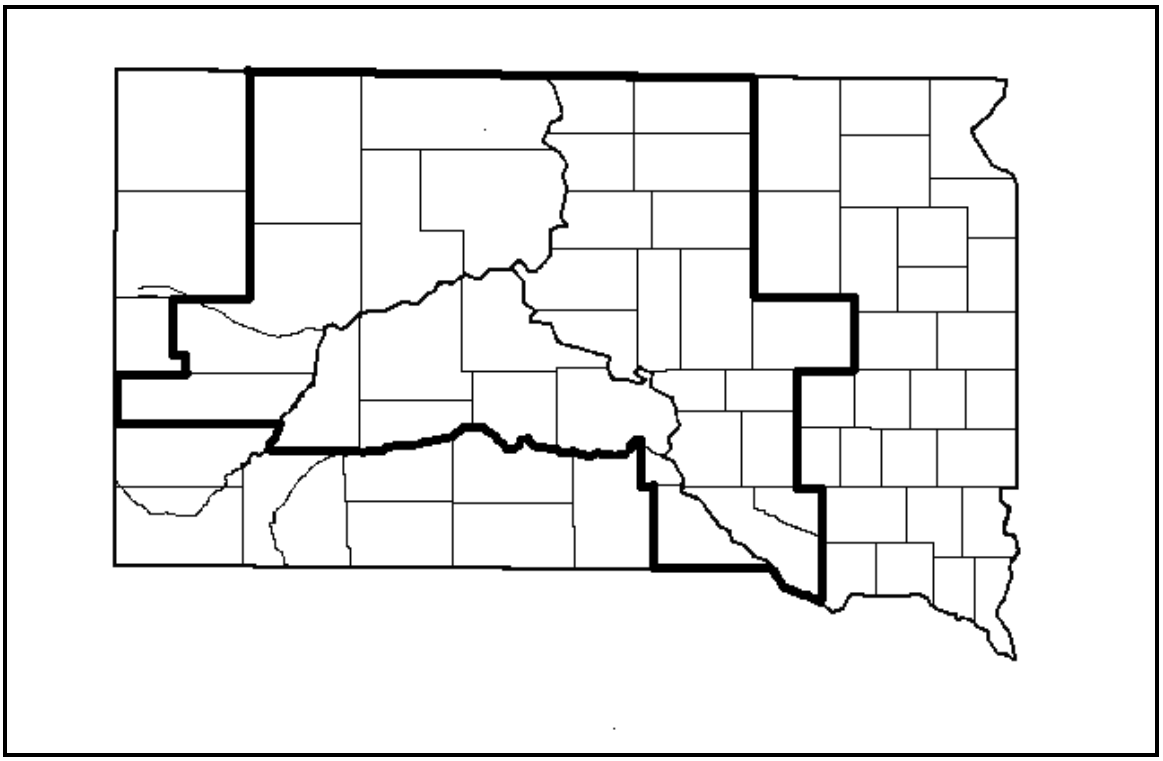
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Lark Bunting</u>



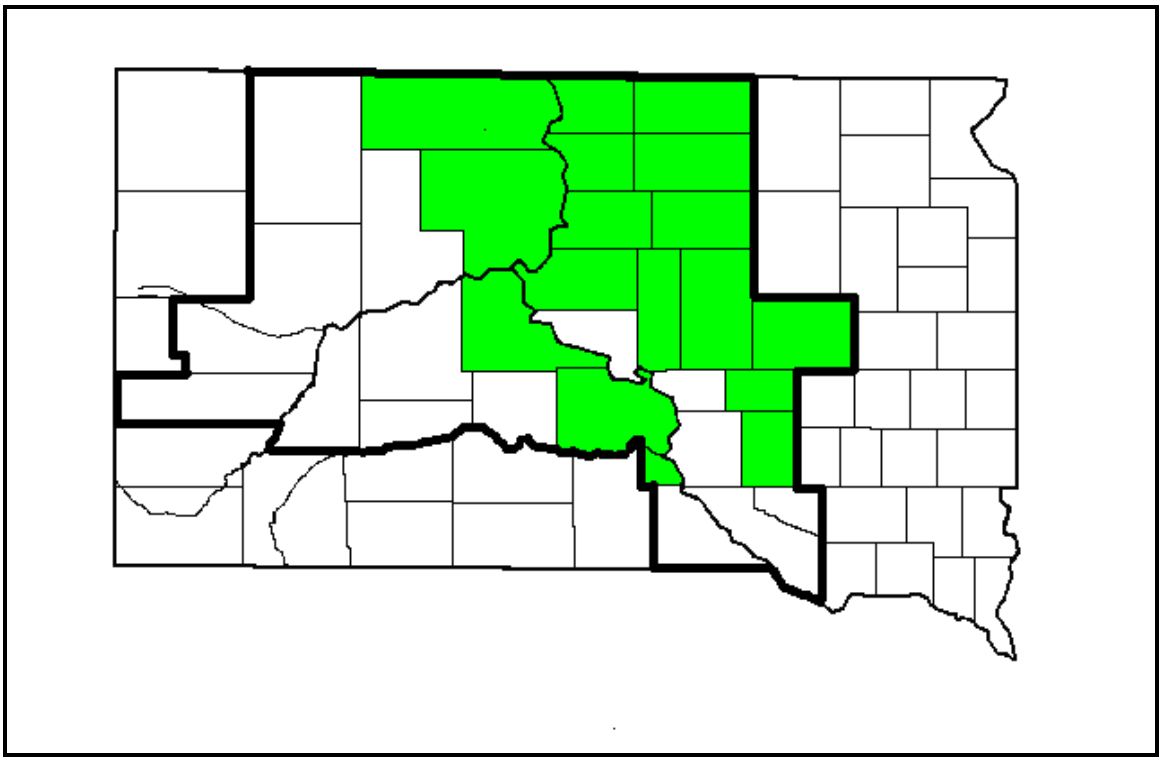
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Le Conte's Sparrow</u>



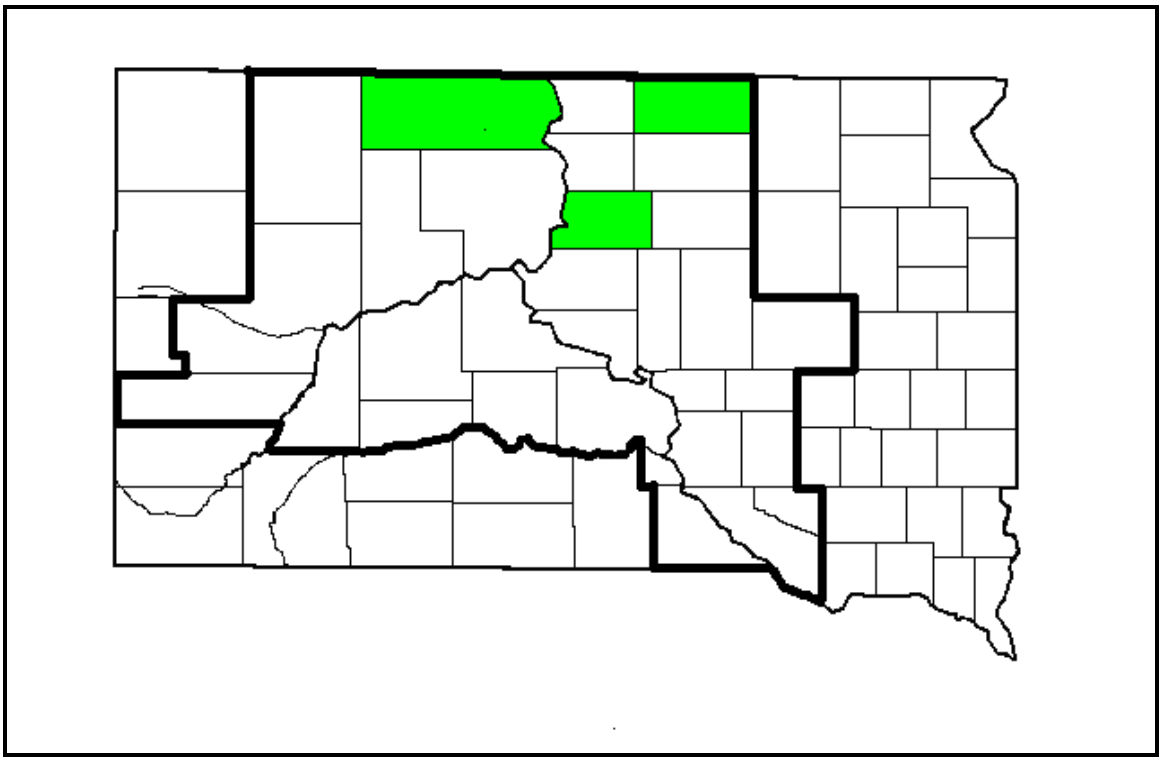
Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

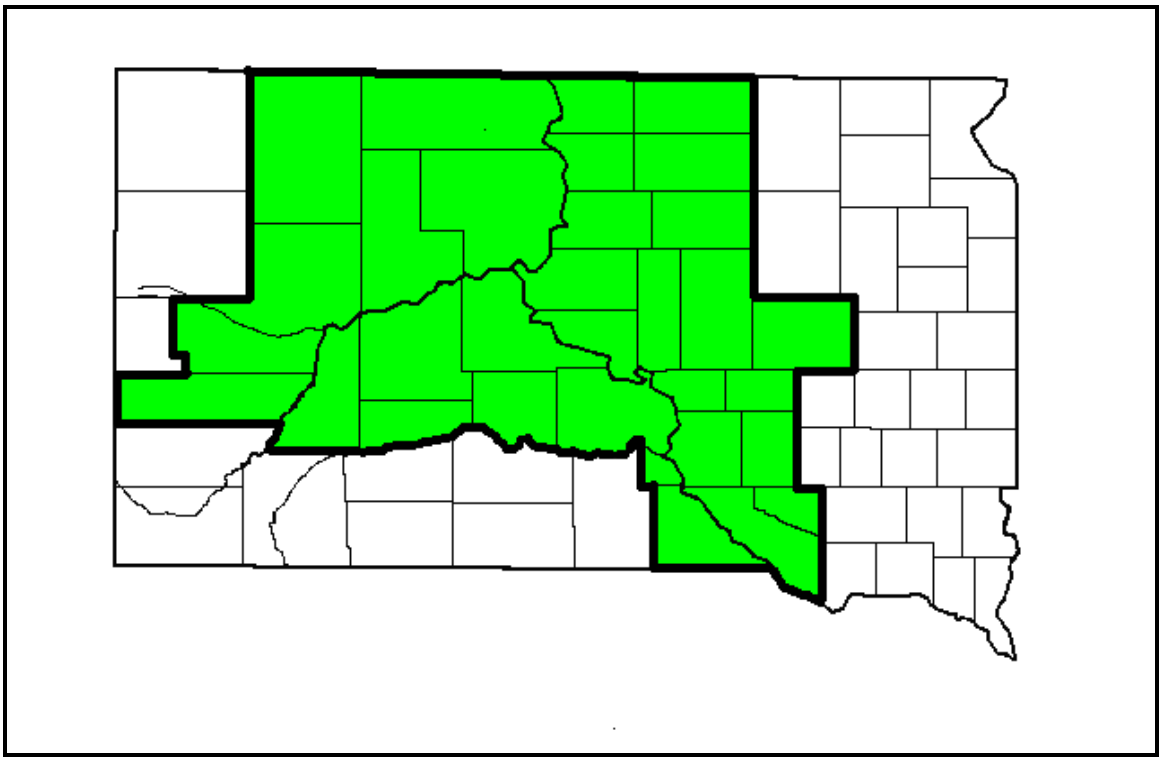
<u>Savannah Sparrow</u>



Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

<u>Sprague's Pipit</u>



Appendix C (Continued). Distribution maps for grassland obligate species generated from transect and walk-about surveys (N=288) (2007 and 2008) in the mixed-grass prairie of South Dakota. Study area indicated by bolded line.

Western Meadowlark