Habitat selection by songbirds in Manitoba's tall-grass prairie: A multi-scale analysis

By: Kristin Mozel

A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

Master of Natural Resources Management

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FACULTY OF GRADUATE STUDIES
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Abstract

Research on North American grassland birds in tall-grass prairie is imperative for avian conservation, as numbers have been declining over the last 40 years with the loss of grassland habitat. Conducting studies at multiple spatial scales helps us to determine the most important scale of response for maintaining populations, which aids wildlife managers in designing effective conservation programs. I examined effects of habitat variables at multiple scales on abundance and diversity of prairie birds. In 2007 and 2008, point counts were conducted at twenty-five prairie fragments and adjacent grassland and agricultural matrix habitat in southern Manitoba. I measured vegetation composition and structure surveys at twenty-four prairie fragments. General Linear Models (GLM) were used to compare richness and densities of bird species between tall-grass prairie and matrix habitat, while Generalized Linear Mixed Models (GLMM) with Akaike's Information Criteria (AIC_c) were used to determine if local, patch or landscape level variables were most important in determining habitat selection and to which habitat variables birds responded most strongly.

Prairies and matrix grassland habitat supported the same number of avian species in both years, and densities of all focal bird species were the same in non-native grasslands as compared with native tall-grass prairies. The agricultural matrix had significantly lower avian species richness in 2008, but supported the same richness in 2007. Bobolinks and sedge wrens were not recorded in agricultural areas in either year. Clay-coloured sparrows and Le Conte's sparrows were not recorded in agricultural fields in 2008, and had significantly lower densities in agricultural areas in 2007. Savannah sparrows had lower densities in agriculture as compared with prairies in 2008, while brown-headed cowbirds were not found in agriculture in 2008.

Overall species richness in tall-grass prairies was mainly driven by vegetation variables. Bobolinks and clay-coloured sparrows were most strongly affected by adjacent matrix habitat and vegetation variables, while brown-headed cowbirds, Le Conte's sparrows, red-winged blackbirds, Savannah sparrows and sedge wrens were mainly affected by local and patch-level mechanisms together. Size of tall-grass prairies influenced the density/presence of the greatest number of avian species, compared with other variables analyzed. At the local level, non-native species richness influenced the most species, with responses among species being variable.

Although non-native grasslands provided habitat for some of the prairie birds in my study, several species selected higher quality prairies or prairies with greater native vegetation richness. Grassland restoration for degraded non-native sites may assist in stabilizing declining populations of Savannah sparrows and Le Conte's sparrows. Variable responses to habitat structure and composition between avian species indicate that managing grasslands to promote heterogeneity is important to sustain a diverse assemblage of avian species. As individual species were affected most strongly by vegetation structure and richness, it follows that management of prairie vegetation through techniques such as grazing and prescribed burning could optimize habitat usability for birds.

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Chapter 1: Purpose of Research

1.1 Introduction

Conservation of tall-grass prairie is critical, as it is one of the most highly fragmented ecosystems in the world with less than 1% of its historic area remaining (Samson and Knopf 1994). Loss and fragmentation of tall-grass prairie can primarily be attributed to its conversion to agriculture, mostly over the last 100 years (Cully et al. 2003). Fragmentation leads to isolation among small remnant patches of natural habitat surrounded by different land uses or vegetation (matrix) (Saunders et al. 1991). Tall-grass prairie also continues to be under pressure from encroachment of woody vegetation (Heisler et al. 2003) and exotic species invasions (Cully at al. 2003) due to suppression of historic disturbances of fire and grazing (Johnson and Winter 1999). To better manage and conserve remaining areas of endangered tall-grass prairie, we need to better understand which species are affected in which ways by tall-grass prairie fragmentation.

Research on North American grassland birds is also imperative, as their numbers have been declining over the last 30 years (Herkert et al. 2003). In fragmented grassland habitats, patch size, patch shape and spatial distribution of patches within the landscape all play a role in sustaining bird populations (Brennan and Kuvlesky 2005). Some of the spatial variation in grassland birds beyond landscape composition and structure may be due to altered distributions of predator communities found in some agricultural systems (Chalfoun et al. 2002) or density of prey (Hamer et al. 2006).

Quality or type of matrix habitat surrounding remnant patches has a great influence on species that inhabit them (Donald and Evans 2006). As birds are highly mobile, their ability to move within the matrix may not be seriously impacted in a

fragmented prairie/agricultural system. However, the matrix might provide new sources of food for prairie birds, influencing their dispersal (Turner 2005). As individual species are affected differently by composition of the matrix, permeability for birds may differ from that of their predators (Chalfoun et al. 2004) and prey (Stoner and Joern 2004).

Although many other studies have analyzed the impacts of habitat characteristics at the local, patch and landscape level on grassland birds, few have been conducted at the most northerly extent of the tall-grass prairie. As remnant patch sizes in northern tall-grass prairie are comparatively smaller than further south, my study provides information on the regional variability that exists throughout the ecosystem.

I examined effects of variables at multiple scales on abundance and diversity of prairie birds. Local-scale variables included vegetation composition and structure. Patch-scale variables included prairie size, shape and overall quality, while landscape-level attributes summarized composition of surrounding matrix habitat. Conducting multi-scale analyses is vital to management and understanding of fragmented agricultural systems (Bergin et al. 2000), as ecological processes and the corresponding relationships for habitat selection may operate at multiple scales. Results from this research will identify the most important spatial scale(s) for grassland bird habitat conservation and management in northern tall-grass prairies.

1.2 Problem Statement

Although much grassland bird research has been conducted recently and we understand a lot more about the causes for population declines in grassland birds than previously, we still lack information on some regional variability in habitat relationships. Identifying the impacts of fragmentation by assessing the influence of different variables

on grassland bird populations will help to determine the best management and conservation techniques for northern tall-grass prairie. My research at remnant tall-grass prairie sites in Manitoba will help us understand factors influencing avian occurrence and abundance and will contribute to conservation and management of both birds and northern prairie habitat.

1.3 Objectives

The purpose of this research is to understand how variables at various spatial scales affect richness and densities of prairie birds in fragmented tall-grass prairie of southern Manitoba. Specific objectives include to:

- Determine the role of remnant tall-grass prairies in Manitoba in sustaining grassland bird populations
- Investigate the influence of variables at local, patch and landscape levels on richness and density of prairie birds in Manitoba
- Understand which spatial scale is most important in management of tall-grass prairies for bird populations in Manitoba

1.4 Research Rationale

Gaining greater understanding of bird diversity in the tall-grass prairie ecosystem is very important to gain further understanding of the effects of habitat fragmentation and loss on prairie birds (Johnson and Igl 2001). Although some research has been done on tall-grass prairie birds in the United States (e.g. Bakker et al. 2002; Fletcher et al. 2006; Johnson and Igl 2001; Reinking 2003; Winter et al. 2000; Winter et al. 2005; Winter et al. 2006; Zimmerman 1992), there have been no peer-reviewed publications for the

landscape ecology of birds in tall-grass prairie in Canada. It is important to conduct research in this most northerly part of the tall-grass prairie, as effects of fragmentation on prairie ecosystems vary regionally (Johnson and Igl 2001).

Insights into the causes for variation in species richness and abundance such as vegetation composition, structure, prairie quality and size will help to improve management of remnant patches of tall-grass prairie in Manitoba. Understanding the impacts of surrounding land cover on avian diversity and abundance will help to improve our understanding of which agricultural practices are best for sustaining bird populations. The spatial scale at which a study is conducted can have a strong influence on its results; the link between physical (climate, geology) and biological factors may only appear at broader landscape scales, while smaller scale studies are more effective at identifying habitat heterogeneity due to vegetation structure and composition (Wiens 1989). Conducting studies at multiple scales will help us to find the best scale at which to apply management strategies.

Chapter 2: Literature Review

2.1 Degradation of Tall-grass Prairie

The tall-grass prairie ecosystem once covered an area of about 577,500 km^2 stretching from Southern Manitoba south to Texas (Reinking 2003). Although Samson and Knopf (1994) estimated that less that 0.1% (Samson and Knopf 1994) of the original 6,000 km^2 of tall-grass prairie remains in Manitoba (2007b), Koper et al. (2010) surveyed 47.24 km^2 of tall-grass prairie, so the true value is at least 0.8% of its historical range. Nonetheless, it is clear that this once contiguous ecoregion has been virtually eliminated from Manitoba. A revisitation study by the authors of remnant tall-grass prairies in Manitoba found that 37% of prairies had been converted to other habitat types between the late 1980s and 2006 (Koper et al. 2010). Due to its level and fertile soils that are well suited for grain production, much of the northern tall-grass prairie has been converted to agriculture (Reinking 2003).

Tall-grass prairie has historically been maintained in a non-equilibrium state by disturbances such as drought, fire and herbivory (Johnson and Winter 1999). Land-use practices that alter disturbance regimes such as fire suppression or removal of large grazing herbivores may cause vegetation change (Heisler et al. 2003) and succession away from a prairie ecosystem. Vegetation change may also arise from increasing amounts of carbon dioxide in the atmosphere, climate change and nitrogen deposition (Archer et al. 2001). These factors may contribute to encroachment of woody vegetation (Heisler et al. 2003), exotic species invasions (Cully et al. 2003) and increasing species loss (Leach and Givnish 1996).

2.2 Population Declines in Prairie Songbirds

Grassland birds have had steeper population declines over a broader area than any other group of birds in North America (Herkert 1995). Although we only have data on breeding bird populations for the past 45 years since initiation of the North American breeding bird survey [which started well after most grasslands were converted to agriculture fields (Johnson and Igl. 2001)], we have seen a continuous decline in grassland birds in this period (Herkert et al. 2003). The Canadian breeding bird survey shows that 31% of songbird species recorded in the Canadian prairie pothole region have declined in population size over the past 40 years, while 63% of these songbird species have declined in population size in the last 10 years (Collins and Downes 2009).

Many different factors contribute to declining populations of grassland birds. While loss and degradation of natural prairies are the most likely causes of population declines (Herkert et al. 1996), many other factors also play a role. Factors influencing bird populations in the fragmented prairie ecosystem include the degree of habitat connectivity (Donald and Evans 2006), land use practices on remnant patches (Heisler et al. 2003), composition of surrounding matrix habit (Dunford and Freemak 2004, Donald and Evans 2006), local vegetation characteristics (Winter et al. 2005, Davis 2004), remnant patch size and amount of edge (Winter et al. 2006) and overall habitat amount and arrangement (Flather and Bevers 2002). Climate change, which may be causing changes in weather and shifts in species ranges and ecosystems, is also a major factor in declining bird populations.

Abundance and diversity of predators may affect breeding success (Herkert et al. 2003), while diversity of prey species can increase avian species richness and abundance

(Hamer et al. 2006). Wintering ecology of grassland birds is not well understood and factors on the wintering grounds could be contributing to population declines (Vickery and Herkert 2001).

2.3 Factors Influencing Songbirds in Tall-grass Prairie

2.3.1 Habitat Loss and Fragmentation

Habitat loss is defined as the removal of habitat from a landscape resulting in a smaller amount of habitat, whereas habitat fragmentation is the breaking apart of landscape (Fahrig 2003). Habitat fragmentation results in a change in microclimate within and in surrounding remnant patches, as well as isolation of remnant patches from one another (Saunders et al. 1991). While habitat loss almost always has negative impacts on biodiversity, habitat fragmentation may have either positive or negative impacts dependant on which species are considered (Fahrig 2003).

Avian response to habitat fragmentation can vary by species. Responses to fragmentation can be dependent on how long a patch has been isolated, its proximity to other patches, and amount of connectivity between patches (Saunders et al. 1991). Results from studies on avian response to fragmentation have differed based on spatial scale of analysis (Stephens et al. 2003). In their multi-scaled study of the impacts of amount and fragmentation of upland grassland habitat on wetland ducks and songbirds, Koper and Schmiegelow (2006) found that few species were influenced by either habitat amount or fragmentation at the landscape level, which conflicted with conclusions of some other studies (e.g. Herkert et al. 2003). Landscape level patterns may result from local-level mechanisms (Koper and Schmiegelow 2006), highlighting the importance of collecting data at multiple-scales.

2.3.2 Matrix Habitat Composition

Quality, type or land use of the matrix surrounding remnant habitat patches has a great influence on species that live in fragmented landscapes (Donald and Evans 2006). The matrix can affect habitat quality in adjacent patches of native habitat (Saunders et al. 1991), species ability to disperse (Ricketts 2001), and persistence of populations in a patch (Fahrig 2001). Although many studies consider matrix habitat to be hostile and impermeable to species, this may not apply in a landscape such as grasslands, where structure of the matrix is similar to natural habitat (Johnson and Igl 2001).

Some prairie birds have higher abundances in native prairies than in non-native grassland or agricultural matrix habitat, whereas other prairie birds show no preference among these grassland types (e.g. Davis et al. 1999). Johnson and Igl (2001) found that breeding bird abundance and diversity in retired cropland (with non-native plant species) showed similar assemblages to native prairies. Matrix habitat types with similar vegetation structure to native grassland have the potential of providing additional habitat (Tubelis et al. 2004) and facilitating dispersal (Turner 2005) but may not be able to sustain bird densities as high as in native prairies (Best 1997).

2.3.3 Habitat Patch Size and Edge Effects

MacArthur and Wilson's (1967) theory of island biogeography, which has been widely applied to the study of fragmented landscapes, suggests that smaller areas will support fewer species due to lower resource availability causing higher species extinction rates (in Cully et al. 2003). Although many studies do show strong species-area relationships, pattern-oriented approaches used in fragmentation studies such as island biogeography have been challenged in recent literature. As many other mechanisms,

such disturbance regimes, vegetation composition and structure and habitat diversity are inherently related to patch size, it is important to study these underlying factors along with patch size so that the inherent complexity of ecosystems is not ignored (Lindenmeyer and Fischer 2006).

Along with other mechanisms, size of remnant patches may influence avian species richness and densities (Hamer et al. 2006). Avian habitat selection in a fragmented landscape may be determined by species-specific area sensitivity or reproductive success in differently sized patches (Johnson and Igl 2001). Reduction in average size of remnant habitat patches may decrease bird populations as some patches may be too small for territory or breeding requirements (Davis 2004). However, grassland birds may not have consistent responses to grassland habitat patch size or characteristics of surrounding landscape (e.g. Winter et al. 2006). Relationships between species and area can provide a general estimation of a remnant patch's ability to support species, but will not provide any information on which habitats can support the greatest number of species or which species may be lost from the patch (Saunders et al. 1991).

Smaller patches have a higher edge to core habitat ratio, which increases the impacts of edge effects. Edge habitats often exhibit different vegetation structure from the core habitat (Davis 2004), which may be due to encroachment of woody vegetation (Winter et al. 2000). This can result in increased competition from forest edge species (Knopf 1986 in Samson and Knopf 1994), higher nest predation rates (Renfrew et. al. 2005) and brood parasitism (Suarez et al. 1997). Species are more likely to be impacted by edge effects at habitat-matrix boundaries, which may result in higher emigration rates (Tischendorf et al. 2005).

2.3.4 Vegetation Structure and Composition

Both vegetation structure and composition can affect habitat selection and reproductive success of grassland songbirds. Different species of grassland songbirds have associations with vegetation characteristics such as litter cover and depth, bare ground cover, vegetation height, vertical density, proportions of grasses, shrubs and forbs and dead canopy cover (e.g. Delisle 1997, Chapman et al. 2004, Davis 2004). Changes in structure such as increasing vegetation density or proportion of woody vegetation will change settlement rates of birds and may increase risk of nest predation (Renfrew et. al. 2005) or brood parasitism (Suarez et al. 1997).

Grassland songbirds generally respond more strongly to vegetation structure than composition, as non-native plants may provide similar functions as native vegetation (Chapman et al. 2004). However, areas with an abundance of non-native plants may not provide the same amount of structural diversity as areas with native plants (Fleishman et al 2003). Avian communities are impacted by overall habitat heterogeneity, which is maintained through natural or artificial or human managed disturbances of fire and grazing (Fuhlendorf et al 2006). Non-native plants may not respond in the same way as native plants to such disturbances, reducing habitat heterogeneity and in turn bird richness and densities (Fuhlendorf and Engle 2001). Various grassland management techniques such as timing of haying, mowing, burning and grazing, all of which change vegetation structure and composition, are currently used in managing songbird populations.

2.4 Natural History of Grassland Songbirds

2.4.1 Bobolink (Dolichonyx oryzivorus)

The breeding male bobolink's black body, golden-buff nape and white scapulars along with his bubbling flight song make him one of the most easily identified birds in North America. This bird is noted for undergoing two complete molts per year as well as its long migration to overwinter in Argentina (Carey et al. 2003). Originally found in grasslands of south-central Canada and the mid-western U.S., bobolinks currently breed in Canada from British Columbia to Newfoundland and into the U.S. as far south as West Virginia (Martin and Gavin 1995). Although much of their original habitat has been converted to agriculture, clearing of deciduous forest habitats for hay and pasture land has created new habitat for bobolinks in the eastern parts of the U. S. (Bent 1958 in Martin and Gavin 1995). Bobolinks prefer fields with a mixture of grasses and broad-leaf forbs (e.g. red clover [*Trifolium pratense*], dandelion [*Taraxacum officinale*]) and tend to have higher densities in larger fields (Bollinger and Gavin 1992 in Martin and Gavin 1995).

The Canadian breeding bird survey indicates that bobolink populations have declined in Canada (-5.2% per year) and the province of Manitoba (-2.1% per year) over the last 40 years (Collins and Downes 2009). In a study done in the eastern U.S., population declines were caused, in part, from destruction of nests through hay-cropping (Bollinger et al. 1990) and overall habitat loss (Martin and Gavin 1995). As bobolink are considered agricultural pests, they have been shot and trapped on their South American wintering grounds, likely contributing to declines in population size (Pettingill Jr. 1983). Current management techniques include delayed mowing of hayfields to reduce nest and

fledgling mortality and mowing or prescribed burning outside the breeding season to maintain habitat structure required by bobolinks (Martin and Gavin 1995).

2.4.2 Brown-headed cowbird (Molothrus ater)

Brown-headed cowbirds are North America's best known brood parasite. They lay their eggs in nests of many bird species, resulting in conservation concerns for several of their host species. Originally found in short-grass plains, clearing of forests and creation of open habitats has allowed them to expand their range to suburban and agricultural landscapes across North America (Mayfield 1965 in Lowther 1993). Brown-headed cowbirds breed from south-east Alaska across all Canadian provinces and south to northern part of Baja California, the middle of Mexico, the Gulf Coast and central Florida (Lowther 1993). They prefer grassland habitats with shrubs and small trees such as prairies, pastures, agricultural fields, residential areas and edges of woodland habitat (Lowther 1993). Studies of parasitized nests have shown that cowbirds have a preference for forest-grassland transition areas as opposed to open prairie or extensive forested areas (Johnson and Temple 1990).

Although brown headed cowbirds are common, the Canadian breeding bird survey (BBS) shows that their populations have been in steady decline in both Canada as a whole (-2.6% per year) and the Province of Manitoba (-3.8% per year) in the past 40 years (Collins and Downes 2009). This is likely to benefit conservation, because fewer brown-headed cowbirds will reduced the impact of brood parasitism on their host species. Current management of brown-headed cowbirds involves trapping and removing them from breeding areas or killing them on their wintering grounds to conserve host species (Lowther 1993).

2.4.3 Clay-coloured Sparrow (Spizella pallida)

Clay-coloured sparrows are the most typical and numerous songbirds of low-shrubby areas in the northern prairie (Carey et al 2003). Their monotonous, buzzy insect-sounding song is very distinctive and easily detected. Clay-coloured sparrows are a common, widespread passerine found in dry, uncultivated shrubby areas in the Great Plains. They breed from south-eastern Yukon, south to eastern British Columbia and eastern Washington, southeast across the Prairie Provinces and states to southern Ontario and Quebec (Knapton 1994). Human settlement and suppression of fires have altered vegetation composition and structure of North American prairies. The encroachment of trembling aspen (*Populus tremuloides*) and increasing abundance of low shrubs (e.g. snowberry [*Symphoricarpos occidentalis*]), has created excellent habitat for clay-coloured sparrows (Knapton 1994).

The Canadian breeding bird survey shows small but steady declines in clay-coloured sparrow populations in Canada (-0.2% per year) and the province of Manitoba (-0.8% per year) in the past 40 years (Collins and Downes 2009). Population declines likely result from loss of shrubby areas due to agriculture practices and urbanization and local pesticide application (Knapton 1994). As this species has fairly high populations and adapts well to human settlement, there are no active management needs (Knapton 1994).

2.4.4 Le Conte's Sparrow (Ammodramus leconteii)

The secretive behavior and quiet, wispy, grasshopper-like song of Le Conte's sparrow makes it challenging for observers to see or hear it. Le Conte's sparrow is an uncommon species that inhabits wet grasslands and marshes in north-central North America. They breed in prairies and grasslands from southern Yukon through the Canadian Prairie Provinces, North Dakota and Minnesota to southwestern Ontario and the northern part of Michigan (Lowther 2005). Le Conte's sparrows frequent open, marshy habitats characterized by grasses and sedges (e.g. *Carex sp*.), wet depressions within tall- and mixed-grass prairies, or the edge of marshes (Lowther 2005). The loss of wetland and grassland habitats caused by European settlement of North America has reduced available habitat for this species.

The Canadian breeding bird survey shows that Le Conte's sparrows, which have fairly low densities, had a drop in population numbers from the late 1970s to the late 1980 but started to increase again into the 1990s and the new millennium. Populations have increased in Canada (2.3% per year) and in the province of Manitoba (3.5% per year) in the last 40 years (Collins and Downes 2009). Annual haying can be detrimental to this species (Murray 1969), as is encroachment of woody vegetation (Dechant et al. 2003). Management techniques such as fire (Madden et al. 1999) or mowing outside of the breeding season (Kantrud 1981 in Lowther 2005) can improve habitat conditions.

2.4.5 Red-winged Blackbird (Agelaius phoeniceus)

Red-winged blackbirds are probably the most abundant birds in North America (Carey et al. 2003). The black body, scarlet and yellow shoulders, distinctive song and territorial behavior of the breeding male make it one of the most recognizable birds in

Canada (Carey et al. 2003). The Red-winged blackbird is an abundant species found in marsh and grassland habitats. They breed almost everywhere on the North American continent and into Central America and the West Indies (Yasukawa et al. 1995). Although they prefer marshes and wet grasslands, red-winged blackbirds have been known to breed in roadside ditches, fallow, hayed and pasture land and even urban parks (Yasukawa et al. 1995).

The Canadian breeding bird survey shows that populations of red-winged blackbirds have declined in Canada (-1.6% per year) but have only declined slightly in the Province of Manitoba (-0.5 % per year) in the past 40 years (Collins and Downes 2009). Red-winged blackbirds are considered to be pests, as they are communal roosters that forage in large groups on agricultural crops. Populations have been managed through shooting, trapping or poisoning (Yasukawa et al. 1995). However, population control is likely better achieved by altering agricultural practices such as using cultivars or forage crops that are more resistant to predation by birds (Dolbeer 1990).

2.4.6 Savannah Sparrow (Passerculus sandwichensis)

The Savannah sparrow is the most abundant songbird of open habitats and is often observed perching on fences, telephone lines, tall plants or bales of hay (Carey et al. 2003). This sparrow was originally named by Alexander Wilson after the city in Georgia in which it was first collected (Wheelwright and Rising 2008). The Savannah sparrow is an abundant grassland passerine found in open habitats throughout North America. They breed in agricultural areas, grasslands, marshes, pastures, suburban areas and tundra from the coast of Alaska, south to Baja California, east thorough almost all of mainland Canada and the central U.S. to the Canadian Maritime Provinces and north-eastern U.S.

coastal states (Wheelwright and Rising 2008). Clearing of forested land provided habitat for Savannah sparrows, allowing them to increase their populations throughout much of the twentieth century (Wheelwright and Rising 2008).

The Canadian breeding bird survey indicates that Savannah sparrow populations declined in Canada (-1.0% per year), but were variable and showed no declines in the Province of Manitoba (0.0 % per year) over the last 40 years (Collins and Downes 2009). Urbanization, more frequent harvesting of agricultural and hayed lands (Wheelwright and Rising 2008) and changes in agricultural practices such as the transition from dairy farming to cropping (Jobin et al. 1996), are all possible factors leading to its population decline. Management techniques for this species include mowing and protection of migratory stopover locations (Wheelwright and Rising 2008).

2.4.7 Sedge Wren (Cistothorus platensis)

The sedge wren is possibly the most nomadic terrestrial bird in North America (Herkert et al 2001). Not much is known about certain aspects of its natural history, as its erratic movements, low site-fidelity and secretive behavior make this species challenging to study (Herket et al 2001). The sedge wren is a widely distributed wetland and wet-grassland bird with populations in North, South and Central America (Herkert et al. 2001). This species breeds in Canada from east-central Alberta through southern Saskatchewan, Manitoba, Ontario and Quebec, and in the U.S. from the Dakotas, east to New York and south to Kentucky (Herkert et al. 2001). Conversion of wetlands and wet grasslands to agriculture has reduced the amount of habitat available for sedge wren.

The Canadian breeding bird burvey indicates that sedge wrens have had a slight increase in population size in Canada (1.2% per year) and the Province of Manitoba

(1.9% per year) in the last 40 years (Collins and Downes 2009). The greatest threat to sedge wrens is loss and drainage of wetlands for agricultural land. As sedge wrens prefer tall, dense vegetation, mowing, grazing and burning of grasslands reduce habitat quality and local breeding densities (Herkert 1994). Protection of wetland and wet sedge meadow habitat is very important in conservation and management of this species (Herkert et al. 2001).

2.5 Conservation and Research Needs

2.5.1 Conservation of Grasslands

Since native prairies have been largely ignored in the effort to conserve biological diversity (Samson and Knopf 1994), management and conservation of remnant fragments is critical for native grassland species (Saunders et al. 1991). In order to conserve prairie landscapes, there is an urgent need to identify and create an inventory of remaining prairie fragments (Sampson and Knopf 1994). By providing sufficient habitat area and maintaining ecosystem processes such as fire and grazing, managers may be able to stabilize grassland bird populations (Brennan and Kuvlesky 2005).

Starting in 1989 and running for a 5 year period, the World Wildlife Fund Canada (WWF) along with the governments of Alberta, Manitoba and Saskatchewan implemented the first Prairie Conservation Action Plan to conserve biological diversity and native species in the Canadian prairies (Manitoba Natural Resources 1998). Subsequently, each of the Prairie Provinces created their own plans for prairie conservation (Environment Canada 2006).

Over 20 years ago, surveys to identify remnant tall-grass prairies were conducted in the prairie region of Manitoba, Canada by the Manitoba Naturalists Society (now

Nature Manitoba) and Manitoba Conservation. Some of the identified lands were secured for conservation through the Critical Wildlife Habitat Program (Manitoba Conservation 2007b) while others were purchased by non-governmental conservation groups. These conservation groups, along with the Province of Manitoba and the City of Winnipeg, are currently conserving and managing tracts of native prairie. Some of these tall-grass prairie lands have been legally protected under Manitoba's Protected Areas Initiative (Manitoba Conservation 2007a). Although much progress has been made, the task of identifying and conserving native tall-grass prairies is not yet complete. With ever-present development pressures, it is imperative that we continue to identify and conserve biodiversity in remaining tall-grass prairie of Manitoba.

2.5.2 Conservation of Grassland Birds

With widespread fragmentation of tall-grass prairie and declining populations of grassland birds, conservation planners need to understand how bird presence and density in remnant patches are influenced by variables at multiple scales. To better understand which variables impact the suitability of a given habitat patch for birds in northern tall-grass prairie, we need to analyze the role of remnant patch size and landscape structure on density and diversity (Winter et al. 2005a). As local-level processes occur concurrently with landscape-level processes, studies should be conducted at multiple scales (Stephens et al. 2003). Variations in patterns of species richness have yet to be fully understood as there is currently no consensus about relative contribution of landscape composition, structure and food availability on prairie birds (Hamer et al. 2006). Further study and conservation efforts are imperative to understanding of spatially

structured population dynamics of species in fragmented landscapes (Bowne and Bowers 2004).

The impact of population declines in prairie birds is more profound than just a lowering of the number of individuals. Declining abundances of grassland birds may decrease species richness at the local level across the entire landscape (Hamer et al. 2006). The crisis of widespread population declines facing grassland birds could create an ecosociopolitical disaster for stakeholders, such as that seen with the spotted owl on the west coast (Brennan and Kuvlesky 2005). Several grassland bird species are already protected under legislation for species at risk. Burrowing owl (*Athene cunicularia*) and loggerhead shrike (*Lanius ludovicianus excubitorides*) are listed as endangered under the Canadian Species at Risk Act (SARA), while Sprague's pipit (*Anthus spragueii*) is listed as threatened under SARA. Baird's Sparrow (*Ammodramus bairdii*) and burrowing owl (*Athene cunicularia*) are listed as endangered under the Manitoba Endangered Species Act. If any more species become listed under species at risk legislation, there will be greater stress for government and non-governmental organizations protecting these species, as well as increased conflict between stakeholders. Coming to a consensus on measures for protection of prairie birds may be very difficult due to opposing interests of the environmental community, industry (for urban development and agriculture), other stakeholders and multiple levels of government.

Chapter 3: Methods

3.1 Study Area and Site Selection

3.1.1 Study Area

Study sites for this research are on remnant patches of tall-grass prairie in southern Manitoba, Canada. The study region has a continental climate with a mean maximum temperature in July of 25.8°C and a mean minimum temperature of -22.8°C in January (Environment Canada 2004). Mean annual precipitation in the area is 515mm, with 416mm occurring as rain (Environment Canada 2004).

Tall-grass prairie in Manitoba is characterized by deep fertile soils, tall-grasses such as big bluestem (*Andropogon gerardi*), prairie cordgrass (*Spartina pectinata*) and Indian grass (*Sorghastrum nutans*), flowers such as goldenrod (*Solidago sp.*), aster (*Aster sp.*) and sunflower (*Helianthus sp.*), and shrubs such as western snowberry (*Symphoricarpus occidentatis*) and rose (*Rosa sp.*). It is also home to several plant species listed under the Manitoba Endangered Species Act (Government of Manitoba 1993). Endangered plants in the Manitoba's tall-grass prairie include the western prairie fringed orchid (*Platanthera praeclara*), the small white lady's slipper (*Cypripedium candidum*) and the great plains ladies' tresses (*Spiranthes magnicamporum)*, while western silvery aster (*Aster sericeus*), Culver's-root (*Veronicastrum virginicum*) and Riddell's Goldenrod (*Solidago riddellii*) are listed as threatened (Manitoba Conservation 2009). Like many highly fragmented systems that show increased vulnerability to exotic species (Cully et al. 2003), Manitoba's tall-grass prairie has many exotic plant species that need to be managed (Manitoba Conservation 2007a, Koper et al. 2010).

3.1.2 Prairie Site Surveys

Potential prairies sites identified through previous surveys of tall-grass prairies conducted in 1987 and 1988 (Joyce 1989) were revisited in 2006 (Koper et al. 2010). Known or probable sites were in provincial parks, Wildlife Management Areas, Prairie Farm Rehabilitation Administration (PFRA) community pastures, or areas known to have endangered, threatened or rare plant species typical of tall-grass prairies (as listed by Manitoba Conservation Data Centre; Hamel, unpublished data, 2006). Each site deemed to be tall-grass prairie was surveyed to determine area and quality grade based on criteria outlined by Manitoba Conservation Data Centre (see Appendix A, Mansell 1995). In 2006, quality of prairies ranged from a high grade of B+, where sites had little anthropogenic disturbance and a high native plant species diversity to a grade of D, where disturbance was evident and there were many non-native species.

To calculate area of prairies, the surveyor walked around the perimeter of each prairie, and around large stands of trees within prairies, with a GPS unit while collecting a series of points. Points were downloaded from the GPS unit into Arc View 3.2 software and were digitized into polygons representing prairies and patches of trees in prairies. Polygons of patches of trees within prairies were subtracted from prairie polygons to calculate area. Area of prairies was calculated using a "calculate areas" script (ESRI 2006). One hundred and forty four prairies varying in size from less than 1 ha to 262 ha were identified.

3.1.3 Study Site Selection

Of prairies identified, 25 were included in my study (Figure 1). Sites were chosen to represent a range of sizes and quality ranks and to cover the geographic range of tall-

grass prairie in southern Manitoba (Table 1). Study sites covered an area approximately 150km from the furthest northern to the furthest southern site and approximately 110 km from furthest east to further western site.

Prairies were surrounded by a variety of matrix habitat types including forest, agriculture, other prairies, non-native grassland (e.g., pasture, hay, and idle land), wetland and urban areas. Twenty-four of the twenty-five study sites had both hostile (forest, urban) and hospitable (other grassland, agriculture) matrix habitat types surrounding them. The site located at the Living Prairie Museum only had hostile habitat types surrounding it. Both bird and vegetation surveys were completed for all prairies over the 2007 and 2008 field seasons.

Table 1. Study site owners, land use, area (ha) and qualities used to evaluate effect of landscape ecology and local vegetation characteristics on tall-grass prairie birds in Manitoba, 2007-2008

Site code	Owner	Land use	Area (ha)	Quality
BD1	Province of Manitoba	Provincial Park	108.54	C
BHP11	Province of Manitoba	Provincial Park	1.09	C
BHP2	Province of Manitoba	Provincial Park	29.89	C
BHP5	Province of Manitoba	Provincial Park	12.98	B-
BHP6	Province of Manitoba	Provincial Park	0.95	B-
BHP7A	Province of Manitoba	Provincial Park	1.74	C+
BHP7B	Province of Manitoba	Provincial Park	1.65	C
BHPG7	Province of Manitoba	Provincial Park	0.55	C
GI	Rural Municipality	Municipal Park	2.89	C+
LF2	Province of Manitoba	Wildlife Management Area	233.11	C+
LPM	City of Winnipeg	Municipal Park	12.49	C
MC26	Private Land	Idle	4.84	B-
MC4	Private Land	Idle	1.50	C
OHM1	Province of Manitoba	Wildlife Management Area	115.78	B
OHMB	Province of Manitoba	Wildlife Management Area	58.15	C-
PAN	Government of Canada	Grazed pasture	72.30	C
PORTA	Government of Canada	Grazed pasture	262.69	C
PORTB	Government of Canada	Grazed pasture	144.68	C
ROT	City of Winnipeg	Municipal Park	6.12	B-
S11A	Private Land	Idle	18.64	C
S56	Conservation organisation	Tall-grass prairie preserve	58.54	B+
S62	Private Land	Idle	45.48	B+
S77	Government of Canada	Grazed pasture	14.75	C+
S80	Private Land	Grazed pasture	46.07	C+
S85A	Conservation organisation	Tall-grass prairie preserve	137.16	C+
S86	Province of Manitoba	Idle	67.60	C+

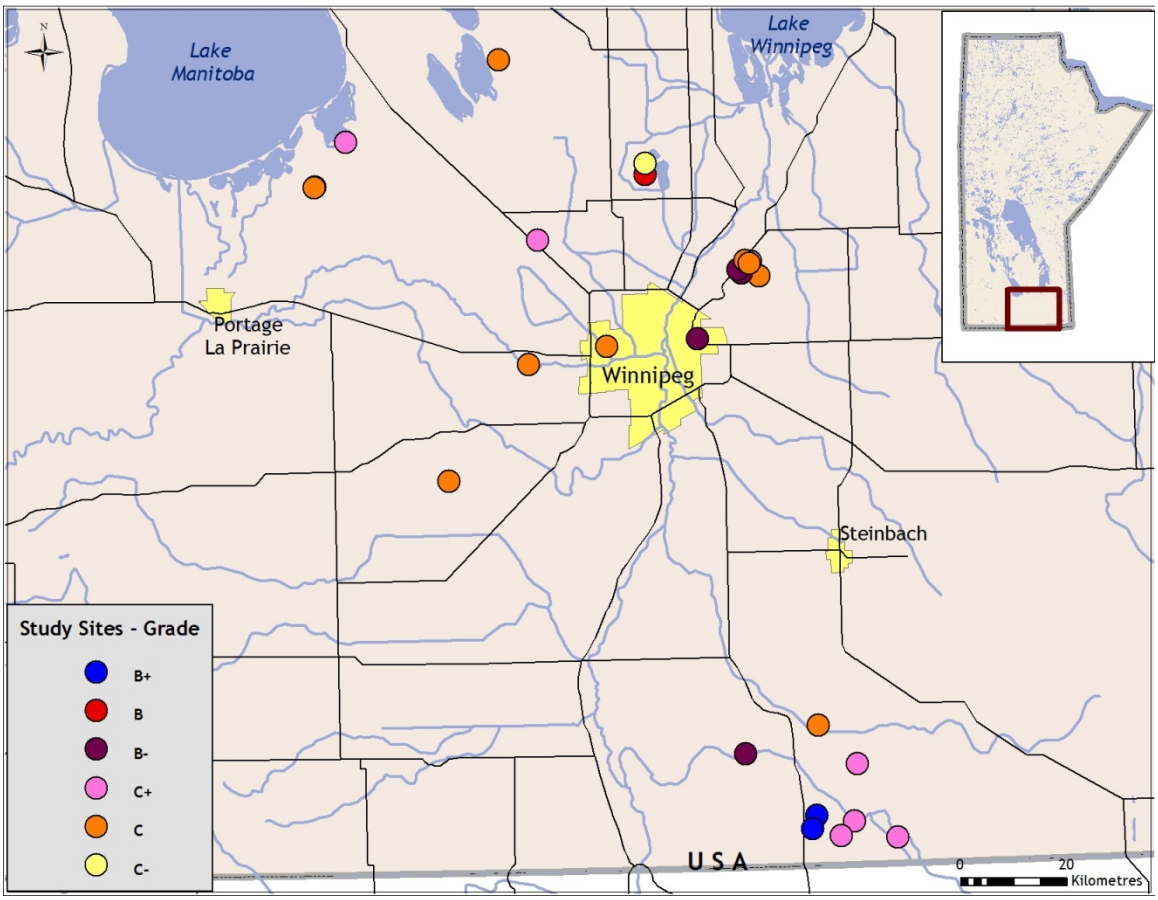

Figure 1. Study site locations and qualities used to evaluate effect of landscape ecology and local vegetation characteristics on tall-grass prairie birds in Manitoba, 2007-2008.

3.3 Data Collection

3.3.1 Avian Point Count Plots

In the 2007 and 2008 field seasons, bird density was estimated at point count plots. Point count plots had a radius of 50m and count duration was 6 minutes (Davis 2004). Plots per prairie varied based on prairie size with a minimum of 1 and maximum of 6 per prairie. Although placement of plots within prairies was random, plots captured both interior and edge habitat in most prairies. Although some of my prairies were too small to spread out the plots, I tried to have plots at least 400m apart (where possible).

All birds were recorded, but only the data for birds within 50m plots was used for analysis.

In conducting point-count sampling, there are several assumptions that must be met: (1) bird detection is accurate, (2) bird detection precedes observer's movements which may affect behavior, (3) accurate measurement or estimation of distances to birds and (4) bird singing behavior is not affected by environmental variables (Rosenstock et al. 2002). To account for the first assumption, all observers were trained in visual and auditory identification by an experienced birder before conducting surveys. To account for the effect of observer movement on bird behavior, duration of point counts were kept short so as not to bias results (Scott and Ramsey 1981 in Rosenstock et al. 2002). For the assumption of distance accuracy, laser rangefinders were used to train observers during point count sampling (Rosenstock et al. 2002). Bird surveys were not conducted if wind was over 20km/h or if it was raining (Davis 2004) to account for bird behavior regarding environmental variables.

Two rounds of point counts were conducted at each point count plot at prairie sites during each of the 2007 and 2008 field seasons. Point counts commenced at dawn and did not go any later than 10:00am. Point counts were not conducted in the rain or if the wind was above 20km/hour. In 2007, three observers conducted point counts at 26 sites. The first round of counts was from May 28th to June 8th and the second round was from June 11th to 28th. In 2008, three observers conducted point counts at 25 sites. The first round of counts was from May 27th to June 11th and the second round was from June 13th to June 25th. One of the sites was not revisited, as I could not obtain landowner permission to return to conduct surveys in the second year of the study.

To understand the degree to which birds used the surrounding matrix habitat, point counts were conducted up to 500m into adjacent land. The same number of point counts conducted in each prairie was also conducted in each of the surrounding matrix habitat types. In the 2007 field season, point counts in matrix habitat sampled other grassland (native or non-native), forest, urban, wetland and agriculture. An analysis of 2007 data showed that forest, urban and wetland areas were almost unused by focal bird species, and thus were not surveyed in the 2008 field season (Table 2).

Table 2. Number of point count plots surveyed for birds in Manitoba tall-grass prairie habitat and in each of the adjacent matrix habitat types, 2007-2008

	Number of plots	
Habitat type	***2007***	***2008***
Native Prairie	91	84*
Grassland	65	57*
Agriculture	18	12*
Forest	53	0
Wetland	21	0
Urban	15	0
Total	263	153

*variations in number of plots between years arises from failure to obtain landowner permission in the second year of study

3.3.2 Vegetation Surveys

From early July to late August in 2007 and 2008, all 25 prairies were surveyed for plant community structure and 24 prairies were sampled for plant community composition. Vegetation plots were in the same location as plots used for avian point counts. One of the study sites (site BHPG7) was omitted from the vegetation composition survey as the patch was too small to fit a vegetation plot and was invaded with many forest species. Sixty plots were surveyed for vegetation composition and structure, while one was surveyed for structure only.

At each prairie, vegetation was surveyed at two to four 20m by 50m plots modified Whittaker plots (e.g. Stohlgren et al. 1999). A 0.2 by 0.5 metre Daubenmire

frame was randomly placed (using a table of random number for paces north and east) to avoid survey bias of selecting for certain plant species. Frame was placed 10 times within each plot (Daubenmire 1959) and all vegetation species were recorded. Within each frame, percentages of ground cover (bare ground, litter, rock, cow patties, moss/lichen) and cover of each plant species was estimated. Composition surveys were conducted at seven of the study sites in 2007 and 2008, with different plots sampled for each year. Six sites were sampled only in 2007 and eleven were sampled only in 2008.

At each frame, visual obstruction was measured with a Robel pole (Robel et al. 1970). The Robel pole was placed next to the frame and measurement was taken from four metres away from the pole with observers eyes at one metre above the ground in each of the four cardinal directions (Robel at al. 1970). Vegetation height was calculated by measuring the tallest plant touching the Robel pole. Litter depth was measured within each frame with a ruler. While vegetation composition was done for different plots in both years, all structural measures were conducted in 2008 due to time constraints in the 2007 field season. As locations of frames were collected with a GPS unit, the plots surveyed for composition in 2007 were re-visited and surveyed for structure in 2008.

3.4 Data Preparation

3.4.1 Avian Data

I reviewed the avian point count data to determine which grassland species had sufficient data for analysis. Species deemed to have sufficient data were those recorded within plots for at least five sites and preferably in more than one plot within prairies or within adjacent matrix. Birds analyzed for the project include: brown headed cowbird

(*Molothrus ater*), bobolink (*Dolichonyx oryzivorus*), clay-coloured sparrow (*Spizella pallida*), Le Conte's sparrow (*Ammodramus leconteii*), red-winged blackbird (*Agelaius phoeniceus*), Savannah sparrow (*Passerculus sandwichensis*) and sedge wren (*Cistothorus platensis*). To prepare raw avian point count data for analysis, density of individual species and overall avian species richness in each point count plot was averaged over both rounds. An average was used, as some of the point counts that were earlier in the season may not have captured individuals that had not yet arrived on breeding ground, while the point counts later in the season may not have recorded individuals that were already nesting. As prairies provide habitat for many birds from various orders and some niche overlap may occur among species, calculations and models for richness include all birds recorded within plots.

3.4.2 Landscape-level Data

Proportions of grassland (native and non-native), forest, urban, wetland and agricultural habitat types within 500 m and 1 km from the edge of each prairie were calculated in ArcGIS 9.2 (ESRI 2006). Manitoba Forest Resource Inventory (FRI) land use data that fell within the buffers were summarized to determine proportions of each matrix habitat type adjacent to prairies. As the FRI data are unnecessarily detailed for my study, I summarized the land use codes into the aforementioned habitat categories.

All hostile matrix habitat types were grouped together for statistical analyses. Based on my 2007 surveys and their obvious structural differences compared with grassland, forest, urban and water were considered hostile. Preliminary Generalized Linear Mixed Models (GLMMs) showed that Akaike's Information Criteria (AIC_c) values for most species of interest were lower for matrix type proportions within 500m of

sites as compared with matrix habitat within 1km, indicating that habitat that falls within 500m from a site is a better predictor of species occurrence and abundance than habit that falls within 1km. Therefore, I used only those values for matrix habitat within 500m of sites in all subsequent models.

3.4.3 Patch-level Data

Patch-level fragmentation indices were calculated using the Patch Analyst extension for ArcGIS 9.2 (ESRI 2006). As Patch Analyst computes several different fragmentation indices, I had to choose which one to include in models to avoid overparameterization. The effects of mean shape index, mean perimeter-area ratio, area-weighted mean patch fractal dimension, total edge and edge density on avian species richness and density were compared in GLMMs to determine which fragmentation index had the lowest AIC_c value. Mean shape index (MSI) was found to be the best predictor of avian density and diversity and was chosen as the index of fragmentation for all subsequent models. MSI indexes complexity of the shape of the areas, where the more complex the shape (and higher the value), the higher the ratio of edge to interior (McGarigal and Marks 1994).

Natural log (ln) of the site area can be a better predictor of bird diversity and density (see Davis 2004) than the arithmetic scale, as the relationship between birds and habitat patch size is rarely linear (Lomolino 2000). For species-area relationships, the rate of increase for species richness is greater for as smaller patches increase in size, but the rate goes down with larger habitat patches (Lomolino 2000). I used GLMM to compare area of prairies in hectares, and natural log of area, to evaluate which was a better predictor. Natural log of the area consistently resulted in lower AIC_c values, so was used

in subsequent models. As our data for prairie quality was ordinal, I chose to convert it to a numerical scale for ease of analysis. I converted the letter grades so that a grade of A = 4.0, B+ = 3.5, B = 3.0, C+=2.5, etc.

3.4.4 Local-level Data

Vegetation data were summarized in several ways for analysis. Each species of plant was categorized as native or non-native based on information provided by NatureServe Explorer (NatureServe 2008). Proportions of cover were calculated for the following categories: native plants (NPropNatCov), non-native plants (NPropNonNatCov), litter (Nprop_lit) and other ground cover (bare ground, rock, and cow patty). Plants were also categorized as forbs, grasses or shrubs. Proportions of cover were calculated for the following categories: forbs (Vprop_forb), shrubs (Vprop_shrub), grasses (Vprop_grass), litter (Vprop_lit) and other ground cover.

Species richness for native and non-native plants was calculated for each Daubenmire frame, and also averaged for each plot. Robel pole readings were taken in each cardinal direction at each vegetation frame and all visual obstruction measures were averaged per plot. Measurements for maximum height and litter depth were also taken at each frame and summarized per plot.

3.5 Data Analysis

3.5.1 Avian Species Statistical Population Distributions

To determine distribution of each species of interest, both histograms and QQ-plots were created in S-plus (Insightful Corp 2003). QQ-plots provide a graphical method

of comparing the distribution of a data set to existing probability distributions. Distributions for all species were compared to normal distributions in QQ plots. Histograms and QQ plots showed that overall richness, clay-coloured sparrows (*Spizella pallida*), Le Conte's sparrows (*Ammodramus leconteii*), Savannah sparrows (*Passerculus sandwichensis*) and sedge wrens (*Cistothorus platensis*) had Poisson distributions. Brown headed cowbirds (*Molothrus ater*), bobolinks (*Dolichonyx oryzivorus*) and red-winged blackbirds (*Agelaius phoeniceus*) did not follow a Poisson distribution, so I chose to represent them as binomial distributions. For species with a binomial distribution I converted the data to presence/absence, reclassifying the data to presence = 1 and absence=0. Subsequent analyses assumed these distributions for the avian response variables.

3.5.2 Avian Species Richness and Density/Presence by Habitat Type

Generalized linear models were conducted using SAS proc GENMOD procedure with the repeated statement for grouping plots within prairies (SAS 2003) to determine if there was a significant difference in avian species richness and individual species densities between prairie and matrix-grassland and prairie and agricultural areas ($p \geq 0.1$). Forest and urban matrix habitat data were not modeled, as avian species of interest were either not found or found in very low densities in forest and urban areas. There were insufficient data for wetland matrix habitat to use in the GLM.

3.5.3 Avian Species Richness and Density/Presence by Local, Patch and Landscape-level Variables

In recent years GLMM have become more popular in modeling clustered count data and are well suited for analyzing biological data that are inherently heterogeneous (Demidenko 2004). GLMM allow for a sampling design that accounts for variation both among and within clusters, such as plots within prairies, making them ideal for analyses at different spatial scales. In my study, local-scale variables are nested within patch-scale variables, allowing analysis of variables at both spatial scales with a single model.

GLMMs were conducted for each spatial scale and among scales (Appendix B) using Proc NLMIXED in SAS (SAS 2003). As this was an exploratory study, I ran many models at individual spatial scales and among spatial scales to gain an understanding of the most influential variables and scales of analysis. I compared models that included 3 landscape variables, 3 patch variables and 12 vegetation variables (Table 3). In total, there were 111 models with 4 at the landscape-level, 4 at the patch-level, 16 at the local-level, 6 at the landscape and patch-level, 41 at the patch and local-level and 40 at the landscape and local-level (Appendix B). Because I analyzed so many models in this exploratory study, some patterns detected may have been spurious. Significant trends should be considered potentially important until future analyses with independent data confirm their relevance.

Models in each category were ranked based on Akaike's Information Criteria (AIC) value using multi-model inference. The value for AIC_c (a second order for AIC) was used, as our dataset was small and possibly overdispersed (Burnham and Anderson 2002). Multi-model inference was applied, as the model with the lowest AIC_c values

cannot truly be considered superior over other models that have very close AIC_c values (Burnham and Anderson 2002).

As I aimed to understand all relationships at multiple levels, I decided to examine best models for each category of models (landscape-only, patch-only, local-only, landscape and patch, patch and local and landscape and patch) as well as best overall model and report on significant relationships within best models. The model with the lowest AIC_c value for each category of models and all models that fell within $\Delta AIC_c < 2$ were considered to be in the set of best models (Burnham and Anderson 2002). Only overall best models are discussed in this thesis, however, top models at each scale for every species are listed in Appendix F.

Table 3. Names and explanations of variables analyzed in Generalized Linear Mixed Models exploring the relationship of landscape, patch and local characteristics to bird density and diversity in Manitoba tall-grass prairie, 2007-2008.

Level	Variable	
Landscape	PropAg500	Proportion of matrix agriculture within 500m of Prairie
	PropGrass500	Proportion of matrix grassland within 500m of Prairie
	Hostile500	Proportion of Hostile matrix within 500m of Prairie
Patch	LnArea	Natural log of Area in hectares
	Quality	Site quality
	MSI	Mean shape index
Local	Robel Ave	Robel pole reading
	Litter depth	Litter depth
	Max ht	Maximum height
	NPropNatCov	Proportion cover of native vegetation
	NPropNonNatCov	Proportion cover of non-native vegetation
	Nprop lit	Proportion cover of litter (as compared with native and non-native vegetation)
	Vprop forb	Proportion of forb cover
	Vprop grass	Proportion of grass cover
	Vprop shrub	Proportion of shrub cover
	Vprop lit	Proportion cover of litter (as compared with forbs, grasses and shrubs)
	Native sp rich	Native plant species richness
	Non Nat sp rich	Non-native plant species richness

Chapter 4: Results

4.1 Habitat Characteristics

4.1.1 Prairie Size, Quality and Matrix Habitat Composition

Tall-grass prairie study sites had an average size of 65.59±82.51SD hectares. Average quality was just below a grade of C+. Tall-grass prairies were surrounded by a variety of matrix habitats. Grassland matrix was the most abundant matrix habitat type and accounted for an average of 37% of the land within 500m of study sites. Forest matrix was the second most abundant, occupying an average of 31% of land within 500m of sites. Other matrix types included agriculture (16%), urban (12%), wetland (2%) and water (2%). Larger prairies tended to be higher quality ($r=0.22$ $p=0.04$), surrounded more grassland ($r=0.6$, $p<0.0001$) and less hostile matrix ($r=-0.52$, $p<0.0001$) than smaller prairies.

4.1.2 Vegetation Composition and Structure

Over 200 species of plants were identified at tall-grass prairie sites (Appendix E). Average plant species richness was 19.68±6.56 SD species per plot, with 16.52±6.72 native species per plot and 3.15±2.59 non-native species per plot. Native grass/rush/sedges that provided the most cover were: (1) big bluestem (*Andropogon gerardi*), (2) carex sp. (*Carex spp*), (3) reed grass (*Calamogrostis sp*.), (4) prairie cordgrass (*Spartina pectinata*) and (5) baltic rush (*Juncus balticus*). Most abundant native forbs were (1) northern bedstraw (*Galium boreale*), (2) many-flowered aster (*Symphyotrichum ericoides*), (3) Canada goldenrod (*Solidago canadensis*), (4) stiff

goldenrod (*Solidago rigida*) and (5) narrow-leaved sunflower (*Helianthus maximiliani*). Most abundant native shrubs included (1) rose (*Rosa sp*.) and (2) western snowberry (*Symphoricarpos occidentalis*).

The most abundant non-native grasses include (1) Kentucky bluegrass (*Poa pratensis*), (2) red top (*Agrostis stolonifera*), (3) smooth brome (*Bromus inermis*), (4) sheep fescue (*Fescuta ovina*) and (5) quack grass (*Agropyron repens*). Abundant non-native forbs were (1) common dandelion (*Taraxacum officinale*), (2) sow thistle (*Sonchus arvensis*), (3) Canada thistle (*Cirsium arvense*), (4) red clover (*Trifolium pretense*) and (5) black medic (*Medicago lupulina*).

Data for Daubenmire cover classes yielded the following averages for ground cover at tall-grass prairie sites. For species composition, I found that an average of 55% of the ground in plots was covered by native vegetation, while 16% was covered by non-native vegetation (see Appendix E). In terms of vegetation types, 37% of the ground was covered in grasses, sedges and rushes, 28% was covered by forbs and 6% was covered by shrubs. The remainder of the ground was covered in litter (22%) and other cover types (7%). Larger prairies had greater native plant species richness ($r=0.3$, $p=0.02$) than smaller prairies.

Vegetation structure showed high variability among plots. The average visual obstruction measure was 23.23±11.06 cm per plot. Average litter depth was 3.75±2.94 cm per plot, while average maximum vegetation height was 76.06±22.41cm per plot. Prairie size was significantly correlated with proportion of litter cover ($r=-0.28$, $p=0.02$).

4.2 Avian Species Richness and Density/Presence

4.2.1 Avian Species Richness and Density/Presence in Tall-grass Prairie

Forty-nine species of Passeriformes (perching birds), four species of Anseriformes (ducks and geese), eight species of Charadriiformes (shorebirds), two species of Ciconiiformes (long-legged wading birds), two species of Columbiformes (doves and pigeons), three species of Falconiformes (diurnal bird of prey), two species of Galliformes (grouse and other foul), one species of Gruiformes (cranes), one species of Pelecaniformes (pelicans) and one species of Piciformes (woodpeckers and relatives) were recorded in plots at tall-grass prairie study sites (see Appendix D). Although all bird species were included in number for richness, only passerine species were analyzed for species density in this research.

The Savannah sparrow was the most abundant species, accounting for over 25% of observed birds for both 2007 and 2008 and occurring in approximately 70% of all plots. The clay-coloured sparrow was the species recorded at the most sites, with observations at 89% of sites in 2007 and 84% of sites in 2008. Of all songbirds analyzed, the bobolink was the least abundant, accounting for 3% of observations in 2007 and 5% in 2008 and was recorded at the fewest prairie sites (Table 4).

Table 4. Percent of total observations of all recorded birds, percent of plots and percent of sites where individual bird species were recorded in Manitoba tall-grass prairie, 2007-2008.

Species	*Year*	*Percent of total observations*	*Percent of plots*	*Percent of sites*
brown-headed cowbird	*2007*	7.4%	28.7%	61.5%
	2008	3.9%	23.0%	52.0%
Bobolink	*2007*	2.7%	9.6%	19.2%
	2008	4.6%	14.9%	24.0%
clay-coloured sparrow	*2007*	8.3%	40.4%	88.5%
	2008	14.8%	57.5%	84.0%
Le Conte's sparrow	*2007*	10.6%	47.9%	53.8%
	2008	7.1%	48.3%	52.0%
red-winged blackbird	*2007*	6.6%	26.6%	46.2%
	2008	7.3%	24.1%	40.0%
Savannah sparrow	*2007*	26.2%	71.3%	76.9%
	2008	25.1%	64.4%	68.0%
sedge wren	*2007*	2.7%	16.0%	23.1%
	2008	9.6%	39.1%	40.0%

4.2.2 Avian Species Richness and Density/Presence by Habitat Type

The results of the generalized linear models comparing habitat types showed that prairies and matrix grassland habitat supported the same number of avian species as tall-grass prairie in both years (Table 5). Agricultural matrix supported the same number of species as tall-grass prairie in 2007 but had significantly lower avian species richness in 2008 (see Appendix D for listing of species by habitat).

Richness was higher for tall-grass prairie habitat and matrix grassland in 2008 than in 2007, while richness in agricultural plots showed higher richness in 2007 as compared to 2008 (Figure 2). Of the species of interest, bobolinks, Le Conte's sparrows

and sedge wrens were not found in agricultural plots, while the clay-colored sparrow was found in agricultural plots in very low densities in 2007 but not in 2008.

The Savannah sparrow was the most abundant species in tall-grass prairie habitat (Figure 2), with densities of 1.23 ± 0.35 individuals per plot in 2007 and 1.23 ± 0.73 individuals per plot in 2008. The second most abundant species, clay-coloured sparrows, had 0.39 ± 0.61 individuals per plot in 2007 and 0.73 ± 0.9 individuals per plot in 2008. Savannah sparrows were also the most abundant species in the grassland matrix, followed by clay-coloured sparrows and sedge wrens. Savannah sparrows, red-winged blackbirds and brown-headed cowbirds were the species with the highest densities in agricultural matrix habitat.

Densities of all avian species except clay-coloured sparrow were statistically the same in prairie as compared with matrix grassland (Table 5). Clay-coloured sparrow was significantly lower in grassland matrix than in prairie in 2007. Densities of several avian species were significantly lower, or no individuals were recorded in agricultural matrix habitat. Bobolinks and sedge wrens were not recorded in agricultural fields in either year. Brown-headed cowbirds had the same densities for both habitat types in 2007 but were not recorded in agricultural areas in 2008. Clay-coloured sparrows and Le Conte's sparrows were both significantly lower in agricultural areas in 2007 and not present in agricultural fields in 2008. Red-winged blackbirds had higher densities only in 2007. Savannah sparrows had significantly lower densities in agriculture in 2008 (Table 5).

Table 5. Results from generalized linear models of avian species richness and densities recorded in surrounding matrix grassland and agricultural areas as compared with Manitoba tall-grass prairie, 2007-2008.

Species	**Year**	**Grassland**				**Agriculture**			
		β	S.E.	*p*	*n*	*β*	S.E.	*p*	*n*
Richness	*2007*	0.03	0.1	0.79	150	-0.16	0.18	0.36	111
	2008	0.07	0.1	0.56	139	**-0.57**	**0.21**	**0.008**	**99**
brown-headed cowbird	*2007*	0.36	0.46	0.44	150	-0.68	0.5	0.17	111
	2008	0.4	0.51	0.44	139	1.2	1	0.26	99
Bobolink	*2007*	0.78	0.67	0.23	150	**NA**			
	2008	-0.29	0.82	0.73	139	**NA**			
clay-coloured sparrow	*2007*	**-0.56**	**0.28**	**0.05**	**150**	**-2.8**	**0.85**	**0.001**	**111**
	2008	-0.43	0.27	0.11	139	**NA**			
Le Conte's sparrow	*2007*	-0.1	0.4	0.78	150	**-2.2**	**0.57**	**0.0001**	**111**
	2008	-0.22	0.4	0.59	139	**NA**			
red-winged blackbird	*2007*	0.22	0.42	0.6	150	**1.18**	**0.59**	**0.05**	**111**
	2008	0.21	0.44	0.63	139	0.06	0.72	0.93	99
Savannah sparrow	*2007*	-0.2	0.24	0.41	150	-0.22	0.26	0.39	111
	2008	-0.27	0.3	0.37	139	**-0.58**	**0.34**	**0.09**	**99**
sedge wren	*2007*	0.48	0.63	0.44	150	**NA**			
	2008	0.34	0.53	0.52	139	**NA**			

Note: NA indicates that no individuals were recorded in habitat type

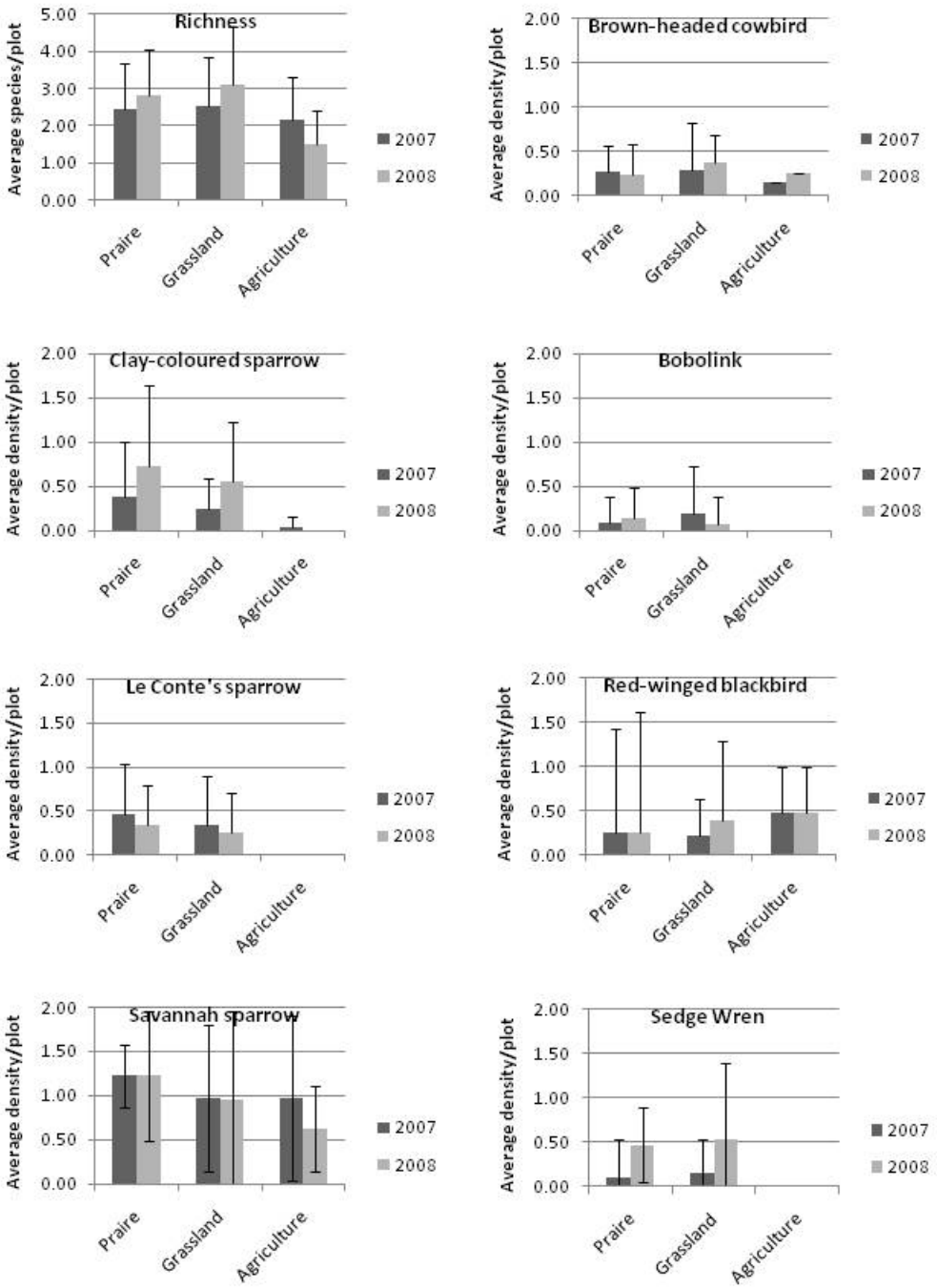

Figure 2. Average avian species richness and individual species densities recorded in plots in tall-grass prairie, adjacent matrix grassland and agricultural areas in Manitoba 2007-2008. Error bars on graphs show standard deviation (SD) of the mean.

4.3 Habitat Relationships for Avian Richness and Density/Presence in Tall-grass Prairies

4.3.1 Avian Species Richness in Tall-grass Prairie

Vegetative variables had the strongest influence on overall avian species richness in both years of the study. Matrix habitat type had no influence on overall avian richness in either year, while patch-scale metrics did not affect avian richness in 2007. In 2007, the only relationship in the top model with confidence intervals that excluded zero was increased avian species richness with greater non-native plant species richness. In 2008 top models, slightly higher avian species richness was recorded in prairies with greater litter depth (Table 6).

Table 6. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for overall avian species richness in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	2	192	0	0.39	Native species richness	0.06	0.04	-0.01	0.13
						Non-native species richness	**0.18**	**0.08**	**0.05**	**0.32**
2008	1	3	201	0	0.22	Robel reading	0.09	0.10	-0.09	0.26
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.03	0.05	-0.05	0.12
	2	5	203	1.4	0.11	Robel reading	0.04	0.11	-0.14	0.23
						Litter depth	**0.05**	**0.03**	**0.00**	**0.11**
						Maximum height	0.04	0.05	-0.04	0.13
						Native species richness	0.07	0.04	0.00	0.15
						Non-native species richness	0.13	0.09	-0.03	0.28
	3	5	203	1.8	0.09	Natural log of Area	0.07	0.05	-0.02	0.16
						Quality	-0.28	0.18	-0.58	0.03
						Robel reading	0.05	0.11	-0.14	0.24
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.09	0.06	-0.01	0.18

4.3.2 Bobolink (Dolichonyx oryzivorus)

Bobolinks responded to local and landscape-scale variables but were less affected by patch-scale characteristics. Models with the lowest AIC_c values for bobolink in 2007 and 2008 included both landscape and vegetation variables (Table 7). The top model for 2007 had no relationships with confidence intervals excluding zero, but in 2008, bobolink presence was lower in areas with more hostile habitat and higher in prairies with a greater proportion on non-native vegetation cover. In both years, matrix habitat alone did not affect presence or absence of bobolink. There was no effect of patch structure on bobolinks in either year.

Table 7. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for bobolink presence/absence in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	10	34	0	0.67	Prop Agriculture (500m)	-103	252	-534	328
						Prop Grass (500m)	-27	108	-212	159
						Prop Hostile Habitat (500m)	-113	240	-523	298
						Prop native vegetation cover	122	10117	-17187	17432
						Prop non-native vegetation cover	9.67	10019	-17132	17151
						Prop litter cover	-1907	7951	-15511	11696
						Prop forb cover	-313	10437	-18170	17544
						Prop grass cover	-513	10676	-18778	17752
						Prop shrub cover	-2197	12520	-23617	19223
						Prop litter cover (FGS)	1086	9055	-14406	16578
2008	1	4	34	0	0.27	**Prop Hostile Habitat (500m)**	**-5.30**	**2.90**	**-10.25**	**-0.34**
						Prop native vegetation cover	20.53	17.31	-9.09	50.14
						Prop non-native vegetation cover	**33.72**	**18.57**	**1.94**	**65.49**
						Prop litter cover	5.18	11.55	-14.58	24.95

4.3.3 Brown headed Cowbird (Molothrus ater)

Brown headed cowbirds appear to be responding to both local and patch-scale variables but are not affected by any landscape level attributes. The best overall model for brown-headed cowbirds in 2007 was a vegetation-only model, while in 2008 a patch and vegetation model had the lowest AIC_c value (Table 8). The 2007 model indicates that presence of brown-headed cowbirds increased with maximum vegetation height, while the 2008 model results suggest that presence was related to lower prairie quality and increased fragmentation of the patch. Brown-headed cowbird presence was not related to type or amount of surrounding matrix habitat in either year. Patch-level mechanisms alone did not affect presence of cowbirds during the study.

Table 8. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for brown-headed cowbird presence/absence in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	10	69	0	0.54	Robel reading	-2.81	1.78	-5.84	0.23
						Litter depth	-0.01	0.20	-0.36	0.33
						Maximum height	**1.45**	**0.78**	**0.11**	**2.78**
						Prop native vegetation cover	-46	214	-411	320
						Prop non-native vegetation cover	-27	214	-394	339
						Prop litter cover	144	254	-291	578
						Prop forb cover	82	209	-275	440
						Prop grass cover	68	208	-287	423
						Prop shrub cover	76	212	-286	439
						Prop litter cover (FGS)	-110	246	-530	310
2008	1	4	56	0	0.34	**Quality**	**-3.66**	**1.58**	**-6.37**	**-0.96**
						Mean Shape Index	**1.40**	**0.72**	**0.17**	**2.62**
						Native species richness	0.25	0.21	-0.11	0.61
						Non-native species richness	-0.83	0.56	-1.79	0.13

4.3.4 Clay-coloured Sparrow (Spizella pallida)

Clay-coloured sparrows responded to variables at all scales but seemed to be most affected by habitat that surrounded prairies. Top models for 2007 included a patch and vegetation model and several landscape and vegetation models. The top models from 2008 included a model at the landscape and local level, a model at the local level and a model at the patch and local scale. Relationships in best models from 2007 indicated that densities were higher in smaller prairies with a higher proportion of forest and lower proportion of grassland surrounding sites. The best 2008 model suggested that clay-coloured sparrow density increased with vegetation height (Table 9).

Table 9. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for clay-coloured sparrow densities in Manitoba's tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	4	91.5	0	0.15	**Natural log of Area**	**-0.47**	**0.13**	**-0.70**	**-0.25**
						Quality	-0.05	0.51	-0.92	0.82
						Native species richness	0.12	0.10	-0.06	0.30
						Non-native species richness	0.19	0.25	-0.23	0.62
	2	5	91.7	0.2	0.13	Prop Agriculture (500m)	-0.61	0.93	-2.19	0.98
						Prop Grassland (500m)	**-3.65**	**1.01**	**-5.38**	**-1.91**
						Prop native vegetation cover	-3.98	3.64	-10.21	2.26
						Prop non-native vegetation cover	-5.49	3.68	-11.78	0.80
						Prop litter cover	-3.62	3.40	-9.45	2.20
	2	5	91.7	0.2	0.13	Prop Agriculture (500m)	-0.77	1.01	-2.50	0.95
						Prop Grassland (500m)	**-3.21**	**1.02**	**-4.96**	**-1.46**
						Robel reading	-0.12	0.28	-0.61	0.36
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	0.19	0.12	-0.01	0.39
	3	4	92.4	0.9	0.09	**Prop Hostile Habitat (500m)**	**2.15**	**0.78**	**0.83**	**3.48**
						Robel reading	-0.07	0.27	-0.54	0.40
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	0.19	0.12	0.00	0.39
	3	3	92.4	0.9	0.09	**Prop Hostile Habitat (500m)**	**2.26**	**0.73**	**1.01**	**3.52**
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.22	-0.55	0.19
	4	5	93.5	2	0.05	Prop Agriculture (500m)	-2.15	6.41	-13.12	8.82
						Prop Grassland (500m)	-4.94	6.89	-16.72	6.84
						Prop Hostile Habitat (500m)	-1.37	6.41	-12.34	9.61
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.21	-0.55	0.18
2008	1	4	142	0	0.20	Prop Hostile Habitat (500m)	1.45	0.69	-1.94	2.36
						Robel reading	0.26	0.22	-2.38	-0.43
						Litter depth	0.06	0.06	-0.21	0.21
						Maximum height	**0.02**	**0.10**	**0.36**	**1.03**
	2	3	144	1.8	0.08	Robel reading	0.09	0.21	-0.27	0.45
						Litter depth	0.04	0.06	-0.06	0.14
						Maximum height	0.07	0.10	-0.10	0.25
	3	5	144	2	0.07	Natural log of Area	-0.17	0.11	-0.36	0.02
						Quality	-0.51	0.43	-1.24	0.22
						Robel reading	0.20	0.21	-0.16	0.57
						Litter depth	0.05	0.06	-0.05	0.15
						Maximum height	0.04	0.12	-0.16	0.24

4.3.5 Le Conte's Sparrow (Ammodramus leconteii)

Models for Le Conte's sparrow indicated that vegetation characteristics, patch metrics and composition of matrix habitat were all important in their habitat selection.

Top models for 2007 and 2008 include patch and vegetation models, while other 2008 top models include landscape and vegetation models (Table 10). The top 2007 model showed the Le Conte's sparrow chose larger, higher quality prairies with a lower degree of fragmentation. The 2008 model indicate that Le Conte's sparrow prefer larger, prairies with greater litter depth and shorter vegetation, surrounded by grassland.

Table 10. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for Le Conte's sparrow densities in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	5	97	0	0.44	**Natural log of Area**	**0.75**	**0.25**	**0.32**	**1.17**
						Quality	**1.29**	**0.54**	**0.37**	**2.22**
						Mean Shape Index	**-0.70**	**0.27**	**-1.16**	**-0.24**
						Native species richness	-0.10	0.11	-0.28	0.08
						Non-native species richness	0.15	0.22	-0.23	0.54
2008	1	5	80	0	0.24	**Natural log of Area**	**0.52**	**0.26**	**0.07**	**0.97**
						Quality	0.55	0.54	-0.39	1.48
						Robel reading	0.35	0.38	-0.30	1.00
						Litter depth	**0.18**	**0.09**	**0.03**	**0.33**
						Maximum height	**-0.42**	**0.21**	**-0.78**	**-0.05**
	2	5	81	1.3	0.12	Prop Agriculture (500m)	0.22	1.30	-2.00	2.45
						Prop Grassland (500m)	**2.83**	**1.34**	**0.53**	**5.12**
						Robel reading	0.33	0.38	-0.31	0.97
						Litter depth	**0.17**	**0.09**	**0.03**	**0.32**
						Maximum height	**-0.36**	**0.19**	**-0.69**	**-0.03**
	3	4	82	1.5	0.11	**Hostile500**	**-1.89**	**0.99**	**-3.59**	**-0.20**
						Robel reading	0.23	0.39	-0.44	0.90
						Litter depth	0.09	0.08	-0.04	0.23
						Maximum height	-0.27	0.19	-0.60	0.06

4.3.6 Red-winged Blackbird (Agelaius phoeniceus)

Red-winged blackbirds responded predominantly to patch metrics and vegetation characteristics but may also be affected by habitat types surrounding prairies. Top models for both years had patch metrics and vegetation variables (Table 11). The best 2007 model indicated that red-winged blackbirds were present in larger, higher quality prairies. In 2008, presence increased in more highly fragmented areas with higher vegetation density. Landscape composition or patch structure did not have an effect on presence of red-winged blackbirds in 2007.

Table 11. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for red-winged blackbird presence/absence in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	6	54	0	0.55	**Natural log of Area**	**1.60**	**0.72**	**0.37**	**2.83**
						Quality	**2.03**	**0.99**	**0.33**	**3.72**
						Prop forb cover	-3.92	12.76	-25.74	17.91
						Prop grass cover	-1.92	13.78	-25.50	21.66
						Prop shrub cover	22.95	14.91	-2.56	48.47
						Prop litter cover	-18.73	12.24	-39.67	2.20
2008	1	5	43	0	0.53	Quality	-0.23	1.32	-2.49	2.02
						Mean Shape Index	**3.18**	**1.41**	**0.77**	**5.59**
						Robel reading	**1.50**	**0.78**	**0.16**	**2.84**
						Litter depth	-0.20	0.21	-0.56	0.17
						Maximum height	0.32	0.40	-0.36	1.01

4.3.7 Savannah Sparrow (Passerculus sandwichensis)

Savannah sparrows responded mainly to patch and vegetation variables, but were also impacted by habitat types surrounding prairies. For both years, models with patch metrics and vegetation variables had the lowest AIC_c values (Table 12). In the best 2007 models, higher densities of Savannah sparrows were found in larger prairies that were

less fragmented, with greater plant species richness (both native and non-native). In 2008, densities were higher is areas that were less fragmented and areas with a lower proportion of litter cover.

Table 12. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for Savannah sparrow density in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	5	160	0	0.23	**Natural log of Area**	**0.19**	**0.11**	**0.00**	**0.37**
						Quality	-0.54	0.39	-1.21	0.12
						Mean Shape Index	**-0.66**	**0.28**	**-1.13**	**-0.19**
						Native species richness	0.12	0.07	-0.01	0.24
						Non-native species richness	0.16	0.15	-0.09	0.42
	2	4	160	0.5	0.18	Quality	-0.63	0.39	-1.30	0.05
						Mean Shape Index	**-0.55**	**0.28**	**-1.02**	**-0.07**
						Native species richness	**0.17**	**0.07**	**0.05**	**0.29**
						Non-native species richness	**0.29**	**0.13**	**0.06**	**0.51**
	2	6	160	0.5	0.18	**Natural log of Area**	**0.26**	**0.11**	**0.07**	**0.44**
						Quality	-0.34	0.38	-0.99	0.32
						Mean Shape Index	**-0.71**	**0.27**	**-1.18**	**-0.25**
						Prop native vegetation cover	0.77	3.20	-4.70	6.23
						Prop non-native vegetation cover	0.95	3.11	-4.36	6.26
						Prop litter cover	-2.36	2.99	-7.48	2.77
2008	1	5	150	0	0.42	Quality	-0.44	0.38	-1.09	0.22
						Mean Shape Index	**-0.64**	**0.30**	**-1.15**	**-0.13**
						Prop native vegetation cover	-0.45	2.50	-4.74	3.83
						Prop non-native vegetation cover	1.83	2.43	-2.32	5.98
						Prop litter cover	**-5.08**	**2.38**	**-9.16**	**-1.01**
	2	6	151	0.9	0.27	Natural log of Area	0.13	0.10	-0.04	0.30
						Quality	-0.38	0.39	-1.04	0.28
						Mean Shape Index	**-0.68**	**0.29**	**-1.18**	**-0.18**
						Prop native vegetation cover	-1.04	2.64	-5.56	3.47
						Prop non-native vegetation cover	1.09	2.58	-3.32	5.50
						Prop litter cover	-5.98	2.58	-10.39	-1.57

4.3.8 Sedge Wren (Cistothorus platensis)

Sedge wren habitat selection was predominantly influenced by patch metrics and vegetative characteristics, but they also responded to matrix habitat composition. Best models for both years contained patch metrics and vegetation variables (Table 13). In both years, results indicate that sedge wrens select larger, lower quality prairies. In 2008,

prairies with a higher degree of fragmentation and lower non-native species richness and cover supported higher sedge wren densities. No influence from matrix habitat type was noted in 2007 landscape-only models.

Table 13. Generalized linear mixed models with lowest AIC_c value and $\Delta AIC_c < 2$ for sedge wren density in Manitoba tall-grass prairies, 2007-2008. Number of parameters in the model (K), Akaike's Information Criteria (AIC_c), difference between lowest AIC_c value and AIC_c value of candidate model (ΔAIC_c), AIC weight (w_i), value of parameter (β), standard error (SE) and 90% confidence interval are listed.

Year	Rank	K	AIC_c	ΔAIC_c	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	4	40	0	0.35	**Natural log of Area**	**1.88**	**0.80**	**0.52**	**3.24**
						Quality	**-3.20**	**1.64**	**-6.00**	**-0.40**
						Native species richness	0.05	0.31	-0.48	0.58
						Non-native species richness	-0.82	0.71	-2.03	0.40
	2	6	41	0.6	0.26	**Natural log of Area**	**1.83**	**0.96**	**0.19**	**3.46**
						Quality	-2.12	1.49	-4.67	0.44
						Prop forb cover	10.35	16.91	-18.58	39.27
						Prop grass cover	23.10	18.41	-8.40	54.61
						Prop shrub cover	-7.67	26.92	-53.72	38.38
						Prop litter cover (FGS)	8.31	14.40	-16.33	32.95
2008	1	5	90	0	0.37	**Natural log of Area**	**0.80**	**0.26**	**0.35**	**1.24**
						Quality	**-1.72**	**0.82**	**-3.12**	**-0.33**
						Mean Shape Index	**0.70**	**0.36**	**0.09**	**1.31**
						Native species richness	0.00	0.11	-0.19	0.19
						Non-native species richness	**-0.87**	**0.37**	**-1.50**	**-0.24**
	2	6	92	1.6	0.17	**Natural log of Area**	**0.74**	**0.25**	**0.30**	**1.17**
						Quality	**-1.64**	**0.82**	**-3.04**	**-0.24**
						Mean Shape Index	**0.80**	**0.38**	**0.14**	**1.46**
						Prop native vegetation cover	-7.45	5.35	-16.60	1.70
						Prop non-native vegetation cover	-11.53	5.18	-20.38	-2.68
						Prop litter cover	-7.66	5.35	-16.81	1.49
	2	4	92	1.6	0.17	**Natural log of Area**	**0.95**	**0.31**	**0.42**	**1.49**
						Quality	-0.47	0.58	-1.47	0.52
						Native species richness	0.00	0.12	-0.20	0.21
						Non-native species richness	-0.67	0.40	-1.35	0.02

4.3.9 Summary of Avian Species Relationships with Habitat Variables

All avian species analyzed, with the exception of bobolinks and clay-coloured sparrows, were most strongly influenced by local and patch-level mechanisms together. Bobolinks and clay-coloured sparrows were predominantly affected by adjacent matrix habitat and vegetation variables. Landscape and vegetation models were also included in the suite of best models for Le Conte's sparrows and clay-coloured sparrows. The set of best models for brown-headed cowbirds and clay-coloured sparrows included vegetation-only models. Adjacent matrix habitat type alone had no notable effect on brown-headed cowbirds (2007 and 2008), bobolinks (2007 and 2008), red-winged blackbirds (2007), Savannah sparrows (2007) and sedge wrens (2008). Patch metrics alone had no influence on brown-headed cowbirds (2007 and 2008), bobolinks (2007), clay-coloured sparrows (2008) and red-winged blackbirds. All species were affected by some vegetation variables.

Size of prairies was the variable that influenced the density/presence of the greatest number of avian species (Table 14). Amount of fragmentation (i.e. mean shape index) and quality also appeared in the best models for multiple species. For landscape variables, proportion of surrounding grassland and hostile matrix appeared to be more important in determining densities/presence than proportion of agricultural matrix. At the local level, non-native species richness influenced the most species. Responses to variables were inconsistent among avian species and between years. Almost all variables increased density/presence in some avian species and reduced density/presence in others, illustrating the diversity in individual species habitat requirements.

Table 14. Summary of variables with confidence intervals excluding zero from all GLMMs for avian species in Manitoba tall-grass prairies, 2007-2008. Bolded text indicates that relationship was found in set of top models ($AIC_c \geq 2$) for species.

	Variable	2007	2008
Landscape	Prop Agriculture (500m)		LCSP(-)
			RWBL(+)
		SAVS (+)	SAVS (+)
	Prop Grass (500m)	**CCSP (-)**	BOBO(-)
		LCSP(-)	**LCSP(+)**
			RWBL(+)
			SAVS(-)
			SEWR(+)
	Prop Hostile Habitat		**BOBO(-)**
		CCSP(+)	
		LCSP(-)	**LCSP(-)**
			RWBL(-)
			SAVS(-)
			SEWR(-)
Patch	Natural log of Area	BHCO(-)	
			BOBO(+)
		CCSP(-)	CCSP (-)
		LCSP(+)	**LCSP(+)**
		RWBL(+)	
		SAVS(+)	SAVS(+)
		SEWR(+)	**SEWR(+)**
	Quality		**BHCO(-)**
			BOBO(-)
		LCSP(+)	
		RWBL(+)	
		SAVS(-)	SAVS(-)
		SEWR(-)	**SEWR(-)**
	Mean Shape Index		**BHCO(+)**
		LCSP(-)	
			RWBL(+)
		SAVS(-)	**SAVS(-)**
			SEWR(+)
Local	Robel reading		**CCSP(-)**
			RWBL(+)
	Litter depth		BOBO(+)
			LCSP(+)
		SAVS(-)	**SAVS(-)**
	Maximum height	**BHCO(+)**	
		CCSP(+)	**CCSP(+)**
			LCSP(-)
		SAVS(-)	
	Prop native vegetation		
	Prop non-native vegetation cover		**BOBO(+)**
			SEWR(-)
	Prop litter cover		**SAVS(-)**
	Prop forb cover		
	Prop grass cover	SEWR(+)	
	Prop shrub cover	RWBL(+)	
	Native species richness	**SAVS(+)**	
	Non-native species richness	BHCO (+)	
		BOBO (+)	BOBO(+)
		LCSP(+)	
		SAVS(+)	
			SEWR(-)

The following codes are used for avian species: BHCO – brown-headed cowbird, BOBO – bobolink, CCSP – clay-coloured sparrow, LCSP – Le Conte's sparrow, RWBL – red-winged blackbird, SAVS – Savannah sparrow, SEWR- sedge wren. A "+" after species code denotes a positive relationship, while a "-"denotes a negative relationship.

Chapter 5: Discussion

5.1 Avian Species Richness and Density/Presence by Habitat Type

5.1.1 Avian Species Richness and Density/Presence in Tall-grass Prairies Compared with Grassland Matrix

My results are consistent with other studies that recorded similar grassland bird species richness in native and non-native grassland habitats, despite differences in plant communities (Chapman et al. 2004) or land use (McMaster and Davis 2001). All of the grassland birds analyzed showed the same densities in matrix grassland as they did in tall-grass prairie, indicating the grassland matrix is providing habitat for grassland birds. As much of the matrix grassland in my study was grazed pasture, it is possible that patches were more open (i.e. less invasion of woody species) than the native tall-grass prairies and the functional extent of matrix grassland patches may be correspondingly broad, increasing the number of species able to inhabit them (see Herkert 1994).

However, we must be cautious when using a metric such as species richness, as this may not be a good indicator of reproduction and survival of individuals. Although birds may be establishing territories and nesting in non-native grasslands, mowing and haying of grasslands may destroy nests and lower survival (McMaster and Davis 2001). Predator (see Chalfoun et al. 2002) and prey (see Hamer et al. 2006) populations may also differ in non-native grasslands, causing lower nest survival or fewer food resources than in native prairies.

Overall, my results suggest that the matrix grassland is providing useable habitat to multiple grassland bird species, which emphasizes the importance in managing lands for avian conservation across the regional landscape. Management techniques such as

delayed haying and mowing or managing levels of grazing may improve survival of species nesting in these non-native grasslands.

5.1.2 Avian Species Richness and Density/Presence in Tall-grass Prairies Compared with Agricultural Matrix

Overall avian species richness was significantly lower in agricultural matrix than in tall-grass prairie in 2008, but was the same in both habitat types in 2007. Another study found a similar total number of avian species in grassland and agricultural habitats, but noted that there were a greater number of nesting species and total nests in grasslands (Best 1997). Even though species richness was similar in 2008, species composition in agricultural matrix may differ from that found in tall-grass prairies.

Other studies have also found that bobolinks, sedge wrens, clay-coloured sparrows, Savannah sparrows and Le Conte's sparrows had much lower densities or were not found in row crops (e.g. Johnson and Igl 1995, Best 1997, Shutler et al. 2000). The differences in vegetative structure between agricultural areas and prairie may explain some of the variation in avian species densities. Agricultural areas have much sparser vegetation with little to no litter on the ground, which makes them unsuitable for certain bird species. In my study, clay-coloured sparrows selected areas with denser, taller vegetation, while bobolinks and Le Conte's sparrows both selected areas with greater litter depth. These species were likely not present or in much lower densities in agricultural areas because the vegetation structure did not meet their habitat requirements.

As brown-headed cowbirds and red-winged blackbirds are abundant habitat generalists (Lowther 1993, Yasukawa et al. 1995) it is not surprising I recorded equal densities of these species in agricultural fields and native prairies. Although densities of

these species was similar between agriculture and prairies, nest density and reproduction rate may have been much lower in agricultural areas (see Best et al 1997).

Although agricultural areas themselves are not providing optimal habitat for grassland bird species, having agriculture in the matrix habitat increased the usage of tall-grass prairies for several species. Densities of Savannah sparrows and red-winged blackbirds both increased with greater amounts of agricultural matrix on the landscape, while bobolinks and Le Conte's sparrows, two species of conservation concern, decreased with more forest or hostile matrix in the landscape. Research suggests that more sparsely treed regions in the North American prairies can sustain higher densities of many grassland bird species (see McMaster and Davis 2001), indicating that agricultural matrix is preferable to birds as compared with forested matrix habitat. These results not only highlight the importance of conservation and protection from further conversion to agriculture of remnant prairies in Manitoba, they also emphasize the value of managing encroachment of woody vegetation and forests in proximity to prairies.

5.2 Habitat Selection by Avian Species in Manitoba Tall-grass Prairie

5.2.1 Importance of Spatial Scales on Avian Species Richness and Density/Presence

Previous studies to identify the most important spatial scale for management of overall richness and individual grassland bird species have produced variable results. These differences may be attributed to regional variation in vegetation structure, prairie fragment sizes and amount of forested area in the matrix habitat. Climatic (see Visser Marcel et al. 2003) and temporal changes may also play a role in the variability in avian responses to spatial scales. My results show that avian responses to spatial scale were

fairly consistent between the two years of the study, but the variables which they responded most strongly to differ between years of the study for several species.

The best scale for management of overall avian species richness in northern tall-grass prairie is at the local level. A study in Alberta mixed-grass prairie also concluded that avian species richness was most affected by local and neighborhood variables and did not respond strongly to landscape variables (Koper and Schmeigelow 2006). However, species composition may have differed between prairies surrounded in a greater amount of forest as compared with other grassland or agriculture. Non-grassland bird species were recorded in a number of sites with urban and forest matrix.

Brown-headed cowbirds, Le Conte's sparrows, red-winged blackbirds, Savannah sparrows and sedge wrens were all affected mainly by patch and vegetation variables. Although my study shows that Le Conte's sparrows select habitat based on patch and local variables, another study concluded that they were only affected by vegetation variables, but were not influenced by patch size or amount of trees in the surrounding landscape (Winter et al. 2005*b*). A threshold for prairie size and landscape composition may exist for Le Conte's sparrow habitat selection, where area sensitivity may only be detected when values fall below that threshold. Red-winged blackbirds in my study were most strongly influenced by patch-level variables, while other research indicates they may not respond to vegetation variables (e.g. Patterson and Best 1996, Delisle 1997). Savannah sparrows respond predominantly to local and patch-level variables, but do not respond to landscape variables (Bakker et al. 2002). Although my results showed that sedge wrens were most strongly affected by vegetation and patch metrics, a study by Herkert (1994) observed that sedge wrens only responded to vegetation variables, while

Bakker et al. (2002) concluded that the best model for this species was based on landscape composition alone.

In my study, bobolinks and clay-coloured sparrows were most strongly influenced by variables at the landscape and local level. In Wisconsin grasslands, bobolinks only respond to landscape variables and were not influenced by vegetation attributes (Ribic and Sample 2001), while in a study in eastern South Dakota found that occurrence is only related to vegetation variables and not influenced by landscape factors (Bakker et al. 2002). However, neither of these studies assessed the influence of plant species richness on bobolink distribution, which was an important factor determining bobolink presence in my study. Clay-coloured sparrows may be most strongly influenced by landscape level variables, such as the amount of surrounding forest, as compared with patch and vegetation variables (Bakker et al. 2002). Although several of my grassland bird species were not influenced by surrounding matrix habitat type alone, the combination of landscape metrics and variables at other scales variables is important for determining habitat selection (Cunningham and Johnson 2006).

5.2.2 Avian Species Richness in Manitoba Tall-grass Prairies

Avian richness increased with non-native plant species richness. However, most other literature concluded that avian habitat selection is driven by vegetation structure, rather than composition (Chapman et al 2004). It is possible that the structure of non-native vegetation was favorable to a greater number of bird species, including generalist species that may use a variety of habitats. In my study, non-native plant species richness was significantly correlated with shorter ($r=-0.43$, $p=0.007$), less dense ($r=0.31$, $p=0.015$) vegetation (Appendix G).

Several of the most abundant non-native plants found in my study sites may be structurally similar to native plants. The second and third most abundant non-native grasses, red top (*Agrostis stolonifera*) and smooth brome (*Bromus inermis*) are around the same height and may provide similar fuction for birds as native big bluestem (*Andropogon gerardii*). In reclaimed mine sites in Indiana seeded with non-native plants, obligate grassland birds preferred sites with greater cover of non-native grasses as compared with native forbs (Scott et al. 2002), indicating that grass cover may be more important in determining avian habitat selection as compared to compostion. Another study in Saskatchewan mixed-grass prairie that compared native prairie and prairie invaded by crested wheatgrass (*Agropyron pectiniforme*) concluded that birds preferred more sheltered habitat regardless of plant compositon (Sutter and Brigham 1997). In my study, the proportion on non-native plants was not correlated with the proportion of grasses, forbs or shrubs (Appendix G), while the correlations between non-native plant cover and shorter vegetation and less litter was weak, indicating that invasion of non-native species may not greatly alter overall community structure in this region of the tall-grass prairie. It is also possible that a greater number of bird species, including generalists, are able to inhabit tall-grass prairies that have slightly shorter vegetation. Higher native and non-native vegetation richness were significantly positively correlated with prairie size (Appendix G), indicating higher habitat heterogeneity may also be a factor in increased grassland bird richness with increased non-native plant species richness. According to the more individual hypothesis (MIH), more heterogeneous areas with greater food resources can support more individuals, and communities with more individuals can support a greater number of species (Srivastava and Lawton 1998).

Increasing non-native plant species richness may create more microhabitats to support a greater diversity in invertebrate prey species (see Yee and Juliano 2007). In turn, tall-grass prairies with greater non-native plant species richness may support an increased number of avian species.

Of the recent studies that have assessed the influence of vegetation composition on birds (see Chapman et al. 2004, Sutter and Brigham 1998, Rottenberry 1984, Bollinger 1995, Wilson and Belcher 1989, Davis and Duncan 1999), most of them compared grasslands seeded with non-native plant species to native prairies, as opposed to looking at overall richness of native and non-native plant species in prairies. Also, most of these studies were conducted in the mixed-grass prairie ecoregion, which has comparatively shorter vegetation than tall-grass prairie. Similarly to non-native grasses in tall-grass prairie, the most abundant non-native grasses in mixed grass prarie are Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) (see Belcher and Wilson 1989). However, as smooth brome is a tall grass, it may be more structurally similar to native tall-grass prairie grasses than to native mixed grass prairie grasses. Avian response to the structure of non-native grasses may be less important in tall-grass prairie as compared with mixed-grass prairie.

No other studies specifically addressed the influence of prairie quality on grassland songbirds. I did not detect any relationship between prairie quality and avian species richness, but did find that avian species richness in this region is being driven mainly by local vegetative variables, which are inherently related to quality. The quality ranking for prairies is based on the history of disturbance, surrounding vegetation types and amount of native versus non-native plant species, but does not account for size,

spatial heterogeneity or land use/management within prairies. Several of the larger, more heterogenous sites in my study, were classified as lower quality, however, they were likely be able to support just as many of bird species as higher quality sites. The quality ranking for tall-grass prairies in this region does not appear to be a good indicator for habitat suitability for birds.

The results from my study in the northern tall-grass prairie are unique and can provide insight into impacts of non-native plant species invasions of native prairie habitat on songbirds. Currently, patches of Manitoba tall-grass prairie being secured for conservation by governments and non-government organisations are the higher quality sites with fewer non-native plants. However, my results highlight that it is also important to conserve the lower quality sites that are providing good habitat for grassland birds.

Although I did not detect any trends in avian richness based on matrix habitat surrounding prairies, several studies have found that local bird abundance and richness were higher in prairies that were in a mosaic of grassland and agricultural dominated landscapes as compared with forest dominated landscapes (Soderstrom and Part 2000, McMaster and Davis 2001). It is possible that I did not detect many strong responses to landscape variables because the majority (55%) of matrix habitat surrounding my study sites was grassland (37%) or agriculture (16%), which is structurally similar to prairie and is used by grassland birds.

5.2.3 Relationships between Avian Species Density/Presence and Local-scale Variables

Habitat selection by all bird species analyzed was affected by some vegetative variables. Non-native plant species richness influenced densities/presence of five of the avian species analyzed, indicating that plant species composition and richness may play

an important role in habitat selection for multiple grassland bird species in the northern tall-grass prairie. Several other studies have concluded that plant structure is a better predictor of avian densities than composition, providing that differences in composition do not translate into structural differences between prairies (Chapman et al. 2004, Sutter and Brigham 1998, Davis and Duncan 1999). However, the prairies with greater non-native plant species richness in my study had shorter, less dense vegetation, leading to obvious structural differences with vegetation composition (see Appendix G). Vegetation height and litter depth also influenced habitat selection by multiple grassland passerines, with responses between species being variable. While the proportion of grasses/sedges influenced sedge wrens and proportion of shrubs influenced bobolinks, proportion of forbs did not influence any species.

As bobolink presence is known to increase with frequency of exotic grasses (Madden et al. 2000), it follows that they would also increase with higher non-native species richness. This preference for non-native vegetation may be further explained by their affinity for open sites and avoidance of wooded edge habitat (Bollinger and Gavin 2004). Of the large prairies in my study, the higher quality sites (with lowest non-native species richness) were found in the tall-grass prairie preserve area, where a large proportion of the matrix habitat is forested.

In Manitoba mixed-grass prairie, Savannah sparrows were positively correlated with native vegetation and negatively correlated with introduced vegetation (Wilson and Belcher 1989). My study found that they were positively associated with both native and non-native plant species richness (i.e. overall richness) in the tall-grass prairie, indicating that responses to vegetation composition may vary regionally and with prairie type.

Clay-coloured sparrows in my study were only affected by vegetation height, but other studies also show that they typically select shrubby areas with greater vegetation density (Bakker et al. 2002, Winter et al. 2006). Other studies have also shown that Le Conte's sparrows can have higher densities in areas with greater litter depth (Dale et al. 1997, Grant et al. 2004) and may nest in areas with shorter vegetation (Winter et al. 2005b).

In New York hay fields, greater abundances of red-winged blackbird were recorded with greater vegetation density (Bollinger 1995), while studies of Conservation Reserve Program (CRP) fields in Iowa (Patterson and Best 1996) and Nebraska (Delisle 1997) concluded that they do not respond to vegetation variables. Higher abundances of Savannah sparrows have been recorded in grasslands with shorter, less dense vegetation (Bakker et al. 2002).

Since all bird species analyzed seem to be affected by some local variables, it follows that active management of grassland patches at the local level is an important management technique for enhancing habitat. Techniques such as prescribed burning and moderate grazing by cattle can change overall vegetation structure and composition, while combating encroachment of woody vegetation.

All vegetation structure measures were collected in a single field season, while composition was collected for different plots in both years. However, both vegetation structure and composition can vary on a year-to-year basis due to precipitation or other climatic variation (Gibson and Hulbert 1987, Gross and Romo 2010, Alder and Levine 2007). While the relative heights and densities among fields are likely to remain similar among years, there is likely to be some variability in this pattern. A comprehensive

analysis of weather data from 2007 and 2008 would provide a better understanding of variation in precipitation and in vegetation structure and composition between these two years which, in turn, could clarify my reported relationship between birds and vegetation.

5.2.4 Relationships between Avian Species Density/Presence and Patch-scale Variables

Results from research assessing impact of prairie size on grassland birds (e.g. Davis 2004, Bakker et al. 2002, Johnson and Igl 1999) have not been consistent, indicating that regional variability and thresholds in fragment size may play a role in area sensitivity recorded in grassland birds. As the definition of patch size is an anthropogenic construct which is based more on human perception of the landscape, rather than the avian perception, various studies may define patches differently, which may also influence end results of studies.

Several studies have also concluded that brown headed cowbirds were not area sensitive (David 2004) and may even show higher abundances in smaller patches (Johnson and Igl 2001), likely due to their attraction to edge habitat. Brown-headed cowbirds select edge habitat so that they will have more nests to parasitize, as there is a high diversity and density of grassland and forest bird species that nest in wooded edges (Johnson and Temple, 1990).

Results for area sensitivity of clay-coloured sparrows differs among previous studies, with some studies concluding that they prefer larger areas (Johnson and Igl. 2001) and other studies indicating they prefer smaller areas (Davis 2004, Bakker et al. 2002). As clay-coloured sparrows generally select shrubby habitat, they were likely recorded in greater densities at smaller sites in the northern tall-grass prairie because these have a high proportion wooded edge habitat.

Le Conte's sparrows favour larger patches in some prairie regions (Johnson and Igl 2001), but are not influenced by patch size in others (Winter et al 2005b). Several studies have concluded that Savannah sparrows are area insensitive (e.g. Johnson and Igl 2001, Davis 2004) while others have found that they select larger prairies (Bakker et al. 2002, Herkert 1994). As Manitoba's northern tall-grass prairie has smaller prairie patches and a greater amount of forest surrounding prairies (see Winter et al. 2005*b*) than in other regions of the tall-grass prairie, my study was able to detect area sensitivity for both Savannah and LeConte's sparrows.

In Manitoba's northern tall-grass prairie, the largest remnant patches are in the tall-grass prairie preserve, which is has a lot of wet-grassland and sedge meadow habitat. As red-winged blackbirds (Yasukawa et al. 1995) and sedge wrens (Herkert et al. 2001) are known to inhabit wetlands and wet-grasslands, it follows that higher densities would be recorded in these larger, wetter prairies.

No other studies have specifically addressed the impact of prairie quality on grassland bird densities; however, my results indicate that prairie quality may have an impact on several species. Brown-headed cowbird presence was greater in lower quality sites, many of which are also smaller prairies. Sedge wrens also showed a preference for lower quality sites, which is possibly due to several of the large lower quality sites in the study being in proximity to wetland habitat (see Fletcher and Koford 2002). Both Le Conte's sparrows and red-winged blackbirds selected higher quality sites. As both of these species tend to select wetter prairies, they showed the highest densities in the wet, but high quality remnant patches in Manitoba's tall-grass prairie preserve.

Amount of fragmentation (mean shape index) also influenced numerous species, where Savannah sparrows and Le Conte's sparrows preferred less fragmented areas and brown-headed cowbirds, red-winged blackbirds and sedge wrens chose more highly fragmented patches. As fragmentation increases, species that select larger prairies will be most strongly impacted by the associated decrease in patch area and loss of grassland habitat (Herkert 1994). Over time, fragmentation of the smallest patches may lead to habitat loss or conversion to wooded habitat (see Koper et al 2010), which will be detrimental to populations of avian species that prefer smaller prairies.

In the northern tall-grass prairie more bird species responded to area as compared to mean shape index. Davis (2004) concluded that the ratio of edge to interior habitat may be a better predictor of area sensitivity in grassland birds than prairie size; however, this result may not be true for the northern tall-grass prairie, which has such a large degree of fragmentation and very small prairie sizes.

5.2.5 Relationships between Avian Species Density/Presence and Landscape-level Variables

At the landscape level, proportion of grassland and proportion of hostile (forested or urban) areas within 500m of prairie patches was more important for determining densities of individual species than the proportion of agriculture surrounding prairies. Increasing forested land adjacent to prairies may reduce densities of some grassland bird species (Grant et al. 2004), while proportion of grassland matrix may increase densities for some bird species (Bakker et al 2002). As the northern tall-grass prairie has a higher proportion of forested matrix as compared with other parts of the tall-grass prairie, the

results of my study provide good information for management in this highly fragmented region.

Brown-headed cowbird densities are not influenced by surrounding grassland and agriculture; however, amounts of human development surrounding grasslands may increase densities (Klug et al. 2009). Clay coloured sparrows have been recorded in higher densities in areas with a lower proportion of grassland surrounding prairies (Bakker et al. 2002) and landscapes with a higher proportion of trees and shrubs (Winter et al. 2006). Encroachment of woody vegetation in the tall-grass prairie likely has a positive impact on clay-coloured sparrow populations, which could explain why their population declines have not been as large as in other grassland species. A study by Grant et al. (2004) also found that presence of Le Conte's sparrows was higher in areas with less woodland within 500 m of prairies.

Although only two of the seven birds analyzed had landscape metrics in their best models, we should not discount the importance that the matrix habitat type has on the patch and local level variables. In an analysis of the vegetation data from this study, Koper et al (2010) determined that native plant species composition in northern tall-grass prairies are significantly influenced by matrix habitat type, where native plant species increase with the proportion of grassland surrounding sites. As well, nest predators and brown-headed cowbirds are known to frequent woodland-grassland edges, which impacts on nesting success of grassland songbirds (Johnson and Temple 1990).

Chapter 6: Conclusions

Remnant tall-grass prairies, non-native grasslands and agricultural fields continue to play a role in sustaining grassland bird populations in the northern range of the tall-grass prairie. Although agricultural fields did not have the same richness or species densities as native prairie or grasslands in one year of the study, they too, are providing grassland birds with habitat and areas to forage. Agricultural matrix is preferable to forest or urban habitats for prairie birds. Encroachment of aspen forest and urbanization in northern tall-grass prairie continues to reduce the amount of habitat available to grassland birds. Woody vegetation at edges of grassland habitat increases the incidence of brood parasitism and overall nest survival (see Shaffer et al. 2003).

Overall avian species richness was primarily affected by vegetation variables. Density of most individual species was influenced by vegetation and patch level variables and several species were not impacted by the surrounding matrix type alone. Non-native plant species richness was the vegetation variable that influenced most species, indicating that it is valuable to consider vegetation composition of grasslands in management and acquisition of lands for conservation. Although quite a few species preferred larger prairies, smaller remnants were still used by species of interest. Although many remnant tall-grass prairie patches are small, those that are in an open agricultural landscape with few trees may still provide habitat for grassland songbirds (see Winter et al. 2006). Thus, conservation planning should incorporate smaller sites in the tall grass prairie that are adjacent to agricultural or other treeless areas.

My study results showed variability in songbird responses to habitat variables between years. As avian populations are inherently variable and can change between

years based on food availability, predator populations, factors on wintering grounds and climatic variables, it is important to conduct longer term research in the same region. My study represented the first two years of research on birds in Manitoba`s tall-grass prairie. My data and results will be used in subsequent research that will, hopefully, provide greater insight into observed habitat associations from this study.

Northern tall-grass prairie is highly fragmented with a greater amount of surrounding woody vegetation and smaller remnant patch sizes than in other areas of the tall-grass prairie. My results differ from others studies in mixed-grass or more southern tall-grass prairie, emphasizing the importance of conducting research throughout the extent of North American prairies to better understand regional variability in avian habitat requirements (see Bakker et al. 2002). My results have provided new insight into avian habitat selection in tall-grass prairie. Some of my unique findings include: 1) plant species composition and structure may both play an important role in avian habitat selection, 2) non-native plant species richness or cover can affect bird species richness and 3) area sensitivity in grassland passerines may only be detected below a certain threshold in prairie size.

Although many avian studies have been conducted in tall-grass prairie, it is very important to conduct more research in this northern region to better understand bird species responses to such a high degree of fragmentation. Further studies on nesting success and the impacts of fire and grazing would help us to gain a greater understanding of the relationships found by my study and would assist in avian conservation planning for this region.

Chapter 7: Management Implications

I suggest that overall avian species richness is primarily associated with vegetation structure and plant richness in northern tall-grass prairie. As avian richness was the same in adjacent non-native grasslands as it was in remnant prairie patches, these grasslands should be incorporated into conservation planning for declining bird populations. Grassland restoration for degraded non-native sites would also assist in stabilizing declining prairie bird populations (Vickery et al. 1999). As individual avian species responded most strongly to either surrounding land use or patch metrics in combination with vegetation variables, conducting studies and management at multiple spatial scales is obviously important to prairie and grassland bird conservation.

Avian species had diverse or even opposite responses to individual variables, which stresses the importance of maintaining heterogeneity in grasslands so that they can support multiple species (see Fuhlendorf and Engle 2001). As individual species were affected most strongly by vegetation structure and richness, it follows that management of prairie vegetation would optimize habitat usability for birds. Key management techniques to maintain heterogeneity include prescribed burning and grazing. Moderate and continuous grazing has been identified as the most ecologically sustainable grazing regime that increases heterogeneity of grasslands (Fuhlendorf and Engle 2001). Prescribed burning at the appropriate time of the year can also increase landscape heterogeneity (see Peterson and Best 1987) and improve habitat for grassland birds.

As some bird species were area sensitive, it is important to focus conservation efforts on managing larger remnant tall-grass prairies. However, as several species use, or even prefer smaller prairies, we should not ignore their conservation value. For generalist

species that use both edge and interior habitat within habitat patches in a fragmented landscape, smaller patches with a greater amount of edge may actually increase populations (Bender et al 1998). With variable responses to habitat characteristics between species, we need to evaluate management recommendations for individual species (Table 15) and use these recommendations to manage all habitats.

Table 15.Management recommendations for conserving grassland bird species in tall-grass prairie, based on literature and results from study on avian species in Manitoba's tall-grass prairie, 2007-2008.

Bird	**Management Recommendations**
Bobolink	-Delay hay-cropping until after nesting is completed (Bollinger et al 1990) -Mowing, prescribed burning to combat encroachment of woody vegetation (Bollinger et al 1990) -Include lower quality grasslands such as hay fields in conservation planning
Brown-headed cowbird	-Burning, mowing of wooded edges to reduce vegetation height and impact of brood parasitism on host species -Protect large tracts of grasslands to reduce density of edge habitat (Shaffer et al. 2003)
Clay-coloured sparrow	-No specific management recommendations needed due to high populations and adaptability of species
Le Conte's sparrow	-Prescribed burning to maintain tall grasses, litter layer and combat encroachment of tall woody vegetation (Lowther 2005) -Protection of grasslands from being converted to agriculture (Lowther 2005) -Conservation of large, high quality sites that have a lot of interior habitat
Red-winged blackbird	-To reduce impact of foraging on farmers, densities may be reduced through use of resistant cultivars, reducing waste grain after harvest, and switching to alternative forage crops that are less susceptible to predation by birds (Yasukawa and Searcy 1995)
Savannah sparrow	-Protection of migratory stopover locations (Wheelright and Rising 2008) -Manage vegetation composition and litter of grasslands through grazing, burning or mowing -Include pastures and other large, open tracts of grassland in conservation planning
Sedge wren	-Protection of wetlands and sedge meadows (Herkert et al 2001) -Conservation of larger prairies with native plant species

My results have some important implications from a socio-economic perspective. Although increasing amounts or agriculture, pastureland and hayed land fragment prairie, grassland bird species prefer landscapes with these habitat types as compared with treed landscapes. From a social perspective, higher quality sites with more native plant species are considered more ecologically important than lower quality areas, yet areas with more non-native vegetation may support more avian species. These results may also apply to other guilds of animals, indicating that the human perception of habitat quality may not be the same as that of animals or insects.

Among both ecologists and politicians, there is sometimes a tendency to conserve rare species and habitats, instead of focusing on keeping common species common (Hamilton 1999). It would be beneficial to shift our focus not only to conservation of high quality, non-disturbed landscapes, but also further consider how we may be able to manage disturbed, fragmented landscapes for species conservation.

Currently, both local and regional governments and non-governmental organizations (NGOs) are promoting conservation of tall-grass prairie in this region. NGO's have been purchasing and managing remnant tall-grass prairies, while the provincial government has been managing and conserving tall-grass prairies as wildlife management areas or within their network of parks and protected areas. Their efforts are significantly contributing to protection of remnant tall-grass prairie and avian conservation. Local and regional governments should provide continued support to the NGOs, so that they can make progress towards their conservation goals of protecting remnant tall-grass prairie for all species which inhabit it. Government agencies could

provide further education or incentives to landowners so that they may properly manage their rangelands or idle lands in a way that is beneficial to bird species (see Riley 2004).

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Appendix A - Manitoba Conservation Ranking guidelines for 1995 and later, including resurveys in 2006 (Mansell, 1995; Appendix A: 15)

Manitoba Conservation Data Centre
Element Occurrence Specifications and Grading Guidelines
Upland Tall-grass Prairie Communities Includes:
Big Bluestem Prairies; Sand Reedgrass Prairies:.
Grading Guidelines:

A Grade:
– diverse mix of graminoid, forb and shrub species;
– no evidence of human disturbance (grazing, haying, herbicide application or fire suppression);
– few or no exotic species;
– surrounded on all sides by a buffer of natural vegetation.

B Grade:
– some evidence of human disturbance (grazing, haying, herbicide application or fire suppression) but with relatively little effect on the community's overall structure and/or composition;
– increased abundance of shrubs and/or exotic species as well as decreased abundance of native species.

C Grade:
– evidence of moderate human disturbance (grazing, haying, herbicide application or fire suppression) which has affected the community's overall structure and/or composition;
– increased abundance of shrubs and/or exotic species as well as decreased abundance of native species;
– the community has the potential to improve in quality to a B (or perhaps an A) grade occurrence over time, or with proper management.

D Grade:
– evidence of heavy human disturbance which has greatly affected the community's overall structure and/or composition;
– dominated by shrubs and exotic species, with low richness of native species;
– community does not appear to be restorable to a higher quality.
Author: Jason A. Greenall Revised: 11 May 1995.

Appendix B – GLMM Models

Landscape-only models

Model	PropAg500	PropGrass500	Hostile500	K
Null				0
L3	X	X	X	3
L4	X	X		2
L5			X	1

Patch-only models

Model	LnArea	Quality	MSI	K
Null				0
P3	X	X	X	3
P4	X	X		2
P5		X	X	2

Landscape and patch models

Model	PropAg500	PropGrass500	Hostile500	LnArea	Quality	MSI	K
Null							0
LP3	X	X	X	X	X	X	6
LP4	X	X		X	X	X	5
LP5			X	X	X	X	4
LP6	X	X	X	X	X		5
LP7	X	X	X		X	X	5

Vegetation-only models

Model	Robel_Ave	Litter_depth	Max_ht	NPropNatCov	NPropNonNatCov	Nprop_lit	Vprop_forb	Vprop_grass	Vprop_shrub	Vprop_lit	Native_sp_rich	Non_Nat_sp_rich	K
Null													0
V3	X	X	X	X	X	X	X	X	X	X	X	X	12
V4				X	X	X	X	X	X	X	X	X	9
V5	X	X	X	X	X	X	X	X	X	X			10
V6				X	X	X	X	X	X	X			7
V7	X	X	X				X	X	X	X	X	X	9
V8	X	X	X	X	X	X					X	X	8
V9				X	X	X					X	X	5
V10	X	X	X	X	X	X							6
V11				X	X	X							3
V12	X	X	X										3
V13	X	X	X				X	X	X	X			7
V14							X	X	X	X			4
V15	X	X	X								X	X	5
V16											X	X	2

Patch and vegetation models

Model	LnArea	Quality	MSI	Robel_Ave	Litter_depth	Max_ht	NPropNatCov	NPropNonNatCov	Nprop_lit	Vprop_forb	Vprop_grass	Vprop_shrub	Vprop_lit	Native_sp_rich	Non_Nat_sp_rich	K
Null																0
PV3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15
PV4	X	X	X				X	X	X	X	X	X	X	X	X	12
PV5	X	X	X	X	X	X	X	X	X	X	X	X	X			13
PV6	X	X	X				X	X	X	X	X	X	X			10
PV7	X	X	X	X	X	X	X	X	X					X	X	11
PV8	X	X	X				X	X	X					X	X	8
PV9	X	X	X	X	X	X	X	X	X							9
PV10	X	X	X				X	X	X							6
PV11	X	X	X	X	X	X										6
PV12	X	X	X	X	X	X				X	X	X	X			10
PV13	X	X	X							X	X	X	X			7
PV14	X	X	X	X	X	X								X	X	8
PV15	X	X	X											X	X	5
PV16	X	X		X	X	X	X	X	X	X	X	X	X	X	X	14
PV17	X	X					X	X	X	X	X	X	X	X	X	11
PV18	X	X		X	X	X	X	X	X	X	X	X	X			12
PV19	X	X					X	X	X	X	X	X	X			9
PV20	X	X		X	X	X				X	X	X	X	X	X	11
PV21	X	X		X	X	X	X	X	X					X	X	10
PV22	X	X					X	X	X					X	X	7
PV23	X	X		X	X	X	X	X	X							8
PV24	X	X					X	X	X							5
PV25	X	X		X	X	X										5
PV26	X	X		X	X	X				X	X	X	X			9
PV27	X	X								X	X	X	X			6
PV28	X	X		X	X	X								X	X	7
PV29	X	X												X	X	4
PV30		X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
PV31		X	X				X	X	X	X	X	X	X	X	X	11
PV32		X	X	X	X	X	X	X	X	X	X	X	X			12
PV33		X	X				X	X	X	X	X	X	X			9
PV34		X	X	X	X	X				X	X	X	X	X	X	11
PV35		X	X	X	X	X	X	X	X					X	X	10
PV36		X	X				X	X	X					X	X	7
PV37		X	X	X	X	X	X	X	X							8
PV38		X	X				X	X	X							5
PV39		X	X	X	X	X										5
PV40		X	X	X	X	X				X	X	X	X			9
PV41		X	X	X	X	X								X	X	7
PV42		X	X											X	X	4

Landscape and vegetation models

Model	PropAg500	PropGrass500	Hostile500	Robel_Ave	Litter_depth	Max_ht	NPropNatCov	NPropNonNatCov	Nprop_lit	Vprop_forb	Vprop_grass	Vprop_shrub	Vprop_lit	Native_sp_rich	Non_Nat_sp_rich	K
Null																0
LV3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	15
LV4	X	X	X				X	X	X	X	X	X	X	X	X	12
LV5	X	X	X	X	X	X	X	X	X	X	X	X	X			13
LV6	X	X	X				X	X	X	X	X	X	X			10
LV7	X	X	X	X	X	X				X	X	X	X	X	X	12
LV8	X	X	X	X	X	X	X	X	X					X	X	11
LV9	X	X	X				X	X	X					X	X	8
LV10	X	X	X	X	X	X	X	X	X							9
LV11	X	X	X				X	X	X							6
LV12	X	X	X	X	X	X										6
LV13	X	X	X	X	X	X				X	X	X	X			10
LV14	X	X	X							X	X	X	X			7
LV15	X	X	X	X	X	X								X	X	8
LV16	X	X	X											X	X	5
LV17	X	X		X	X	X	X	X	X	X	X	X	X	X	X	14
LV18	X	X					X	X	X	X	X	X	X	X	X	11
LV19	X	X		X	X	X	X	X	X	X	X	X	X			12
LV20	X	X					X	X	X	X	X	X	X			9
LV21	X	X		X	X	X	X	X	X					X	X	10
LV22	X	X					X	X	X					X	X	7
LV23	X	X		X	X	X	X	X	X							8
LV24	X	X					X	X	X							5
LV25	X	X		X	X	X										5
LV26	X	X		X	X	X				X	X	X				8
LV27	X	X								X	X	X				5
LV28			X	X	X	X	X	X	X	X	X	X	X	X	X	13
LV29			X				X	X	X	X	X	X	X	X	X	10
LV30			X	X	X	X	X	X	X	X	X	X	X			11
LV31			X				X	X	X	X	X	X	X			8
LV32			X	X	X	X				X	X	X	X	X	X	10
LV33			X	X	X	X	X	X	X					X	X	9
LV34			X				X	X	X					X	X	6
LV35			X	X	X	X	X	X	X							7
LV36			X				X	X	X							4
LV37			X	X	X	X										4
LV38			X	X	X	X				X	X	X	X			8
LV39			X							X	X	X	X			5
LV40			X	X	X	X								X	X	6
LV41			X											X	X	3

Appendix C – Listing of bird species found at each tall-grass prairie site

Bird species recorded in provincial park sites

Beaudry Park - Site BD1	
2007	*2008*
American goldfinch	American crow
Brown headed cowbird	American goldfinch
Bobolink	Bobolink
Clay-coloured sparrow	Clay-coloured sparrow
Horned lark	Le Conte's sparrow
Le Conte's sparrow	Ovenbird
Savannah sparrow	Red-winged blackbird
Sedge wren	Savannah sparrow
	Sedge wren
	Song sparrow
	Western meadowlark
	Yellow warbler

Birds Hill Park - Site BHP2	
2007	*2008*
American crow	American crow
American goldfinch	American goldfinch
Barn swallow	Blue jay
Black-capped chickadee	Canada goose
Clay-coloured sparrow	Clay-coloured sparrow
Chipping sparrow	Chipping sparrow
Common raven	Dark-eyed junco
Red-eyed vireo	Least flycatcher
Savannah sparrow	Ovenbird
Vesper sparrow	Red-eyed vireo
White-throated sparrow	Savannah sparrow
Yellow warbler	Song sparrow
	Vesper sparrow
	Wilson’s snipe
	Yellow warbler

Birds Hill Park - Site BHP5	
2007	*2008*
American goldfinch	American crow
Brown headed cowbird	American goldfinch
Blue jay	Brown headed cowbird
Canada goose	Clay-coloured sparrow
Clay-coloured sparrow	Common raven
Chipping sparrow	Le Conte's sparrow
Franklin's gull	Least flycatcher
Lark Sparrow	Red-eyed vireo
Savannah sparrow	Savannah sparrow
Song sparrow	Song sparrow
Vesper sparrow	Vesper sparrow
Yellow warbler	Yellow warbler
	Yellow-rumped warbler

Bird species recorded in provincial park sites

Birds Hill Park - Site BHP6	
2007	*2008*
Clay-coloured sparrow	American crow
Chipping sparrow	American goldfinch
Grey catbird	Clay-coloured sparrow
Hermit thrush	Red-eyed vireo
Vesper sparrow	Vesper sparrow
Yellow warbler	Yellow warbler

Birds Hill Park - Site BHP7A	
2007	*2008*
American crow	American crow
Black-capped chickadee	Brown headed cowbird
Brown headed cowbird	Clay-coloured sparrow
Blue jay	Lark sparrow
Blue-winged warbler	Least flycatcher
Clay-coloured sparrow	Ovenbird
Yellow warbler	Red-eyed vireo
	Tennessee warbler
	White crowned sparrow
	Yellow warbler

Birds Hill Park - Site BHP7B	
2007	*2008*
American robin	American crow
Black-capped chickadee	American goldfinch
Brown headed cowbird	Brown headed cowbird
Clay-coloured sparrow	Blue jay
Chipping sparrow	Clay-coloured sparrow
Grey catbird	Cedar waxwing
Least flycatcher	Chipping sparrow
Ovenbird	Common raven
Red-eyed vireo	Grey catbird
White-throated sparrow	Least flycatcher
Yellow warbler	Ovenbird
	Yellow warbler

Bird species in recorded provincial park sites

Birds Hill Park - Site BHP11 (Campground)	
2007	*2008*
Brown headed cowbird	American goldfinch
Clay-coloured sparrow	Clay-coloured sparrow
Chipping sparrow	Dicksissel
Common raven	Hermit thrush
Grey catbird	Lark sparrow
Least flycatcher	Least flycatcher
Vesper sparrow	Red-eyed vireo
Yellow warbler	

Birds Hill Park - Site BHPG7 (Campground)	
2007	*2008*
Brown headed cowbird	Brown headed cowbird
Clay-coloured sparrow	Clay-coloured sparrow
Grey catbird	Grey catbird
Ovenbird	Hermit thrush
White-throated sparrow	Ovenbird
Yellow warbler	Red-eyed vireo
	Yellow warbler

Bird species recorded in private land sites

Private Land - Site S11A	
2007	*2008*
American goldfinch	Brown headed cowbird
Brown headed cowbird	Bobolink
Brewers blackbird	Brewers blackbird
Clay-coloured sparrow	Clay-coloured sparrow
European starling	Common yellowthroat
Mourning dove	Le Conte's sparrow
Red-winged blackbird	Northern harrier
Savannah sparrow	Red-winged blackbird
Song sparrow	Savannah sparrow
Western meadowlark	Sedge wren

Private Land - Site S62	
2007	*2008*
American goldfinch	American goldfinch
Brown headed cowbird	American robin
Blue jay	Black-billed magpie
Blue-winged teal	Brown headed cowbird
Clay-coloured sparrow	Clay-coloured sparrow
Common yellowthroat	Common yellowthroat
Eastern Kingbird	Dark-eyed junco
Flycatcher	Eastern kingbird
Le Conte's sparrow	Hermit thrush
Red-eyed vireo	Le Conte's sparrow
Red-winged blackbird	Mourning dove
Savannah sparrow	Northern harrier
Sedge wren	Red-eyed vireo
Sandhill crane	Red-winged blackbird
Western meadowlark	Sedge wren
Yellow warbler	Sandhill crane
	Song sparrow
	Tree swallow
	Western meadowlark
	Wilson’s snipe
	Yellow warbler

Private Land - Site S80
2007
American crow
American goldfinch
Brown headed cowbird
Clay-coloured sparrow
Eastern Kingbird
Grey catbird
Le Conte's sparrow
Nelson's sharp tailed sparrow
Red-tailed hawk
Ruffed grouse
Red-winged blackbird
Savannah sparrow
Sedge wren
Sandhill crane
Song sparrow
Western meadowlark
Woodpecker
Yellow warbler

Bird species recorded in municipal park sites

Gross Isle - Site GI	
2007	*2008*
American goldfinch	American goldfinch
Brown headed cowbird	Barn swallow
Clay-coloured sparrow	Brown headed cowbird
Franklin's gull	Clay-coloured sparrow
Least flycatcher	Common yellowthroat
Red-winged blackbird	Least flycatcher
Savannah sparrow	Mourning dove
Song sparrow	Red-winged blackbird
Tree swallow	Savannah sparrow
Yellow warbler	Song sparrow

Living Prairie Museum - Site LPM	
2007	*2008*
American crow	American crow
American goldfinch	American goldfinch
Barn swallow	Clay-coloured sparrow
Canada goose	Chipping sparrow
Clay-coloured sparrow	Common grackle
Chipping sparrow	Franklin's gull
Eastern Kingbird	House sparrow
Franklin's gull	Mallard
House sparrow	Merlin
Merlin	Red-eyed vireo
Rock pigeon	Rock pigeon
Red-winged blackbird	Savannah sparrow
Savannah sparrow	

Rotary Prairie - Site ROT	
2007	*2008*
Brown headed cowbird	American goldfinch
Clay-coloured sparrow	Brown headed cowbird
Common yellowthroat	Brewers blackbird
European starling	Clay-coloured sparrow
Le Conte's sparrow	Le Conte's sparrow
Least Flycatcher	Mallard
Mallard	Ring-billed gull
Red-winged blackbird	Red-winged blackbird
Savannah sparrow	Savannah sparrow
Western meadowlark	Song sparrow
Yellow warbler	Western meadowlark

Bird species recorded in PFRA pasture sites

Pansy PFRA Pasture - Site PAN	
2007	*2008*
American goldfinch	American crow
American robin	American goldfinch
Barn swallow	Barn swallow
Black-billed magpie	Brown headed cowbird
Brown headed cowbird	Blue jay
Brewers blackbird	Brewers blackbird
Clay-coloured sparrow	Clay-coloured sparrow
Eastern kingbird	Common raven
Killdeer	Common yellowthroat
Le Conte's sparrow	Eastern Kingbird
Marbled godwit	Killdeer
Mallard	Le Conte's sparrow
Red-tailed hawk	Mourning dove
Red-winged blackbird	Nelson's sharp tailed sparrow
Savannah sparrow	Red-eyed vireo
Sedge wren	Red-winged blackbird
Song sparrow	Savannah sparrow
Tree swallow	Sedge wren
Western meadowlark	Sandhill crane
	Song sparrow
Yellow-headed blackbird	Western meadowlark
	Wilson’s snipe
	Yellow warbler

Portage PFRA Pasture - Site PORTA	
2007	*2008*
Barn swallow	American goldfinch
Brown headed cowbird	Brown headed cowbird
Bobolink	Bobolink
Clay-coloured sparrow	Canada goose
Common yellowthroat	Clay-coloured sparrow
Hairy woodpecker	Common yellowthroat
Le Conte's sparrow	Le Conte's sparrow
Marbled godwit	Mallard
Red-winged blackbird	Mourning dove
Savannah sparrow	Red-winged blackbird
Sedge wren	Savannah sparrow
Western meadowlark	Sedge wren
	Western meadowlark
	Willet
	Wilson’s snipe

Bird species recorded in PFRA pasture sites

Portage PFRA Pasture - Site PORTB	
2007	*2008*
American crow	American crow
American goldfinch	American goldfinch
Brown headed cowbird	Brown headed cowbird
Blue-winged teal	Bobolink
Clay-coloured sparrow	Brewers blackbird
Common raven	Canada goose
Common yellowthroat	Clay-coloured sparrow
Eastern Kingbird	Common yellowthroat
Killdeer	Killdeer
Le Conte's sparrow	Le Conte's sparrow
Marbled godwit	Marbled godwit
Red-winged blackbird	Mallard
Savannah sparrow	Ring-billed gull
Sedge wren	Red-winged blackbird
Western kingbird	Savannah sparrow
Western meadowlark	Song sparrow
Yellow warbler	Western meadowlark
	Willet

Gardenton PFRA Pasture - Site S77	
2007	*2008*
American crow	American crow
American goldfinch	Brown headed cowbird
Brown headed cowbird	Bobolink
Blue jay	Clay-coloured sparrow
Bobolink	Common yellowthroat
Clay-coloured sparrow	Le Conte's sparrow
Common yellowthroat	Red-eyed vireo
Grey catbird	Red-winged blackbird
Le Conte's sparrow	Savannah sparrow
Ruffed grouse	Sandhill crane
Savannah sparrow	Song sparrow
Song sparrow	Wilson’s snipe
Western meadowlark	Yellow warbler
Yellow warbler	Yellow-rumped warbler

Bird species recorded in Wildlife Management Area sites

Lake Francis WMA - Site LF2	
2007	*2008*
American bittern	American bittern
American goldfinch	American crow
Barn swallow	American goldfinch
Brown headed cowbird	American robin
Bobolink	Brown headed cowbird
Canada goose	Bobolink
Clay-coloured sparrow	Canada goose
Common yellowthroat	Clay-coloured sparrow
Eastern kingbird	Common yellowthroat
Le Conte's sparrow	Franklin's gull
Mourning dove	Le Conte's sparrow
Red-winged blackbird	Mallard
Savannah sparrow	Mourning dove
Sedge wren	Red-winged blackbird
Western meadowlark	Savannah sparrow
Yellow warbler	Sedge wren
	Sandhill crane
	Song sparrow
	Tree swallow
	Western meadowlark
	Wilson’s snipe
	Yellow warbler

Oak Hammock Marsh WMA - Site OHM1	
2007	*2008*
American bittern	Brown headed cowbird
American crow	Canada goose
American goldfinch	Clay-coloured sparrow
American white pelican	Common yellowthroat
Black-crowned night heron	Le Conte's sparrow
Brown headed cowbird	Marbled godwit
Bobolink	Mallard
Clay-coloured sparrow	Red-winged blackbird
Cliff swallow	Savannah sparrow
Common yellowthroat	Sedge wren
Franklin's gull	Song sparrow
Gadwall	Western meadowlark
Le Conte's sparrow	Yellow warbler
Marbled godwit	
Mallard	
Northern harrier	
Nelson's sharp tailed sparrow	
Red-winged blackbird	
Savannah sparrow	
Sedge wren	
Sharp-tailed grouse	
Tree swallow	
Western meadowlark	
Willet	
Yellow warbler	

Oak Hammock Marsh WMA - Site OHMB	
2007	*2008*
American crow	American goldfinch
American goldfinch	Canada goose
Blue-winged teal	Clay-coloured sparrow
Canada goose	Common yellowthroat
Clay-coloured sparrow	Le Conte's sparrow
Common yellowthroat	Mallard
Franklin's gull	Northern harrier
Le Conte's sparrow	Nelson's sharp tailed sparrow
Northern harrier	Red-winged blackbird
Red-winged blackbird	Savannah sparrow
Savannah sparrow	Sedge wren
Sedge wren	Tree swallow
Sandhill crane	Western meadowlark
Tree swallow	Willet
Western meadowlark	Yellow-headed blackbird

Yellow-headed blackbird

Bird species recorded in tall-grass prairie preserve sites

Tall grass Prairie Preserve - Site S56	
2007	*2008*
American goldfinch	American crow
American robin	American goldfinch
Baltimore Oriole	American robin
Barn swallow	Baltimore Oriole
Black-capped chickadee	Brown headed cowbird
Brown headed cowbird	Blue jay
Blue-winged teal	Bobolink
Clay-coloured sparrow	Canada goose
Common yellowthroat	Clay-coloured sparrow
Eastern Kingbird	Common yellowthroat
Le Conte's sparrow	Eastern kingbird
Least flycatcher	Eastern towhee
Lesser yellowlegs	Killdeer
Marbled godwit	Le Conte's sparrow
Mourning dove	Mallard
Palm warbler	Rose-breasted grosbeak
Ruffed grouse	Red-tailed hawk
Red-winged blackbird	Red-winged blackbird
Savannah sparrow	Savannah sparrow
Sandhill crane	Sedge wren
Song sparrow	Sandhill crane
Tree swallow	Song sparrow
Vesper sparrow	Western meadowlark
Wilson's phalarope	Wilson’s snipe
Yellow warbler	Yellow warbler

Tall grass Prairie Preserve - Site S85A	
2007	*2008*
American goldfinch	American crow
Brown headed cowbird	American goldfinch
Clay-coloured sparrow	Baltimore Oriole
Common yellowthroat	Black-capped chickadee
Eastern kingbird	Brown headed cowbird
Le Conte's sparrow	Blue jay
Marbled godwit	Canada goose
Red-winged blackbird	Clay-coloured sparrow
Savannah sparrow	Common grackle
Sedge wren	Common yellowthroat
Sandhill crane	Dark-eyed junco
Tree swallow	Eastern kingbird
Vesper sparrow	Le Conte's sparrow
Western meadowlark	Marbled godwit
Yellow warbler	Mourning dove
Yellow-headed blackbird	Red-winged blackbird
	Savannah sparrow
	Sedge wren
	Sandhill crane
	Song sparrow
	Tree swallow
	Western meadowlark
	Wilson’s snipe
	Yellow warbler

Gardenton Floodway - Site S86	
2007	*2008*
American bittern	American crow
American crow	American goldfinch
American goldfinch	Bank swallow
Brown headed cowbird	Bobolink
Bobolink	Brewers blackbird
Clay-coloured sparrow	Clay-coloured sparrow
Common grackle	Common raven
Common yellowthroat	Common yellowthroat
Eastern kingbird	Eastern kingbird
Le Conte's sparrow	Least flycatcher
Marbled godwit	Red-winged blackbird
Red-eyed vireo	Savannah sparrow
Red-winged blackbird	Sedge wren
Savannah sparrow	Sandhill crane
Sedge wren	Song sparrow
Sora rail	White-throated sparrow
Song sparrow	Wilson’s snipe
Woodpecker	Yellow warbler
Yellow warbler	
Yellow-rumped warbler	

Appendix D – Checklist of avian species recorded in surveys of tall-grass prairie and adjacent matrix grassland and agricultural habitat in Manitoba, 2007-2008

	Prairie		Grassland		Agriculture	
Species	***2007***	***2008***	***2007***	***2008***	***2007***	***2008***
American crow	√	√	√			√
American goldfinch	√		√	√	√	√
American robin		√		√		√
American white pelican	√		√			
Baltimore oriole	√	√		√		
Bank swallow		√				
Barn swallow	√	√	√	√	√	
Black and white warbler	√					
Black tern	√		√		√	
Black-billed magpie	√	√	√			
Black-capped chickadee			√	√		
Blue jay	√		√	√		
Blue-headed vireo			√			
Blue-winged teal	√		√	√		
Bobolink	√	√	√	√		
Brewer's blackbird	√	√	√	√	√	√
Brown-headed cowbird	√	√	√	√	√	√
Canada goose	√	√	√	√	√	√
Cedar waxwing		√				
Chipping sparrow	√	√	√	√		
Clay-coloured sparrow	√	√	√	√	√	
Cliff swallow	√					
Common grackle	√	√		√		
Common raven		√				√
Common yellowthroat	√		√	√		
Eastern bluebird				√		
Eastern Kingbird	√	√	√	√	√	
Eastern phoebe		√				
Eastern towhee				√		
European starling			√			
Franklin's gull	√	√		√	√	
Gadwall	√					
Gray catbird	√	√		√		
Hairy woodpecker	√					
Horned Lark	√				√	√
House sparrow				√		
Killdeer		√	√	√	√	√
Lark sparrow	√	√	√			
Le Conte's sparrow	√	√	√	√	√	
Least flycatcher	√	√		√		

	Prairie		Grassland		Agriculture	
Species	***2007***	***2008***	***2007***	***2008***	***2007***	***2008***
Mallard		√	√	√	√	√
Marbled godwit	√	√	√	√		
Merlin	√					
Mourning Dove					√	
Nelson's sharp tailed sparrow	√	√	√	√		
Northern harrier		√	√	√		
Northern shoveler				√		
Ovenbird	√					
Red-winged blackbird	√	√	√	√	√	√
Ring-billed gull		√				
Rock pigeon			√			
Sandhill crane		√	√	√		
Savannah sparrow	√	√	√	√	√	√
Sedge wren	√	√	√	√		
Sharp-tailed grouse	√					
Song sparrow		√	√	√		
Sora rail	√					
Tennessee warbler		√				
Tree swallow	√	√	√	√		√
Vesper sparrow	√	√	√	√		
Western kingbird	√					
Western meadowlark	√	√	√			
White-crowned sparrow		√				
Willet	√	√		√	√	
Wilson's phalarope	√					
Wilson's snipe	√	√	√	√	√	
Yellow Warbler	√	√	√	√	√	√
Yellow-headed blackbird	√	√	√		√	
Yellow-rumped warbler				√		

Appendix E – Checklist of plant species recorded in surveys at tall-grass prairie sites

Plant species recorded in provincial park sites

Common Name	Scientific name	BD1	BHP2	BHP5	BHP6	BHP7A	BHP7B
Native species							
Yarrow	*Achillea millefolium*	√					
Giant hyssop	*Agastache foeniculum*						
Northern wheatgrass	*Agropyron dasystachyum*						
Wheatgrass sp.	*Agropyron sp.*	√					
Rough hair grass	*Agrostis scabra*						
Slender agalinis	*Agalinis tenuifolia*						
Prairie onion	*Allium textile*						√
Nodding onion	*Allium cernuum*						
Common ragweed	*Ambrosia artemisiifolia*		√				
Giant ragweed	*Ambrosia trifida*						
Big bluestem	*Andropogon gerardi*	√		√	√	√	√
Pygmy flower	*Androsace septentrionalis*						
Saskatoon	*Amelanchier alnifolia*					√	
Canada anemone	*Anemone canadensis*						
Long-fruited anemone	*Anemone cylindrica*		√	√		√	√
Cut-leaved anemone	*Anemone cylindrica*			√			
Anemone sp.	*Anemone sp.*			√	√		
Low everlasting	*Antennaria aprica*						
Small-leaf pussytoes	*Antennaria parvifolia*						
Antennaria sp.	*Antennaria sp.*			√			
Spreading dogbane	*Apocynum androsaemifolium*						
Indian hemp	*Apocynum cannabinum*						
Rock cress	*Arabis sp.*						
Silverweed	*Argentina anserina*						
Hillside arnica	*Arnica fulgens*						
Plains wormwood	*Artemisia campestris*		√	√			
Pasture sage	*Artemisia cana*			√			√
Prairie sage	*Artemisia frigida*		√		√	√	√
White sagebrush	*Artemisia ludoviciana*						
Wormwood	*Artemisia sp.*						
Showy milkweed	*Asclepias speciosa*						
Common milkweed	*Asclepias syriaca*						√
Milkweed sp.	*Asclepias sp.*					√	
Ground plum	*Astragalus crassicarpus*						
Missouri milkvetch	*Astragalus missouriensis*						
Milk vetch species	*Astragalus sp.*						
Dwarf birch	*Betula nana*						
Blue gramma	*Bouteloua gracilis*						
Fringed brome	*Bromus ciliatus*						
Reed grass	*Calamagrostis inexpansa*			√	√		
Hedge false bindweed	*Calystegia sepium*						
Harebell	*Campanula rotundifolia*			√		√	
Sedge sp.	*Carex sp.*	√				√	
Field chickweed	*Cerastium arvense*						
Goosefoot sp.	*Chenopodium sp.*						
Water hemlock sp.	*Cicuta sp.*						
Flodman's thistle	*Cirsium flodmanii*						

Common Name	Scientific name	BD1	BHP2	BHP5	BHP6	BHP7A	BHP7B
Thistle sp.	*Cirsium sp.*						
Bastard toad-flax	*Comandra umbellata*						
Bindweed sp.	*Convolvulus sp.*	√					
Red-osier dogwood	*Cornus sericea*						
Beaked hazelnut	*Corylus cornata*						
White prairie clover	*Dalea candida*						√
Purple prairie clover	*Dalea purpurea*		√	√			√
Shrubby cinquefoil	*Dasiphora fruticosa*						
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*						
Salt grass sp.	*Distichlis sp.*						
Wolf willow	*Elaeagnus commutata*						
Spike rush	*Eleocharis sp.*	√					
Horsetail	*Equisetum arvense*						
Scouring rush	*Equisetum hymale*					√	
Horsetail sp.	*Equisetum sp.*						
Fleabane sp.	*Erigeron sp.*						
Virginia strawberry	*Fragaria virginiana ssp. glauca*						
Fescue sp.	*Festuca sp.*		√	√			
Blanketflower	*Gaillardia aristata*						
Northern bedstraw	*Galium boreale*			√			
Closed gentian	*Gentiana andrewsii*						
Geranium	*Geranium sp.*						
Yellow avens	*Geum aleppicum*						
Three flowered avens	*Geum triflorum*		√	√			
Wild licorice	*Glycyrrhiza lepidota*						
Beautiful sunflower	*Helianthus laetiflorus var. rigida*	√			√		√
Narrow-leaved sunflower	*Helianthus maximiliani*						
Sunflower sp.	*Helianthus sp.*						
Needle and thread grass	*Hesperostipa comata*						
Alumroot	*Heuchera richardsonii*						
Foxtail barley	*Hordeum jubatum*						
Long-leaved bluets	*Houstonia longiflora*					√	
Rush sp.	*Juncus sp.*						
Baltic rush	*Juncus balticus*	√					
Creeping juniper	*Juniperus horizontalis*			√			
June grass	*Koeleria macrantha*						
Blue lettuce	*Lactuca pulchella*						
Mint sp.	*Lamiaceae sp.*						
Vetchling sp.	*Lathyrus sp.*	√				√	
Meadow blazingstar	*Liatris ligulistylis*						
Blazingstar	*Liatris sp.*						
Western wood lily	*Lilium philadelphicum*						
Prairie flax	*Linum lewisii*						
Stiffstem flax	*Linum rigidum*						
Hoary puccoon	*Lithospermum canescens*			√		√	√
Narrow-leaved puccoon	*Lithospermium incisum*						
Kalm's lobelia	*Lobelia kalmii*						
Lobelia sp.	*Lobelia sp.*						

Common Name	Scientific name	BD1	BHP2	BHP5	BHP6	BHP7A	BHP7B
Water horehound	*Lycopus americanus*						
Northern bugleweed	*Lycopus uniflorus*						
Skeleton-plant	*Lygodesmia juncea*						
Fringed loosestrife	*Lysimachia cilata*						
Whorled loosestrife	*Lysimachia quadrifolia*						
False lily of the valley	*Maianthemum stellatam*						
Wild mint	*Mentha arvensis*						
Wild bergamot	*Monarda fistulosa*					√	
Scratch grass	*Muhlenbergia asperifolia*						
Plains Muhlenbergia	*Muhlenbergia cuspidata*						
Soft-leaf muhly	*Muhlenbergia richardsonis*	√					
Muhly sp.	*Muhlenbergia sp.*						
Switch grass	*Panicum virgatum*						
Panic grass sp.	*Panicum sp.*			√			
Grass-of-parnassus	*Parnassia palustris*						
Canadian lousewort	*Pedicularis canadensis*						
Purple prairie clover	*Petalostemon purpureum*						
Bleugrass species	*Poa sp.*	√					
Smartweed sp.	*Polygonum sp.*						
Water smartweed	*Polygonum amphibium*						
Trembling aspen	*Populus tremuloides*						
White cinqfoil	*Potentilla arguta*						
Shrubby cinqfoil	*Potentilla fruiticosa*						
Cinquefoil sp.	*Potentilla sp.*						
Selfheal	*Prunella vulgaris*						
Choke cherry	*Prunus virginiana*					√	
Silverleaf psoralea	*Psoralea agrophylla*						
Indian breadroot	*Psoralea esculenta*			√			
Rose sp.	*Rosa sp.*		√		√		
Black-eyed susan	*Rudbeckia hirta*			√			
Western dock	*Rumex occidentalis*						
Willow sp.	*Salix sp.*						
Senecio sp.	*Senecio sp.*					√	
Little bluestem	*Schizachyrium scoparium*						
Bulrush	*Scirpus sp.*						
Blue-eyed grass	*Sisyrichum montanum*						√
Canada goldenrod	*Solidago canadensis*					√	
Flat topped goldenrod	*Solidago gramniflora*						
Low goldenrod	*Solidago missouriensis*		√		√		
Velvety goldenrod	*Solidago mollis*			√			
Showy goldenrod	*Solidago nemoralis*		√				
Stiff goldenrod	*Solidago rigida*	√				√	
Goldenrod sp.	*Solidago sp.*						
Indian grass	*Sorghastrum nutans*						
Cordgrass	*Spartina pectinata*				√		
White meadowsweet	*Spiraea alba*						
Lady's tresses	*Spiranthes sp.*						
Prairie dropseed	*Sporobolus heterolepis*			√	√		

Common Name	Scientific name	BD1	BHP2	BHP5	BHP6	BHP7A	BHP7B
Needle and thread grass	*Stipa comata*			√			
Marsh hedge nettle	*Stachys palustris*						
Snowberry	*Symphoricarpos occidentalis*						
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*						
Many-flowered aster	*Symphyotrichum ericoides*	√	√			√	
Rush aster	*Symphyotrichum junciformis*						
Smooth blue aster	*Symphyotrichum laeve*						
White upland aster	*Symphyotrichum ptarmicoides*						
Western silvery aster	*Symphyotrichum sericeum*			√			
Willow aster	*Symphyotrichum simplex*						
Aster sp.	*Symphyotrichum sp.*						
Veiny meadow-rue	*Thalictrum venulosum*						
Meadow-rue	*Thalictrum sp.*						
Sticky asphodel	*Tofieldia glutinosa*						
Poison ivy	*Toxicodendron radicans*				√	√	
Seaside arrow-grass	*Triglochin maritima*						
Cattail	*Typha sp.*	√					
Vetch sp.	*Vicia sp.*	√	√				
Canada violet	*Viola canadensis*						
Northern bog violet	*Viola nephrophylla*						
Crowfoot violet	*Viola pedatifida*						
Violet sp.	*Viola sp.*						
White camus	*Zigadenus elegans*						
Heart leaved alexander	*Zizia aptera*						
Non-native species							
Quackgrass	*Agropyron repens*						
Redtop	*Agrostis stolonifera*	√					
Smooth brome	*Bromus inermis*	√					
Canada thistle	*Cirsium arvense*	√					
Hawk's beard	*Crepis tectorum*						
Sheep fescue	*Festuca ovina*		√	√	√		
Black medic	*Medicago lupulina*						
White sweet-clover	*Melilotus alba*	√					
Sweet-clover sp.	*Melilotus sp.*	√					
Yellow sweet-clover	*Melilotus officinalis*	√					
Reed canary grass	*Phalaris arundinacea*	√					
Timothy	*Phleum pratense*	√					
Common plantain	*Plantago major*						
Hoary plantain	*Plantago media*						
Kentucky bluegrass	*Poa pratensis*				√	√	√
Curly dock	*Rumex crispus*						
Perennial sow-thistle	*Sonchus arvensis*	√					
Common dandelion	*Taraxacum officinale*	√					
Pennycress	*Thlapsi arvense*						
Goat's beard	*Tragopogon dubius*						
Red clover	*Trifolium pratense*	√					
Bird vetch	*Vicia cracca*	√					

Plant species recorded in private land sites

Common Name	Scientific name	MC26	MC4	S11A	S 62
Native species					
Yarrow	*Achillea millefolium*				
Giant hyssop	*Agastache foeniculum*				
Northern wheatgrass	*Agropyron dasystachyum*				
Wheatgrass sp.	*Agropyron sp.*				
Rough hair grass	*Agrostis scabra*				√
Slender agalinis	*Agalinis tenuifolia*				
Prairie onion	*Allium textile*		√		
Nodding onion	*Allium cernuum*				
Common ragweed	*Ambrosia artemisiifolia*	√			
Giant ragweed	*Ambrosia trifida*				
Big bluestem	*Andropogon gerardi*	√	√		√
Pygmy flower	*Androsace septentrionalis*				
Saskatoon	*Amelanchier alnifolia*				
Canada anemone	*Anemone canadensis*	√		√	
Long-fruited anemone	*Anemone cylindrica*				
Cut-leaved anemone	*Anemone cylindrica*				
Anemone sp.	*Anemone sp.*				
Low everlasting	*Antennaria aprica*				
Small-leaf pussytoes	*Antennaria parvifolia*				
Antennaria sp.	*Antennaria sp.*				
Spreading dogbane	*Apocynum androsaemifolium*				
Indian hemp	*Apocynum cannabinum*				√
Rock cress	*Arabis sp.*				
Silverweed	*Argentina anserina*		√		
Hillside arnica	*Arnica fulgens*				
Plains wormwood	*Artemisia campestris*				
Pasture sage	*Artemisia cana*	√		√	
Prairie sage	*Artemisia frigida*	√			
White sagebrush	*Artemisia ludoviciana*				
Wormwood	*Artemisia sp.*				
Showy milkweed	*Asclepias speciosa*				
Common milkweed	*Asclepias syriaca*	√			
Milkweed sp.	*Asclepias sp.*				
Ground plum	*Astragalus crassicarpus*				
Missouri milkvetch	*Astragalus missouriensis*				
Milkvetch species	*Astragalus sp.*			√	
Dwarf birch	*Betula nana*				
Blue gramma	*Bouteloua gracilis*				
Fringed brome	*Bromus ciliatus*				
Reed grass	*Calamagrostis inexpansa*		√	√	√
Hedge false bindweed	*Calystegia sepium*				
Harebell	*Campanula rotundifolia*				
Sedge sp.	*Carex sp.*		√	√	√
Field chickweed	*Cerastium arvense*				
Goosefoot sp.	*Chenopodium sp.*				
Water hemlock sp.	*Cicuta sp.*				
Flodman's thistle	*Cirsium flodmanii*				

Common Name	Scientific name	MC26	MC4	S11A	S 62
Thistle sp.	*Cirsium sp.*	√			
Bastard toad-flax	*Comandra umbellata*				
Bindweed sp.	*Convolvulus sp.*				
Red-osier dogwood	*Cornus sericea*				
Beaked hazelnut	*Corylus cornata*				
White prairie clover	*Dalea candida*				
Purple prairie clover	*Dalea purpurea*				√
Shrubby cinquefoil	*Dasiphora fruticosa*				
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*				
Salt grass sp.	*Distichlis sp.*				
Wolf willow	*Elaeagnus commutata*		√		
Spike rush	*Eleocharis sp.*				√
Horsetail	*Equisetum arvense*				
Scouring rush	*Equisetum hymale*				√
Horsetail sp.	*Equisetum sp.*				
Fleabane sp.	*Erigeron sp.*				
Virginia strawberry	*Fragaria virginiana ssp. glauca*		√		√
Fescue sp.	*Festuca sp.*				
Blanketflower	*Gaillardia aristata*				
Northern bedstraw	*Galium boreale*		√	√	√
Closed gentian	*Gentiana andrewsii*				√
Geranium	*Geranium sp.*				
Yellow avens	*Geum aleppicum*				
Three flowered avens	*Geum triflorum*				√
Wild licorice	*Glycyrrhiza lepidota*				√
Beautiful sunflower	*Helianthus laetiflorus var. rigida*		√	√	
Narrow-leaved sunflower	*Helianthus maximiliani*		√	√	
Sunflower sp.	*Helianthus sp.*				
Needle and thread grass	*Hesperostipa comata*				
Alumroot	*Heuchera richardsonii*				
Foxtail barley	*Hordeum jubatum*				
Long-leaved bluets	*Houstonia longiflora*				
Rush sp.	*Juncus sp.*				
Baltic rush	*Juncus balticus*				√
Creeping juniper	*Juniperus horizontalis*				
June grass	*Koeleria macrantha*		√		
Blue lettuce	*Lactuca pulchella*				
Mint sp.	*Lamiaceae sp.*				
Vetchling sp.	*Lathyrus sp.*				
Meadow blazingstar	*Liatris ligulistylis*		√		
Blazingstar	*Liatris sp.*				
Western wood lily	*Lilium philadelphicum*				
Prairie flax	*Linum lewisii*				
Stiffstem flax	*Linum rigidum*				
Hoary puccoon	*Lithospermum canescens*				√
Narrow-leaved puccoon	*Lithospermium incisum*				
Kalm's lobelia	*Lobelia kalmii*				
Lobelia sp.	*Lobelia sp.*				

Common Name	Scientific name	MC26	MC4	S11A	S 62
Water horehound	*Lycopus americanus*				
Northern bugleweed	*Lycopus uniflorus*				
Skeleton-plant	*Lygodesmia juncea*				
Fringed loosestrife	*Lysimachia cilata*		√		
Whorled loosestrife	*Lysimachia quadrifolia*				
False lily of the valley	*Maianthemum stellatam*				
Wild mint	*Mentha arvensis*				√
Wild bergamot	*Monarda fistulosa*				
Scratch grass	*Muhlenbergia asperifolia*				√
Plains Muhlenbergia	*Muhlenbergia cuspidata*				
Soft-leaf muhly	*Muhlenbergia richardsonis*		√		√
Muhly sp.	*Muhlenbergia sp.*				
Switch grass	*Panicum virgatum*		√		
Panic grass sp.	*Panicum sp.*				
Grass-of-parnassus	*Parnassia palustris*				
Canadian lousewort	*Pedicularis canadensis*				
Purple prairie clover	*Petalostemon purpureum*				
Bleugrass species	*Poa sp.*				√
Smartweed sp.	*Polygonum sp.*			√	√
Water smartweed	*Polygonum amphibium*				
Trembling aspen	*Populus tremuloides*		√		
White cinqfoil	*Potentilla arguta*				
Shrubby cinqfoil	*Potentilla fruiticosa*				
Cinquefoil sp.	*Potentilla sp.*				
Selfheal	*Prunella vulgaris*				
Choke cherry	*Prunus virginiana*				
Silverleaf psoralea	*Psoralea agrophylla*				
Indian breadroot	*Psoralea esculenta*				
Rose sp.	*Rosa sp.*	√	√	√	
Black-eyed susan	*Rudbeckia hirta*		√		
Western dock	*Rumex occidentalis*			√	
Willow sp.	*Salix sp.*		√		√
Senecio sp.	*Senecio sp.*				
Little bluestem	*Schizachyrium scoparium*	√	√		
Bulrush	*Scirpus sp.*				√
Blue-eyed grass	*Sisyrichum montanum*				
Canada goldenrod	*Solidago canadensis*		√	√	√
Flat topped goldenrod	*Solidago gramniflora*				
Low goldenrod	*Solidago missouriensis*				
Velvety goldenrod	*Solidago mollis*				
Showy goldenrod	*Solidago nemoralis*		√		√
Stiff goldenrod	*Solidago rigida*	√	√		
Goldenrod sp.	*Solidago sp.*				√
Indian grass	*Sorghastrum nutans*				√
Cordgrass	*Spartina pectinata*			√	√
White meadowsweet	*Spiraea alba*			√	
Lady's tresses	*Spiranthes sp.*				
Prairie dropseed	*Sporobolus heterolepis*				

Common Name	Scientific name	MC26	MC4	S11A	S 62
Needle and thread grass	*Stipa comata*				
Marsh hedge nettle	*Stachys palustris*				
Snowberry	*Symphoricarpos occidentalis*	√	√	√	
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*				
Many-flowered aster	*Symphyotrichum ericoides*	√	√	√	√
Rush aster	*Symphyotrichum junciformis*				
Smooth blue aster	*Symphyotrichum laeve*	√	√		√
White upland aster	*Symphyotrichum ptarmicoides*				
Western silvery aster	*Symphyotrichum sericeum*	√			
Willow aster	*Symphyotrichum simplex*			√	√
Aster sp.	*Symphyotrichum sp.*				√
Veiny meadow-rue	*Thalictrum venulosum*				
Meadow-rue	*Thalictrum sp.*				
Sticky asphodel	*Tofieldia glutinosa*				
Poison ivy	*Toxicodendron radicans*				
Seaside arrow-grass	*Triglochin maritima*				√
Cattail	*Typha sp.*				
Vetch sp.	*Vicia sp.*				
Canada violet	*Viola canadensis*		√		
Northern bog violet	*Viola nephrophylla*		√		√
Crowfoot violet	*Viola pedatifida*				
Violet sp.	*Viola sp.*				√
White camus	*Zigadenus elegans*				
Heart leaved alexander	*Zizia aptera*				
Non-native species					
Quackgrass	*Agropyron repens*				
Redtop	*Agrostis stolonifera*			√	√
Smooth brome	*Bromus inermis*	√	√		
Canada thistle	*Cirsium arvense*		√	√	
Hawk's beard	*Crepis tectorum*				
Sheep fescue	*Festuca ovina*				
Black medic	*Medicago lupulina*				
White sweet-clover	*Melilotus alba*				
Sweet-clover sp.	*Melilotus sp.*				
Yellow sweet-clover	*Melilotus officinalis*				
Reed canary grass	*Phalaris arundinacea*			√	
Timothy	*Phleum pratense*				
Common plantain	*Plantago major*				
Hoary plantain	*Plantago media*				
Kentucky bluegrass	*Poa pratensis*	√	√	√	
Curly dock	*Rumex crispus*				
Perennial sow-thistle	*Sonchus arvensis*		√		√
Common dandelion	*Taraxacum officinale*				
Pennycress	*Thlapsi arvense*				
Goat's beard	*Tragopogon dubius*				
Red clover	*Trifolium pratense*				
Bird vetch	*Vicia cracca*				

Plant species recorded in municipal park sites

Common Name	Scientific name	G I	LPM	ROT
Native species				
Yarrow	*Achillea millefolium*	√		√
Giant hyssop	*Agastache foeniculum*			
Northern wheatgrass	*Agropyron dasystachyum*			
Wheatgrass sp.	*Agropyron sp.*	√		
Rough hair grass	*Agrostis scabra*		√	
Slender agalinis	*Agalinis tenuifolia*			
Prairie onion	*Allium textile*	√		
Nodding onion	*Allium cernuum*			
Common ragweed	*Ambrosia artemisiifolia*			
Giant ragweed	*Ambrosia trifida*			
Big bluestem	*Andropogon gerardi*	√	√	√
Pygmy flower	*Androsace septentrionalis*			
Saskatoon	*Amelanchier alnifolia*			
Canada anemone	*Anemone canadensis*			√
Long-fruited anemone	*Anemone cylindrica*			√
Cut-leaved anemone	*Anemone cylindrica*			
Anemone sp.	*Anemone sp.*			
Low everlasting	*Antennaria aprica*			
Small-leaf pussytoes	*Antennaria parvifolia*			
Antennaria sp.	*Antennaria sp.*			√
Spreading dogbane	*Apocynum androsaemifolium*			
Indian hemp	*Apocynum cannabinum*			√
Rock cress	*Arabis sp.*			
Silverweed	*Argentina anserina*			
Hillside arnica	*Arnica fulgens*			
Plains wormwood	*Artemisia campestris*			
Pasture sage	*Artemisia cana*			
Prairie sage	*Artemisia frigida*	√		√
White sagebrush	*Artemisia ludoviciana*			
Wormwood	*Artemisia sp.*			
Showy milkweed	*Asclepias speciosa*			
Common milkweed	*Asclepias syriaca*			
Milkweed sp.	*Asclepias sp.*			
Ground plum	*Astragalus crassicarpus*			
Missouri milkvetch	*Astragalus missouriensis*			
Milkvetch sp.	*Astragalus sp.*	√	√	
Dwarf birch	*Betula nana*			
Blue gramma	*Bouteloua gracilis*			
Fringed brome	*Bromus ciliatus*			
Reed grass	*Calamagrostis inexpansa*	√		
Hedge false bindweed	*Calystegia sepium*			
Harebell	*Campanula rotundifolia*	√		√
Sedge sp.	*Carex sp.*			√
Field chickweed	*Cerastium arvense*			
Goosefoot sp.	*Chenopodium sp.*			
Water hemlock sp.	*Cicuta sp.*			
Flodman's thistle	*Cirsium flodmanii*			

Common Name	Scientific name	G I	LPM	ROT
Thistle sp.	*Cirsium sp.*			
Bastard toad-flax	*Comandra umbellata*			
Bindweed sp.	*Convolvulus sp.*			
Red-osier dogwood	*Cornus sericea*			
Beaked hazelnut	*Corylus cornata*			
White prairie clover	*Dalea candida*			
Purple prairie clover	*Dalea purpurea*			√
Shrubby cinquefoil	*Dasiphora fruticosa*			
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*			
Salt grass sp.	*Distichlis sp.*			
Wolf willow	*Elaeagnus commutata*	√		
Spike rush	*Eleocharis sp.*			
Horsetail	*Equisetum arvense*			
Scouring rush	*Equisetum hymale*			
Horsetail sp.	*Equisetum sp.*			
Fleabane sp.	*Erigeron sp.*			
Virginia strawberry	*Fragaria virginiana ssp. glauca*	√		√
Fescue sp.	*Festuca sp.*			
Blanketflower	*Gaillardia aristata*			
Northern bedstraw	*Galium boreale*	√	√	√
Closed gentian	*Gentiana andrewsii*			
Geranium	*Geranium sp.*	√		
Yellow avens	*Geum aleppicum*			
Three flowered avens	*Geum triflorum*	√		√
Wild licorice	*Glycyrrhiza lepidota*			
Beautiful sunflower	*Helianthus laetiflorus var. rigida*	√	√	
Narrow-leaved sunflower	*Helianthus maximiliani*	√		√
Sunflower sp.	*Helianthus sp.*			√
Needle and thread grass	*Hesperostipa comata*			
Alumroot	*Heuchera richardsonii*	√	√	
Foxtail barley	*Hordeum jubatum*			
Long-leaved bluets	*Houstonia longiflora*			
Rush sp.	*Juncus sp.*			
Baltic rush	*Juncus balticus*			
Creeping juniper	*Juniperus horizontalis*			
June grass	*Koeleria macrantha*			
Blue lettuce	*Lactuca pulchella*	√		
Mint sp.	*Lamiaceae sp.*			
Vetchling sp.	*Lathyrus sp.*			
Meadow blazingstar	*Liatris ligulistylis*			√
Blazingstar	*Liatris sp.*			
Western wood lily	*Lilium philadelphicum*			
Prairie flax	*Linum lewisii*			
Stiffstem flax	*Linum rigidum*			
Hoary puccoon	*Lithospermum canescens*			
Narrow-leaved puccoon	*Lithospermium incisum*			
Kalm's lobelia	*Lobelia kalmii*			
Lobelia sp.	*Lobelia sp.*			

Common Name	Scientific name	G I	LPM	ROT
Water horehound	*Lycopus americanus*			
Northern bugleweed	*Lycopus uniflorus*			
Skeleton-plant	*Lygodesmia juncea*			
Fringed loosestrife	*Lysimachia cilata*			
Whorled loosestrife	*Lysimachia quadrifolia*			
False lily of the valley	*Maianthemum stellatam*			
Wild mint	*Mentha arvensis*			
Wild bergamot	*Monarda fistulosa*			
Scratch grass	*Muhlenbergia asperifolia*			
Plains Muhlenbergia	*Muhlenbergia cuspidata*			
Soft-leaf muhly	*Muhlenbergia richardsonis*			
Muhly sp.	*Muhlenbergia sp.*			
Switch grass	*Panicum virgatum*			
Panic grass sp.	*Panicum sp.*			√
Grass-of-parnassus	*Parnassia palustris*			
Canadian lousewort	*Pedicularis canadensis*			
Purple prairie clover	*Petalostemon purpureum*			
Bluegrass species	*Poa sp.*			
Smartweed sp.	*Polygonum sp.*			
Water smartweed	*Polygonum amphibium*			
Trembling aspen	*Populus tremuloides*			
White cinqfoil	*Potentilla arguta*	√	√	
Shrubby cinqfoil	*Potentilla fruiticosa*			
Cinquefoil sp.	*Potentilla sp.*			
Selfheal	*Prunella vulgaris*			
Choke cherry	*Prunus virginiana*			
Silverleaf psoralea	*Psoralea agrophylla*	√	√	
Indian breadroot	*Psoralea esculenta*			
Rose sp.	*Rosa sp.*	√	√	√
Black-eyed susan	*Rudbeckia hirta*			
Western dock	*Rumex occidentalis*			
Willow sp.	*Salix sp.*			
Senecio sp.	*Senecio sp.*			√
Little bluestem	*Schizachyrium scoparium*			
Bulrush	*Scirpus sp.*			
Blue-eyed grass	*Sisyrichum montanum*			
Canada goldenrod	*Solidago canadensis*	√	√	√
Flat topped goldenrod	*Solidago gramniflora*			
Low goldenrod	*Solidago missouriensis*			
Velvety goldenrod	*Solidago mollis*			
Showy goldenrod	*Solidago nemoralis*			
Stiff goldenrod	*Solidago rigida*	√		√
Goldenrod sp.	*Solidago sp.*	√		
Indian grass	*Sorghastrum nutans*			
Cordgrass	*Spartina pectinata*	√		√
White meadowsweet	*Spiraea alba*			
Lady's tresses	*Spiranthes sp.*			
Prairie dropseed	*Sporobolus heterolepis*			

Common Name	Scientific name	G I	LPM	ROT
Needle and thread grass	*Stipa comata*			
Marsh hedge nettle	*Stachys palustris*			
Snowberry	*Symphoricarpos occidentalis*	√	√	
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*			√
Many-flowered aster	*Symphyotrichum ericoides*	√	√	√
Rush aster	*Symphyotrichum junciformis*			
Smooth blue aster	*Symphyotrichum laeve*	√		√
White upland aster	*Symphyotrichum ptarmicoides*			
Western silvery aster	*Symphyotrichum sericeum*			
Willow aster	*Symphyotrichum simplex*			
Aster sp.	*Symphyotrichum sp.*			
Veiny meadow-rue	*Thalictrum venulosum*			√
Meadow-rue	*Thalictrum sp.*	√		
Sticky asphodel	*Tofieldia glutinosa*			
Poison ivy	*Toxicodendron radicans*			
Seaside arrow-grass	*Triglochin maritima*			
Cattail	*Typha sp.*			
Vetch sp.	*Vicia sp.*			√
Canada violet	*Viola canadensis*			
Northern bog violet	*Viola nephrophylla*			
Crowfoot violet	*Viola pedatifida*			
Violet sp.	*Viola sp.*			√
White camus	*Zigadenus elegans*			
Heart leaved alexander	*Zizia aptera*			√
Non-native species				
Quackgrass	*Agropyron repens*			
Redtop	*Agrostis stolonifera*			
Smooth brome	*Bromus inermis*		√	√
Canada thistle	*Cirsium arvense*			√
Hawk's beard	*Crepis tectorum*			
Sheep fescue	*Festuca ovina*			
Black medic	*Medicago lupulina*			
White sweet-clover	*Melilotus alba*	√		
Sweet-clover sp.	*Melilotus sp.*			
Yellow sweet-clover	*Melilotus officinalis*			
Reed canary grass	*Phalaris arundinacea*			
Timothy	*Phleum pratense*			
Common plantain	*Plantago major*			
Hoary plantain	*Plantago media*			
Kentucky bluegrass	*Poa pratensis*	√	√	√
Curly dock	*Rumex crispus*			√
Perennial sow-thistle	*Sonchus arvensis*	√		√
Common dandelion	*Taraxacum officinale*			√
Pennycress	*Thlapsi arvense*			
Goat's beard	*Tragopogon dubius*			
Red clover	*Trifolium pratense*			
Bird vetch	*Vicia cracca*			√

Plant species recorded in PFRA pasture sites

Common Name	Scientific name	PAN	PORTA	PORTB	S 77
Native species					
Yarrow	*Achillea millefolium*	√	√	√	
Giant hyssop	*Agastache foeniculum*				
Northern wheatgrass	*Agropyron dasystachyum*		√		
Wheatgrass sp.	*Agropyron sp.*	√			√
Rough hair grass	*Agrostis scabra*				
Slender agalinis	*Agalinis tenuifolia*				√
Prairie onion	*Allium textile*				
Nodding onion	*Allium cernuum*				
Common ragweed	*Ambrosia artemisiifolia*		√		
Giant ragweed	*Ambrosia trifida*				
Big bluestem	*Andropogon gerardi*		√	√	√
Pygmy flower	*Androsace septentrionalis*				
Saskatoon	*Amelanchier alnifolia*				
Canada anemone	*Anemone canadensis*	√			
Long-fruited anemone	*Anemone cylindrica*				
Cut-leaved anemone	*Anemone cylindrica*				
Anemone sp.	*Anemone sp.*			√	
Low everlasting	*Antennaria aprica*	√	√		
Small-leaf pussytoes	*Antennaria parvifolia*				
Antennaria sp.	*Antennaria sp.*		√	√	
Spreading dogbane	*Apocynum androsaemifolium*				
Indian hemp	*Apocynum cannabinum*		√	√	
Rock cress	*Arabis sp.*				
Silverweed	*Argentina anserina*		√		
Hillside arnica	*Arnica fulgens*				
Plains wormwood	*Artemisia campestris*				
Pasture sage	*Artemisia cana*				
Prairie sage	*Artemisia frigida*		√	√	
White sagebrush	*Artemisia ludoviciana*				
Wormwood	*Artemisia sp.*				
Showy milkweed	*Asclepias speciosa*				
Common milkweed	*Asclepias syriaca*				
Milkweed sp.	*Asclepias sp.*				
Ground plum	*Astragalus crassicarpus*				
Missouri milkvetch	*Astragalus missouriensis*				
Milkvetch species	*Astragalus sp.*				
Dwarf birch	*Betula nana*			√	
Blue gramma	*Bouteloua gracilis*				
Fringed brome	*Bromus ciliatus*				
Reed grass	*Calamagrostis inexpansa*	√	√	√	
Hedge false bindweed	*Calystegia sepium*				
Harebell	*Campanula rotundifolia*				
Sedge sp.	*Carex sp.*	√	√	√	√
Field chickweed	*Cerastium arvense*				
Goosefoot sp.	*Chenopodium sp.*				
Water hemlock sp.	*Cicuta sp.*				
Flodman's thistle	*Cirsium flodmanii*	√	√	√	

Common Name	Scientific name	PAN	PORTA	PORTB	S 77
Thistle sp.	*Cirsium sp.*		√	√	
Bastard toad-flax	*Comandra umbellata*				
Bindweed sp.	*Convolvulus sp.*				
Red-osier dogwood	*Cornus sericea*	√			
Beaked hazelnut	*Corylus cornata*				
White prairie clover	*Dalea candida*				
Purple prairie clover	*Dalea purpurea*			√	√
Shrubby cinquefoil	*Dasiphora fruticosa*				
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*				
Salt grass sp.	*Distichlis sp.*				
Wolf willow	*Elaeagnus commutata*		√	√	
Spike rush	*Eleocharis sp.*	√	√	√	√
Horsetail	*Equisetum arvense*				
Scouring rush	*Equisetum hymale*	√			
Horsetail sp.	*Equisetum sp.*				
Fleabane sp.	*Erigeron sp.*				
Virginia strawberry	*Fragaria virginiana ssp. glauca*	√	√	√	
Fescue sp.	*Festuca sp.*				
Blanketflower	*Gaillardia aristata*				
Northern bedstraw	*Galium boreale*	√	√	√	
Closed gentian	*Gentiana andrewsii*				√
Geranium	*Geranium sp.*				
Yellow avens	*Geum aleppicum*		√		
Three flowered avens	*Geum triflorum*				
Wild licorice	*Glycyrrhiza lepidota*		√	√	√
Beautiful sunflower	*Helianthus laetiflorus var. rigida*				
Narrow-leaved sunflower	*Helianthus maximiliani*				
Sunflower sp.	*Helianthus sp.*				
Needle and thread grass	*Hesperostipa comata*				
Alumroot	*Heuchera richardsonii*				
Foxtail barley	*Hordeum jubatum*	√	√	√	
Long-leaved bluets	*Houstonia longiflora*				
Rush sp.	*Juncus sp.*	√	√		√
Baltic rush	*Juncus balticus*	√	√	√	√
Creeping juniper	*Juniperus horizontalis*				
June grass	*Koeleria macrantha*				
Blue lettuce	*Lactuca pulchella*			√	
Mint sp.	*Lamiaceae sp.*				
Vetchling sp.	*Lathyrus sp.*		√		
Meadow blazingstar	*Liatris ligulistylis*		√		
Blazingstar	*Liatris sp.*				
Western wood lily	*Lilium philadelphicum*				
Prairie flax	*Linum lewisii*				
Stiffstem flax	*Linum rigidum*				
Hoary puccoon	*Lithospermum canescens*				
Narrow-leaved puccoon	*Lithospermium incisum*				
Kalm's lobelia	*Lobelia kalmii*				√
Lobelia sp.	*Lobelia sp.*				

Common Name	Scientific name	PAN	PORTA	PORTB	S 77
Water horehound	*Lycopus americanus*				
Northern bugleweed	*Lycopus uniflorus*		√		
Skeleton-plant	*Lygodesmia juncea*				
Fringed loosestrife	*Lysimachia cilata*	√		√	
Whorled loosestrife	*Lysimachia quadrifolia*				
False lily of the valley	*Maianthemum stellatam*				
Wild mint	*Mentha arvensis*		√		
Wild bergamot	*Monarda fistulosa*				
Scratch grass	*Muhlenbergia asperifolia*		√		
Plains Muhlenbergia	*Muhlenbergia cuspidata*				
Soft-leaf muhly	*Muhlenbergia richardsonis*		√	√	
Muhly sp.	*Muhlenbergia sp.*		√		
Switch grass	*Panicum virgatum*				
Panic grass sp.	*Panicum sp.*				
Grass-of-parnassus	*Parnassia palustris*				
Canadian lousewort	*Pedicularis canadensis*				
Purple prairie clover	*Petalostemon purpureum*		√		
Bluegrass species	*Poa sp.*				
Smartweed sp.	*Polygonum sp.*				
Water smartweed	*Polygonum amphibium*				
Trembling aspen	*Populus tremuloides*				
White cinqfoil	*Potentilla arguta*				
Shrubby cinqfoil	*Potentilla fruiticosa*	√	√		
Cinquefoil sp.	*Potentilla sp.*				
Selfheal	*Prunella vulgaris*	√			
Choke cherry	*Prunus virginiana*				
Silverleaf psoralea	*Psoralea agrophylla*				
Indian breadroot	*Psoralea esculenta*				
Rose sp.	*Rosa sp.*	√	√	√	√
Black-eyed susan	*Rudbeckia hirta*	√			
Western dock	*Rumex occidentalis*				
Willow sp.	*Salix sp.*	√			
Senecio sp.	*Senecio sp.*				
Little bluestem	*Schizachyrium scoparium*				
Bulrush	*Scirpus sp.*				
Blue-eyed grass	*Sisyrichum montanum*				
Canada goldenrod	*Solidago canadensis*		√	√	
Flat topped goldenrod	*Solidago gramniflora*				
Low goldenrod	*Solidago missouriensis*			√	
Velvety goldenrod	*Solidago mollis*				
Showy goldenrod	*Solidago nemoralis*				
Stiff goldenrod	*Solidago rigida*		√	√	√
Goldenrod sp.	*Solidago sp.*				√
Indian grass	*Sorghastrum nutans*				
Cordgrass	*Spartina pectinata*	√	√	√	√
White meadowsweet	*Spiraea alba*		√	√	
Lady's tresses	*Spiranthes sp.*				
Prairie dropseed	*Sporobolus heterolepis*				

Common Name	Scientific name	PAN	PORTA	PORTB	S 77
Needle and thread grass	*Stipa comata*				
Marsh hedge nettle	*Stachys palustris*	√			
Snowberry	*Symphoricarpos occidentalis*		√	√	
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*				
Many-flowered aster	*Symphyotrichum ericoides*	√	√	√	√
Rush aster	*Symphyotrichum junciformis*				
Smooth blue aster	*Symphyotrichum laeve*	√	√	√	√
White upland aster	*Symphyotrichum ptarmicoides*				√
Western silvery aster	*Symphyotrichum sericeum*				
Willow aster	*Symphyotrichum simplex*	√	√	√	
Aster sp.	*Symphyotrichum sp.*	√	√	√	√
Veiny meadow-rue	*Thalictrum venulosum*				
Meadow-rue	*Thalictrum sp.*			√	
Sticky asphodel	*Tofieldia glutinosa*				
Poison ivy	*Toxicodendron radicans*				
Seaside arrow-grass	*Triglochin maritima*				
Cattail	*Typha sp.*				
Vetch sp.	*Vicia sp.*				
Canada violet	*Viola canadensis*				
Northern bog violet	*Viola nephrophylla*				
Crowfoot violet	*Viola pedatifida*				
Violet sp.	*Viola sp.*	√		√	√
White camus	*Zigadenus elegans*				
Heart leaved alexander	*Zizia aptera*		√	√	
Non-native species					
Quackgrass	*Agropyron repens*		√	√	
Redtop	*Agrostis stolonifera*	√	√	√	√
Smooth brome	*Bromus inermis*	√		√	
Canada thistle	*Cirsium arvense*		√	√	
Hawk's beard	*Crepis tectorum*	√	√		
Sheep fescue	*Festuca ovina*		√		
Black medic	*Medicago lupulina*	√	√	√	
White sweet-clover	*Melilotus alba*				
Sweet-clover sp.	*Melilotus sp.*				
Yellow sweet-clover	*Melilotus officinalis*				
Reed canary grass	*Phalaris arundinacea*				
Timothy	*Phleum pratense*	√		√	√
Common plantain	*Plantago major*	√			√
Hoary plantain	*Plantago media*	√			
Kentucky bluegrass	*Poa pratensis*	√	√	√	√
Curly dock	*Rumex crispus*			√	
Perennial sow-thistle	*Sonchus arvensis*		√	√	√
Common dandelion	*Taraxacum officinale*	√	√	√	√
Pennycress	*Thlapsi arvense*				
Goat's beard	*Tragopogon dubius*				
Red clover	*Trifolium pratense*	√	√		√
Bird vetch	*Vicia cracca*				

Plant species recorded in Wildlife Management Area sites

Common Name	Scientific name	LF2	OHM1	OHMB
Native species				
Yarrow	*Achillea millefolium*	√	√	√
Giant hyssop	*Agastache foeniculum*	√		
Northern wheatgrass	*Agropyron dasystachyum*	√	√	√
Wheatgrass sp.	*Agropyron sp.*	√		√
Rough hair grass	*Agrostis scabra*			
Slender agalinis	*Agalinis tenuifolia*			
Prairie onion	*Allium textile*			
Nodding onion	*Allium cernuum*		√	
Common ragweed	*Ambrosia artemisiifolia*	√		
Giant ragweed	*Ambrosia trifida*		√	
Big bluestem	*Andropogon gerardi*	√	√	
Pygmy flower	*Androsace septentrionalis*			
Saskatoon	*Amelanchier alnifolia*			
Canada anemone	*Anemone canadensis*			
Long-fruited anemone	*Anemone cylindrica*			
Cut-leaved anemone	*Anemone cylindrica*			
Anemone sp.	*Anemone sp.*			
Low everlasting	*Antennaria aprica*			
Small-leaf pussytoes	*Antennaria parvifolia*			
Antennaria sp.	*Antennaria sp.*		√	
Spreading dogbane	*Apocynum androsaemifolium*			
Indian hemp	*Apocynum cannabinum*		√	
Rock cress	*Arabis sp.*			
Silverweed	*Argentina anserina*			
Hillside arnica	*Arnica fulgens*			
Plains wormwood	*Artemisia campestris*			
Pasture sage	*Artemisia cana*			
Prairie sage	*Artemisia frigida*			
White sagebrush	*Artemisia ludoviciana*			
Wormwood	*Artemisia sp.*			
Showy milkweed	*Asclepias speciosa*			
Common milkweed	*Asclepias syriaca*			
Milkweed sp.	*Asclepias sp.*			
Ground plum	*Astragalus crassicarpus*			
Missouri milkvetch	*Astragalus missouriensis*			
Milk vetch species	*Astragalus sp.*			
Dwarf birch	*Betula nana*			
Blue gramma	*Bouteloua gracilis*			
Fringed brome	*Bromus ciliatus*			
Reed grass	*Calamagrostis inexpansa*	√	√	√
Hedge false bindweed	*Calystegia sepium*			
Harebell	*Campanula rotundifolia*		√	
Sedge sp.	*Carex sp.*	√	√	√
Field chickweed	*Cerastium arvense*			
Goosefoot sp.	*Chenopodium sp.*			
Water hemlock sp.	*Cicuta sp.*			
Flodman's thistle	*Cirsium flodmanii*	√	√	

Common Name	Scientific name	LF2	OHM1	OHMB
Thistle sp.	*Cirsium sp.*	√		
Bastard toad-flax	*Comandra umbellata*		√	
Bindweed sp.	*Convolvulus sp.*			
Red-osier dogwood	*Cornus sericea*			
Beaked hazelnut	*Corylus cornata*			
White prairie clover	*Dalea candida*			
Purple prairie clover	*Dalea purpurea*			
Shrubby cinquefoil	*Dasiphora fruticosa*			
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*			
Salt grass sp.	*Distichlis sp.*			√
Wolf willow	*Elaeagnus commutata*			
Spike rush	*Eleocharis sp.*			√
Horsetail	*Equisetum arvense*			
Scouring rush	*Equisetum hymale*			
Horsetail sp.	*Equisetum sp.*			
Fleabane sp.	*Erigeron sp.*			
Virginia strawberry	*Fragaria virginiana ssp. glauca*			
Fescue sp.	*Festuca sp.*			
Blanketflower	*Gaillardia aristata*	√		
Northern bedstraw	*Galium boreale*		√	√
Closed gentian	*Gentiana andrewsii*			
Geranium	*Geranium sp.*			
Yellow avens	*Geum aleppicum*			
Three flowered avens	*Geum triflorum*			
Wild licorice	*Glycyrrhiza lepidota*		√	
Beautiful sunflower	*Helianthus laetiflorus var. rigida*		√	
Narrow-leaved sunflower	*Helianthus maximiliani*	√	√	√
Sunflower sp.	*Helianthus sp.*		√	
Needle and thread grass	*Hesperostipa comata*			
Alumroot	*Heuchera richardsonii*			
Foxtail barley	*Hordeum jubatum*	√		√
Long-leaved bluets	*Houstonia longiflora*			
Rush sp.	*Juncus sp.*		√	√
Baltic rush	*Juncus balticus*		√	√
Creeping juniper	*Juniperus horizontalis*			
June grass	*Koeleria macrantha*			
Blue lettuce	*Lactuca pulchella*	√		
Mint sp.	*Lamiaceae sp.*			
Vetchling sp.	*Lathyrus sp.*			
Meadow blazingstar	*Liatris ligulistylis*	√	√	
Blazingstar	*Liatris sp.*			
Western wood lily	*Lilium philadelphicum*		√	
Prairie flax	*Linum lewisii*	√		
Stiffstem flax	*Linum rigidum*			
Hoary puccoon	*Lithospermum canescens*			
Narrow-leaved puccoon	*Lithospermium incisum*			
Kalm's lobelia	*Lobelia kalmii*			
Lobelia sp.	*Lobelia sp.*			

Common Name	Scientific name	LF2	OHM1	OHMB
Water horehound	*Lycopus americanus*			
Northern bugleweed	*Lycopus uniflorus*			
Skeleton-plant	*Lygodesmia juncea*			
Fringed loosestrife	*Lysimachia cilata*			
Whorled loosestrife	*Lysimachia quadrifolia*			
False lily of the valley	*Maianthemum stellatam*		√	
Wild mint	*Mentha arvensis*			
Wild bergamot	*Monarda fistulosa*			
Scratch grass	*Muhlenbergia asperifolia*			√
Plains Muhlenbergia	*Muhlenbergia cuspidata*			
Soft-leaf muhly	*Muhlenbergia richardsonis*	√	√	√
Muhly sp.	*Muhlenbergia sp.*			
Switch grass	*Panicum virgatum*			√
Panic grass sp.	*Panicum sp.*		√	
Grass-of-parnassus	*Parnassia palustris*			
Canadian lousewort	*Pedicularis canadensis*			
Purple prairie clover	*Petalostemon purpureum*			
Bluegrass species	*Poa sp.*			
Smartweed sp.	*Polygonum sp.*			
Water smartweed	*Polygonum amphibium*			
Trembling aspen	*Populus tremuloides*			
White cinqfoil	*Potentilla arguta*			
Shrubby cinqfoil	*Potentilla fruiticosa*			
Cinquefoil sp.	*Potentilla sp.*			
Selfheal	*Prunella vulgaris*			
Choke cherry	*Prunus virginiana*			
Silverleaf psoralea	*Psoralea agrophylla*	√		
Indian breadroot	*Psoralea esculenta*			
Rose sp.	*Rosa sp.*		√	
Black-eyed susan	*Rudbeckia hirta*			
Western dock	*Rumex occidentalis*			
Willow sp.	*Salix sp.*			
Senecio sp.	*Senecio sp.*		√	√
Little bluestem	*Schizachyrium scoparium*	√		√
Bulrush	*Scirpus sp.*			
Blue-eyed grass	*Sisyrichum montanum*		√	
Canada goldenrod	*Solidago canadensis*	√	√	√
Flat topped goldenrod	*Solidago gramniflora*		√	
Low goldenrod	*Solidago missouriensis*			
Velvety goldenrod	*Solidago mollis*			
Showy goldenrod	*Solidago nemoralis*		√	
Stiff goldenrod	*Solidago rigida*	√	√	
Goldenrod sp.	*Solidago sp.*	√	√	
Indian grass	*Sorghastrum nutans*			
Cordgrass	*Spartina pectinata*	√	√	√
White meadowsweet	*Spiraea alba*			
Lady's tresses	*Spiranthes sp.*			
Prairie dropseed	*Sporobolus heterolepis*			

Common Name	Scientific name	LF2	OHM1	OHMB
Needle and thread grass	*Stipa comata*			
Marsh hedge nettle	*Stachys palustris*			√
Snowberry	*Symphoricarpos occidentalis*	√		
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*			
Many-flowered aster	*Symphyotrichum ericoides*	√	√	√
Rush aster	*Symphyotrichum junciformis*		√	
Smooth blue aster	*Symphyotrichum laeve*	√	√	√
White upland aster	*Symphyotrichum ptarmicoides*			√
Western silvery aster	*Symphyotrichum sericeum*			
Willow aster	*Symphyotrichum simplex*			√
Aster sp.	*Symphyotrichum sp.*	√	√	
Veiny meadow-rue	*Thalictrum venulosum*			
Meadow-rue	*Thalictrum sp.*	√		
Sticky asphodel	*Tofieldia glutinosa*			
Poison ivy	*Toxicodendron radicans*			
Seaside arrow-grass	*Triglochin maritima*			√
Cattail	*Typha sp.*			
Vetch sp.	*Vicia sp.*			
Canada violet	*Viola canadensis*			
Northern bog violet	*Viola nephrophylla*			
Crowfoot violet	*Viola pedatifida*			
Violet sp.	*Viola sp.*		√	√
White camus	*Zigadenus elegans*			
Heart leaved alexander	*Zizia aptera*	√	√	√
Non-native species				
Quackgrass	*Agropyron repens*	√		
Redtop	*Agrostis stolonifera*			
Smooth brome	*Bromus inermis*		√	
Canada thistle	*Cirsium arvense*	√	√	√
Hawk's beard	*Crepis tectorum*	√		
Sheep fescue	*Festuca ovina*	√		√
Black medic	*Medicago lupulina*			
White sweet-clover	*Melilotus alba*	√		
Sweet-clover sp.	*Melilotus sp.*			
Yellow sweet-clover	*Melilotus officinalis*			
Reed canary grass	*Phalaris arundinacea*			
Timothy	*Phleum pratense*			
Common plantain	*Plantago major*			
Hoary plantain	*Plantago media*	√		
Kentucky bluegrass	*Poa pratensis*	√	√	
Curly dock	*Rumex crispus*			
Perennial sow-thistle	*Sonchus arvensis*	√	√	√
Common dandelion	*Taraxacum officinale*	√	√	
Pennycress	*Thlapsi arvense*			
Goat's beard	*Tragopogon dubius*			
Red clover	*Trifolium pratense*			
Bird vetch	*Vicia cracca*			

Plant species recorded in Tall-grass prairie preserve sites

Common Name	Scientific name	S 56	S85A	S86
Native species				
Yarrow	*Achillea millefolium*	√	√	√
Giant hyssop	*Agastache foeniculum*			
Northern wheatgrass	*Agropyron dasystachyum*	√	√	
Wheatgrass sp.	*Agropyron sp.*	√		
Rough hair grass	*Agrostis scabra*			√
Slender agalinis	*Agalinis tenuifolia*			√
Prairie onion	*Allium textile*			
Nodding onion	*Allium cernuum*			
Common ragweed	*Ambrosia artemisiifolia*		√	
Giant ragweed	*Ambrosia trifida*			
Big bluestem	*Andropogon gerardi*	√	√	√
Pygmy flower	*Androsace septentrionalis*			
Saskatoon	*Amelanchier alnifolia*			
Canada anemone	*Anemone canadensis*	√		
Long-fruited anemone	*Anemone cylindrica*			
Cut-leaved anemone	*Anemone cylindrica*			
Anemone sp.	*Anemone sp.*			
Low everlasting	*Antennaria aprica*			
Small-leaf pussytoes	*Antennaria parvifolia*			
Antennaria sp.	*Antennaria sp.*			
Spreading dogbane	*Apocynum androsaemifolium*			
Indian hemp	*Apocynum cannabinum*		√	√
Rock cress	*Arabis sp.*			
Silverweed	*Argentina anserina*		√	√
Hillside arnica	*Arnica fulgens*			
Plains wormwood	*Artemisia campestris*			
Pasture sage	*Artemisia cana*			
Prairie sage	*Artemisia frigida*			
White sagebrush	*Artemisia ludoviciana*			
Wormwood	*Artemisia sp.*			
Showy milkweed	*Asclepias speciosa*			
Common milkweed	*Asclepias syriaca*			
Milkweed sp.	*Asclepias sp.*			
Ground plum	*Astragalus crassicarpus*			
Missouri milkvetch	*Astragalus missouriensis*			
Milkvetch species	*Astragalus sp.*			
Dwarf birch	*Betula nana*	√		
Blue gramma	*Bouteloua gracilis*			
Fringed brome	*Bromus ciliatus*	√		
Reed grass	*Calamagrostis inexpansa*	√	√	√
Hedge false bindweed	*Calystegia sepium*			
Harebell	*Campanula rotundifolia*	√	√	
Sedge sp.	*Carex sp.*	√	√	√
Field chickweed	*Cerastium arvense*			
Goosefoot sp.	*Chenopodium sp.*			
Water hemlock sp.	*Cicuta sp.*	√		
Flodman's thistle	*Cirsium flodmanii*			

Common Name	Scientific name	S 56	S85A	S86
Thistle sp.	*Cirsium sp.*			
Bastard toad-flax	*Comandra umbellata*			
Bindweed sp.	*Convolvulus sp.*			
Red-osier dogwood	*Cornus sericea*			
Beaked hazelnut	*Corylus cornata*	√		
White prairie clover	*Dalea candida*			
Purple prairie clover	*Dalea purpurea*			
Shrubby cinquefoil	*Dasiphora fruticosa*			
Tufted hairgrass (f.rt)	*Deschampsia caespitosa*	√	√	√
Salt grass sp.	*Distichlis sp.*			
Wolf willow	*Elaeagnus commutata*			
Spike rush	*Eleocharis sp.*	√	√	√
Horsetail	*Equisetum arvense*	√		
Scouring rush	*Equisetum hymale*	√		
Horsetail sp.	*Equisetum sp.*			
Fleabane sp.	*Erigeron sp.*			
Virginia strawberry	*Fragaria virginiana ssp. glauca*	√	√	√
Fescue sp.	*Festuca sp.*			√
Blanketflower	*Gaillardia aristata*	√		
Northern bedstraw	*Galium boreale*	√	√	√
Closed gentian	*Gentiana andrewsii*		√	√
Geranium	*Geranium sp.*			
Yellow avens	*Geum aleppicum*			
Three flowered avens	*Geum triflorum*			
Wild licorice	*Glycyrrhiza lepidota*	√		
Beautiful sunflower	*Helianthus laetiflorus var. rigida*	√	√	√
Narrow-leaved sunflower	*Helianthus maximiliani*	√		√
Sunflower sp.	*Helianthus sp.*		√	
Needle and thread grass	*Hesperostipa comata*			
Alumroot	*Heuchera richardsonii*			
Foxtail barley	*Hordeum jubatum*			
Long-leaved bluets	*Houstonia longiflora*			
Rush sp.	*Juncus sp.*		√	
Baltic rush	*Juncus balticus*	√	√	√
Creeping juniper	*Juniperus horizontalis*			
June grass	*Koeleria macrantha*	√		√
Blue lettuce	*Lactuca pulchella*			
Mint sp.	*Lamiaceae sp.*			
Vetchling sp.	*Lathyrus sp.*			
Meadow blazingstar	*Liatris ligulistylis*	√	√	√
Blazingstar	*Liatris sp.*			
Western wood lily	*Lilium philadelphicum*			
Prairie flax	*Linum lewisii*			
Stiffstem flax	*Linum rigidum*			
Hoary puccoon	*Lithospermum canescens*			
Narrow-leaved puccoon	*Lithospermium incisum*			
Kalm's lobelia	*Lobelia kalmii*		√	
Lobelia sp.	*Lobelia sp.*			

Common Name	Scientific name	S 56	S85A	S86
Water horehound	*Lycopus americanus*			√
Northern bugleweed	*Lycopus uniflorus*			√
Skeleton-plant	*Lygodesmia juncea*			
Fringed loosestrife	*Lysimachia cilata*			
Whorled loosestrife	*Lysimachia quadrifolia*	√	√	√
False lily of the valley	*Maianthemum stellatam*			
Wild mint	*Mentha arvensis*			√
Wild bergamot	*Monarda fistulosa*			
Scratch grass	*Muhlenbergia asperifolia*			
Plains Muhlenbergia	*Muhlenbergia cuspidata*			
Soft-leaf muhly	*Muhlenbergia richardsonis*	√	√	√
Muhly sp.	*Muhlenbergia sp.*			
Switch grass	*Panicum virgatum*			
Panic grass sp.	*Panicum sp.*		√	√
Grass-of-parnassus	*Parnassia palustris*	√		
Canadian lousewort	*Pedicularis canadensis*			√
Purple prairie clover	*Petalostemon purpureum*	√	√	
Bluegrass species	*Poa sp.*	√		
Smartweed sp.	*Polygonum sp.*			√
Water smartweed	*Polygonum amphibium*	√		
Trembling aspen	*Populus tremuloides*	√		√
White cinqfoil	*Potentilla arguta*			
Shrubby cinqfoil	*Potentilla fruiticosa*	√	√	
Cinquefoil sp.	*Potentilla sp.*			
Selfheal	*Prunella vulgaris*		√	
Choke cherry	*Prunus virginiana*			
Silverleaf psoralea	*Psoralea agrophylla*			
Indian breadroot	*Psoralea esculenta*			
Rose sp.	*Rosa sp.*	√	√	
Black-eyed susan	*Rudbeckia hirta*	√	√	√
Western dock	*Rumex occidentalis*			
Willow sp.	*Salix sp.*	√	√	√
Senecio sp.	*Senecio sp.*	√	√	
Little bluestem	*Schizachyrium scoparium*	√		
Bulrush	*Scirpus sp.*	√		√
Blue-eyed grass	*Sisyrichum montanum*	√	√	√
Canada goldenrod	*Solidago canadensis*	√		√
Flat topped goldenrod	*Solidago gramniflora*		√	√
Low goldenrod	*Solidago missouriensis*	√		
Velvety goldenrod	*Solidago mollis*			
Showy goldenrod	*Solidago nemoralis*			
Stiff goldenrod	*Solidago rigida*	√	√	√
Goldenrod sp.	*Solidago sp.*	√	√	√
Indian grass	*Sorghastrum nutans*	√		
Cordgrass	*Spartina pectinata*	√	√	√
White meadowsweet	*Spiraea alba*			
Lady's tresses	*Spiranthes sp.*		√	
Prairie dropseed	*Sporobolus heterolepis*			

Common name	Scientific name	S 56	S85A	S86
Needle and thread grass	*Stipa comata*			
Marsh hedge nettle	*Stachys palustris*	√	√	
Snowberry	*Symphoricarpos occidentalis*			
Lindley's aster/fringed aster	*Symphyotrichum ciliolatus*	√		
Many-flowered aster	*Symphyotrichum ericoides*	√	√	√
Rush aster	*Symphyotrichum junciformis*		√	
Smooth blue aster	*Symphyotrichum laeve*	√		
White upland aster	*Symphyotrichum ptarmicoides*		√	
Western silvery aster	*Symphyotrichum sericeum*			
Willow aster	*Symphyotrichum simplex*	√	√	√
Aster sp.	*Symphyotrichum sp.*		√	√
Veiny meadow-rue	*Thalictrum venulosum*			
Meadow-rue	*Thalictrum sp.*	√		
Sticky asphodel	*Tofieldia glutinosa*	√		
Poison ivy	*Toxicodendron radicans*			
Seaside arrow-grass	*Triglochin maritima*			
Cattail	*Typha sp.*			
Vetch sp.	*Vicia sp.*	√	√	
Canada violet	*Viola canadensis*			
Northern bog violet	*Viola nephrophylla*		√	
Crowfoot violet	*Viola pedatifida*			
Violet sp.	*Viola sp.*	√	√	
White camus	*Zigadenus elegans*	√		
Heart leaved alexander	*Zizia aptera*	√		√
Non-native species				
Quackgrass	*Agropyron repens*			
Redtop	*Agrostis stolonifera*	√	√	√
Smooth brome	*Bromus inermis*	√		
Canada thistle	*Cirsium arvense*			
Hawk's beard	*Crepis tectorum*			
Sheep fescue	*Festuca ovina*			
Black medic	*Medicago lupulina*			
White sweet-clover	*Melilotus alba*	√		√
Sweet-clover sp.	*Melilotus sp.*			
Yellow sweet-clover	*Melilotus officinalis*			
Reed canary grass	*Phalaris arundinacea*			
Timothy	*Phleum pratense*			
Common plantain	*Plantago major*			
Hoary plantain	*Plantago media*			
Kentucky bluegrass	*Poa pratensis*		√	
Curly dock	*Rumex crispus*			
Perennial sow-thistle	*Sonchus arvensis*			
Common dandelion	*Taraxacum officinale*		√	
Pennycress	*Thlapsi arvense*			
Goat's beard	*Tragopogon dubius*			
Red clover	*Trifolium pratense*			√
Bird vetch	*Vicia cracca*			

Appendix F – Results of best GLMMs for species richness and densities at various spatial scales

Richness

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	2	192	0	0.39	Native species richness	0.06	0.04	-0.01	0.13
						Non-native species richness	0.18	0.08	0.05	0.32
2008	1	3	201	0	0.22	Robel reading	0.09	0.10	-0.09	0.26
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.03	0.05	-0.05	0.12
	2	5	203	1.4	0.11	Robel reading	0.04	0.11	-0.14	0.23
						Litter depth	0.05	0.03	0.00	0.11
						Maximum height	0.04	0.05	-0.04	0.13
						Native species richness	0.07	0.04	0.00	0.15
						Non-native species richness	0.13	0.09	-0.03	0.28
	3	5	203	1.8	0.09	Natural log of Area	0.07	0.05	-0.02	0.16
						Quality	-0.28	0.18	-0.58	0.03
						Robel reading	0.05	0.11	-0.14	0.24
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.09	0.06	-0.01	0.18
						Best Landscape Only Model(s)				
2007	1	0	280	0	0.36	NA				
	2	2	280	0.1	0.34	Prop Agriculture (500m)	0.43	0.31	-0.10	0.95
						Prop Grassland (500m)	-0.34	0.30	-0.85	0.17
	3	3	281	1.3	0.19	Prop Agriculture (500m)	-0.81	1.22	-2.90	1.26
						Prop Grassland (500m)	-1.71	1.34	-4.01	0.58
						Prop Hostile Habitat (500m)	-1.28	1.21	-3.34	0.79
2008	1	0	295	0	0.42	NA				
	2	1	295	0.3	0.36	Prop Hostile Habitat (500m)	-0.30	0.23	-0.69	0.08
						Best Patch Only Model(s)				
2007	1	0	280	0	0.60	NA				
2008	1	0	295	0	0.42	NA				
	2	2	295	0.8	0.28	Quality	-0.21	0.17	-0.50	0.09
						Mean Shape Index	0.17	0.09	0.01	0.32
	3	2	297	2	0.15	Natural log of Area	0.07	0.04	-0.01	0.14
						Quality	-0.02	0.12	-0.22	0.18
						Best Vegetation Only Model(s)				
2007	1	2	192	0	0.75	Native species richness	0.06	0.04	-0.01	0.13
						Non-native species richness	0.18	0.08	0.05	0.32
2008	1	3	201	0	0.27	Robel reading	0.09	0.10	-0.09	0.26
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.03	0.05	-0.05	0.12
	2	5	203	1.4	0.13	Robel reading	0.04	0.11	-0.14	0.23
						Litter depth	0.05	0.03	0.00	0.11
						Maximum height	0.04	0.05	-0.04	0.13
						Native species richness	0.07	0.04	0.00	0.15
						Non-native species richness	0.13	0.09	-0.03	0.28

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Patch Model(s)										
2007	1	0	280	0	0.69	NA				
2008	1	0	295	0	0.71	NA				
Best Patch and Vegetation Model(s)										
2007	1	4	197	0	0.35	Quality	-0.01	0.23	-0.41	0.39
						Mean Shape Index	-0.09	0.12	-0.30	0.12
						Native species richness	0.06	0.04	-0.01	0.14
						Non-native species richness	0.17	0.09	0.02	0.32
	2	4	197	0.2	0.32	Natural log of Area	-0.03	0.06	-0.13	0.06
						Quality	-0.08	0.20	-0.43	0.26
						Native species richness	0.07	0.05	-0.01	0.15
						Non-native species richness	0.19	0.09	0.03	0.35
2008	1	5	203	0	0.24	Natural log of Area	0.07	0.05	-0.02	0.16
						Quality	-0.28	0.18	-0.58	0.03
						Robel reading	0.05	0.11	-0.14	0.24
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.09	0.06	-0.01	0.18
	2	5	204	0.6	0.18	Quality	-0.34	0.21	-0.70	0.02
						Mean Shape Index	0.12	0.11	-0.07	0.31
						Robel reading	0.08	0.10	-0.09	0.26
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.05	0.05	-0.03	0.14
	3	7	204	0.9	0.15	Quality	-0.48	0.23	-0.88	-0.08
						Mean Shape Index	0.12	0.11	-0.08	0.31
						Robel reading	0.03	0.11	-0.17	0.22
						Litter depth	0.06	0.03	0.01	0.12
						Maximum height	0.07	0.05	-0.02	0.16
						Native species richness	0.10	0.05	0.02	0.18
						Non-native species richness	0.09	0.09	-0.06	0.25
	4	7	205	1.8	0.10	Natural log of Area	0.02	0.06	-0.08	0.13
						Quality	-0.37	0.20	-0.71	-0.02
						Robel reading	0.02	0.11	-0.17	0.22
						Litter depth	0.06	0.03	0.01	0.12
						Maximum height	0.08	0.06	-0.02	0.18
						Native species richness	0.10	0.05	0.01	0.18
						Non-native species richness	0.08	0.10	-0.09	0.26

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Vegetation Model(s)										
2007						Prop Hostile Habitat	0.04023			
	1	3	195	0	0.35	(500m)	0.3003		-0.47	0.55
						Native species richness	0.06	0.04	-0.01	0.13
						Non-native species richness	0.18	0.08	0.04	0.32
	2	5	196	1.2	0.19	Prop AG	0.21	0.35	-0.39	0.81
						Prop Grass	-0.58	0.38	-1.24	0.07
						Prop forb	1.77	0.93	0.18	3.35
						Prop Grass	0.75	1.25	-1.38	2.88
						Prop shrub	1.32	1.32	-2.37	2.15
2008						Prop Hostile Habitat				
	1	4	204	0	0.39	(500m)	-0.01	0.30	-0.52	0.49
						Robel reading	0.09	0.11	-0.10	0.28
						Litter depth	0.03	0.03	-0.02	0.08
						Maximum height	0.03528 0.05058		-0.05	0.12

Bobolink

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	10	33.5	0	0.67	Prop Agriculture (500m)	-103.20	251.93	-534.22	327.82
						Prop Grass (500m)	-26.73	108.41	-212.21	158.75
						Prop Hostile Habitat (500m)	-112.50	240.13	-523.33	298.33
						Prop native vegetation cover	122.23	10117.00	-17187.00	17432.00
						Prop non-native vegetation cover	9.67	10019.00	-17132.00	17151.00
						Prop litter cover	-1907.42	7951.40	-15511.00	11696.00
						Prop forb cover	-313.41	10437.00	-18170.00	17544.00
						Prop grass cover	-512.66	10676.00	-18778.00	17752.00
						Prop shrub cover	-2197.01	12520.00	-23617.00	19223.00
						Prop litter cover (FGS)	1086.03	9055.01	-14406.00	16578.00
2008	1	4	33.8	0	0.27	**Prop Hostile Habitat (500m)**	**-5.30**	**2.90**	**-10.25**	**-0.34**
						Prop native vegetation cover	20.53	17.31	-9.09	50.14
						Prop non-native vegetation cover	**33.72**	**18.57**	**1.94**	**65.49**
						Prop litter cover	5.18	11.55	-14.58	24.95
						Best Landscape Only Model(s)				
2007	1	0	51.2	0	0.64	NA	–	–	–	–
2008	1	0	59.5	0	0.45	NA	–	–	–	–
	2	1	60.4	0.9	0.29	Prop Hostile Habitat (500m)	-3.28	3.26	-8.86	2.29
						Best Patch Only Model(s)				
2007	1	0	51.2	0	0.49	NA	–	–	–	–
	2	2	52.2	1	0.30	Natural Log of Area	0.64	0.53	-0.28	1.55
						Quality	-1.74	1.46	-4.24	0.76
2008	1	2	57.7	0	0.43	Natural Log of Area	1.39	0.98	-0.29	3.07
						Quality	-2.63	1.93	-5.94	0.67
	2	3	58.7	1	0.26	Natural Log of Area	1.24	0.91	-0.31	2.80
						Quality	-5.83	4.58	-13.67	2.01
						Mean Shape Index	2.11	2.25	-1.75	5.97
	3	0	59.5	1.8	0.18	NA	–	–	–	–
	4	2	60.2	2.5	0.12	Quality	-4.52	3.06	-9.76	0.72
						Mean Shape Index	2.09	1.66	-0.75	4.93
						Best Vegetation Only Model(s)				
2007	1	4	38.7	0	0.40	Prop forb cover	8.84	15.02	-16.86	34.53
						Prop grass cover	11.63	18.21	-19.53	42.79
						Prop shrub cover	-140.75	94.34	-302.15	20.65
						Prop litter cover (FGS)	-6.60	14.80	-31.93	18.73
	2	2	40.3	1.6	0.18	Native species richness	-0.48	0.36	-1.09	0.15
						Non-native species richness	**0.91**	**0.52**	**0.02**	**1.80**

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
2008	1	3	36	0	0.35	Prop native vegetation cover	14.52	15.08	-11.29	40.32
						Prop non-native vegetation cover	24.69	15.92	-2.55	51.92
						Prop litter cover	4.27	12.53	-17.18	25.71
	2	6	36.2	0.2	0.31	Robel reading	1.47	1.15	-0.51	3.44
						Litter depth	0.42	0.37	-0.22	1.06
						Maximum height	-0.42	0.58	-1.40	0.57
						Prop native vegetation cover	2.28	15.60	-24.41	28.97
						Prop non-native vegetation cover	16.66	15.30	-9.52	42.84
						Prop litter cover	-3.11	12.68	-24.80	18.58
	3	5	37.4	1.4	0.17	Robel reading	1.49	1.01	-0.24	3.21
						Litter depth	0.47	0.34	-0.12	1.06
						Maximum height	-0.29	0.54	-1.22	0.64
						Native species richness	-0.07	0.49	-0.91	0.77
						Non-native species richness	**2.09**	**1.08**	**0.24**	**3.95**
						Best Landscape and Patch Model(s)				
2007	1	0	51.2	0	0.86	NA				
2008	1	6	50.8	0	0.80	Prop Agriculture (500m)	-17.06	11.23	-36.27	2.15
						Prop Grass (500m)	**-39.52**	**19.51**	**-72.90**	**-6.13**
						Prop Hostile Habitat (500m)	**-23.59**	**12.18**	**-44.43**	**-2.75**
						Natural Log of Area	**2.06**	**0.89**	**0.54**	**3.59**
						Quality	-7.83	9.54	-24.15	8.50
						Mean Shape Index	5.06	5.27	-3.96	14.07
						Best Patch and Vegetation Model(s)				
2007	1	6	40.4	0	0.35	Natural Log of Area Est	0.96	0.81	-0.42	2.35
						Quality	1.92	1.42	-4.34	0.51
						Prop forb cover	7.87	14.21	-16.45	32.19
						Prop grass cover	18.82	17.44	-11.01	48.65
						Prop shrub cover	**-110.65**	**56.79**	**-207.81**	**-13.50**
						Prop litter cover (FGS)	-4.68	11.77	-24.83	15.46
	2	7	41.4	1	0.21	Natural Log of Area Est	1.27	0.92	-0.31	2.85
						Quality	-5.30	3.51	-11.30	0.70
						Mean Shape Index	2.38	2.03	-1.09	5.85
						Prop forb cover	1.30	15.78	-25.69	28.30
						Prop grass cover	19.59	19.02	-12.95	52.12
						Prop shrub cover	**-162.38**	**86.08**	**-309.66**	**-15.11**
						Prop litter cover (FGS)	-10.16	15.16	-36.10	15.78
	3	4	42.4	2	0.13	Natural Log of Area Est	0.78	0.58	-0.21	1.77
						Quality	0.27	1.52	-2.34	2.88
						Native species richness	-0.74	0.45	-1.51	0.02
						Non-native species richness	0.59	0.59	-0.42	1.61

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
2008	1	7	38.1	0	0.17	Natural Log of Area Est	1.13	0.96	-0.52	2.78
						Quality	-2.95	1.93	-6.26	0.35
						Robel reading	1.26	1.26	-0.89	3.41
						Litter depth	**0.56**	**0.32**	**0.01**	**1.10**
						Maximum height	0.18	0.71	-1.03	1.39
						Native species richness	0.13	0.63	-0.95	1.21
						Non-native species richness	**2.22**	**1.26**	**0.07**	**4.37**
	2	5	38.5	0.4	0.14	Natural Log of Area Est	1.25	0.98	-0.43	2.93
						Quality	**-5.28**	**2.47**	**-9.51**	**-1.05**
						Robel reading	0.43	1.01	-1.29	2.15
						Litter depth	0.42	0.28	-0.06	0.91
						Maximum height	0.44	0.64	-0.66	1.54
	3	5	39	0.9	0.11	Natural Log of Area Est	0.48	0.55	-0.46	1.42
						Quality	-1.27	1.94	-4.58	2.04
						Prop native vegetation cover	16.86	14.56	-8.06	41.78
						Prop non-native vegetation cover	25.69	15.23	-0.36	51.74
						Prop litter cover	3.40	12.43	-17.87	24.67
	4	7	39.3	1.2	0.09	Quality	-4.78	3.23	-10.31	0.74
						Mean Shape Index	1.39	1.64	-1.42	4.21
						Robel reading	0.78	1.11	-1.11	2.68
						Litter depth	0.60	0.37	-0.03	1.24
						Maximum height	0.21	0.67	-0.95	1.36
						Native species richness	0.33	0.57	-0.64	1.31
						Non-native species richness	**2.26**	**1.11**	**0.36**	**4.15**
	5	5	39.5	1.4	0.08	Quality	-2.83	2.59	-7.25	1.59
						Mean Shape Index	0.92	1.46	-1.58	3.42
						Prop native vegetation cover	16.75	14.72	-8.44	41.93
						Prop non-native vegetation cover	25.46	15.18	-0.51	51.43
						Prop litter cover	5.15	11.65	-14.79	25.09
Best Landscape and Vegetation Model(s)										
2007	1	10	33.5	0	0.81	Prop Agriculture (500m)	-103.20	251.93	-534.22	327.82
						Prop Grass (500m)	-26.73	108.41	-212.21	158.75
						Prop Hostile Habitat (500m)	-112.50	240.13	-523.33	298.33
						Prop native vegetation cover	122.23	10117.00	-17187.00	17432.00
						Prop non-native vegetation cover	9.67	10019.00	-17132.00	17151.00
						Prop litter cover	-1907.42	7951.40	-15511.00	11696.00
						Prop forb cover	-313.41	10437.00	-18170.00	17544.00
						Prop grass cover	-512.66	10676.00	-18778.00	17752.00
						Prop shrub cover	-2197.01	12520.00	-23617.00	19223.00
						Prop litter cover (FGS)	1086.03	9055.01	-14406.00	16578.00
2008	1	4	33.8	0	0.50	**Prop Hostile Habitat (500m)**	**-5.30**	**2.90**	**-10.25**	**-0.34**
						Prop native vegetation cover	20.53	17.31	-9.09	50.14
						Prop non-native vegetation cover	**33.72**	**18.57**	**1.94**	**65.49**
						Prop litter cover	5.18	11.55	-14.58	24.95

Brown-headed cowbird

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	10	69	0	0.54	Robel reading	-2.81	1.78	-5.84	0.23
						Litter depth	-0.01	0.20	-0.36	0.33
						Maximum height	**1.45**	**0.78**	**0.11**	**2.78**
						Prop native vegetation cover	-45.74	213.88	-411.00	320.00
						Prop non-native vegetation cover	-27.47	214.24	-394.00	339.07
						Prop litter cover	143.55	253.70	-290.50	577.60
						Prop forb cover	82.36	208.94	-275.11	439.82
						Prop grass cover	68.08	207.54	-286.99	423.15
						Prop shrub cover	76.45	211.79	-285.89	438.79
						Prop litter cover (FGS)	-109.99	245.73	-530.41	310.43
2008	1	4	56.4	0	0.34	**Quality**	**-3.66**	**1.58**	**-6.37**	**-0.96**
						Mean Shape Index	**1.40**	**0.72**	**0.17**	**2.62**
						Native species richness	0.25	0.21	-0.11	0.61
						Non-native species richness	-0.83	0.56	-1.79	0.13
						Best Landscape Only Model(s)				
2007	1	0	102	0	0.65	NA	–	–	–	–
	2	1	104	2	0.24	Prop Hostile Habitat (500m)	0.40	1.11	-1.51	2.30
2008	1	0	97.4	0	0.63	NA	–	–	–	–
	2	1	99.2	1.8	0.26	Prop Hostile Habitat (500m)	-0.54	0.90	-2.07	1.00
						Best Patch Only Model(s)				
2007	1	0	102	0	0.53	NA	–	–	–	–
2008	1	0	97.4	0	0.46	NA	–	–	–	–
	2	2	98	0.6	0.34	Quality	-1.29	0.80	-2.66	0.08
						Mean Shape Index	**0.73**	**0.42**	**0.02**	**1.44**
						Best Vegetation Only Model(s)				
2007	1	10	69	0	0.82	Robel reading	-2.81	1.78	-5.84	0.23
						Litter depth	-0.01	0.20	-0.36	0.33
						Maximum height	**1.45**	**0.78**	**0.11**	**2.78**
						Prop native vegetation cover	-45.74	213.88	-411.00	320.00
						Prop non-native vegetation cover	-27.47	214.24	-394.00	339.07
						Prop litter cover	143.55	253.70	-290.50	577.60
						Prop forb cover	82.36	208.94	-275.11	439.82
						Prop grass cover	68.08	207.54	-286.99	423.15
						Prop shrub cover	76.45	211.79	-285.89	438.79
						Prop litter cover (FGS)	-109.99	245.73	-530.41	310.43
2008	1	2	60.2	0	0.38	Native species richness	0.10	0.23	-0.30	0.50
						Non-native species richness	-0.59	0.61	-1.62	0.45
	2	3	60.7	0.5	0.29	Prop native vegetation cover	18.03	13.86	-5.68	41.74
						Prop non-native vegetation cover	12.37	11.69	-7.63	32.36
						Prop litter cover	13.35	11.71	-6.68	33.38
	3	3	61.4	1.2	0.21	Robel reading	-0.20	0.46	-0.99	0.59
						Litter depth	0.14	0.12	-0.07	0.36
						Maximum height	0.22	0.22	-0.15	0.60

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Patch Model(s)										
2007	1	0	102	0	0.84	NA	–	–	–	–
2008	1	0	97.4	0	0.74	NA	–	–	–	–
Best Patch and Vegetation Model(s)										
2007	1	12	73.2	0	0.22	Natural log of Area	-0.46	0.46	-1.25	0.33
						Quality	-1.01	1.58	-3.72	1.69
						Robel reading	-3.29	2.46	-7.50	0.92
						Litter depth	0.04	0.24	-0.38	0.46
						Maximum height	1.59	1.05	-0.21	3.38
						Prop native vegetation cover	-47.18	262.81	-496.81	402.45
						Prop non-native vegetation cover	-29.20	263.17	-479.46	421.05
						Prop litter cover	150.09	306.77	-374.75	674.94
						Prop forb cover	90.19	257.23	-349.90	530.29
						Prop grass cover	73.59	254.75	-362.26	509.44
						Prop shrub cover	76.04	261.01	-370.51	522.59
						Prop litter cover (FGS)	-116.75	296.72	-624.41	390.91
	2	4	74	0.8	0.14	**Natural log of Area**	**-0.53**	**0.23**	**-0.91**	**-0.14**
						Quality	-0.63	0.84	-2.06	0.81
						Native species richness	0.29	0.19	-0.03	0.62
						Non-native species richness	0.62	0.38	-0.02	1.26
	3	12	74.7	1.5	0.10	Quality	-1.55	1.85	-4.72	1.61
						Mean Shape Index	0.42	1.07	-1.41	2.25
						Robel reading	-3.05	2.20	-6.81	0.71
						Litter depth	0.02	0.23	-0.39	0.42
						Maximum height	1.58	0.94	-0.04	3.19
						Prop native vegetation cover	-43.59	236.10	-447.52	360.34
						Prop non-native vegetation cover	-26.15	236.64	-431.02	378.71
						Prop litter cover	137.01	280.28	-342.51	616.54
						Prop forb cover	80.90	230.75	-313.88	475.68
						Prop grass cover	64.08	229.21	-328.07	456.23
						Prop shrub cover	71.99	234.58	-329.36	473.34
						Prop litter cover (FGS)	-105.79	271.56	-570.39	358.81
	4	5	74.8	1.6	0.10	**Natural log of Area**	**-0.63**	**0.24**	**-1.05**	**-0.21**
						Quality	-1.23	0.98	-2.91	0.46
						Mean Shape Index	0.68	0.52	-0.21	1.57
						Native species richness	0.34	0.20	0.00	0.67
						Non-native species richness	**0.73**	**0.39**	**0.06**	**1.40**
2008	1	4	56.4	0	0.74	**Quality**	**-3.66**	**1.58**	**-6.37**	**-0.96**
						Mean Shape Index	**1.40**	**0.72**	**0.17**	**2.62**
						Native species richness	0.25	0.21	-0.11	0.61
						Non-native species richness	-0.83	0.56	-1.79	0.13

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Vegetation Model(s)										
2007	1	4	76.6	0	0.26	Prop Hostile Habitat (500m)	-0.99	1.87	-4.18	2.20
						Robel reading	-1.21	0.97	-2.87	0.46
						Litter depth	-0.05	0.15	-0.31	0.20
						Maximum height	0.48	0.34	-0.11	1.06
	2	3	78.3	1.7	0.11	Prop Hostile Habitat (500m)	0.50	1.05	-1.30	2.31
						Native species richness	0.08	0.15	-0.18	0.33
						Non-native species richness	0.27	0.29	-0.24	0.77
2008	1	3	61.5	0	0.23	Prop Hostile Habitat (500m)	-1.62	1.69	-4.52	1.27
						Native species richness	0.06	0.23	-0.33	0.46
						Non-native species richness	-0.56	0.64	-1.65	0.52
	2	4	61.6	0.1	0.21	Prop Hostile Habitat (500m)	-2.22	2.16	-5.92	1.49
						Native cover	19.65	14.38	-4.95	44.24
						Non-native cover	13.72	12.03	-6.86	34.30
						Litter cover	15.57	12.54	-5.88	37.03
	3	4	62.1	0.6	0.17	Prop Hostile Habitat (500m)	-2.98	3.20	-8.45	2.50
						Robel reading	-0.80	0.95	-2.43	0.84
						Litter depth	0.13	0.16	-0.14	0.40
						Maximum height	0.50	0.45	-0.27	1.28

Clay-coloured sparrow

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	4	91.5	0	0.15	**Natural log of Area**	**-0.47**	**0.13**	**-0.70**	**-0.25**
						Quality	-0.05	0.51	-0.92	0.82
						Native species richness	0.12	0.10	-0.06	0.30
						Non-native species richness	0.19	0.25	-0.23	0.62
	2	5	91.7	0.2	0.13	Prop Agriculture (500m)	-0.61	0.93	-2.19	0.98
						Prop Grassland (500m)	**-3.65**	**1.01**	**-5.38**	**-1.91**
						Prop native vegetation cover	-3.98	3.64	-10.21	2.26
						Prop non-native vegetation cover	-5.49	3.68	-11.78	0.80
						Prop litter cover	-3.62	3.40	-9.45	2.20
	2	5	91.7	0.2	0.13	Prop Agriculture (500m)	-0.77	1.01	-2.50	0.95
						Prop Grassland (500m)	**-3.21**	**1.02**	**-4.96**	**-1.46**
						Robel reading	-0.12	0.28	-0.61	0.36
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	0.19	0.12	-0.01	0.39
	3	4	92.4	0.9	0.09	**Prop Hostile Habitat (500m)**	**2.15**	**0.78**	**0.83**	**3.48**
						Robel reading	-0.07	0.27	-0.54	0.40
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	**0.19**	**0.12**	**0.00**	**0.39**
	3	3	92.4	0.9	0.09	**Prop Hostile Habitat (500m)**	**2.26**	**0.73**	**1.01**	**3.52**
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.22	-0.55	0.19
	4	5	93.5	2	0.05	Prop Agriculture (500m)	-2.15	6.41	-13.12	8.82
						Prop Grassland (500m)	-4.94	6.89	-16.72	6.84
						Prop Hostile Habitat (500m)	-1.37	6.41	-12.34	9.61
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.21	-0.55	0.18
2008	1	4	142.2	0	0.20	Prop Hostile Habitat (500m)	1.45	0.69	-1.94	2.36
						Robel reading	**0.26**	**0.22**	**-2.38**	**-0.43**
						Litter depth	0.06	0.06	-0.21	0.21
						Maximum height	**0.02**	**0.10**	**0.36**	**1.03**
	2	3	144	1.8	0.08	Robel reading	0.09	0.21	-0.27	0.45
						Litter depth	0.04	0.06	-0.06	0.14
						Maximum height	0.07	0.10	-0.10	0.25
	3	5	144.2	2	0.07	Natural log of Area	-0.17	0.11	-0.36	0.02
						Quality	-0.51	0.43	-1.24	0.22
						Robel reading	0.20	0.21	-0.16	0.57
						Litter depth	0.05	0.06	-0.05	0.15
						Maximum height	0.04	0.12	-0.16	0.24

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Landscape Only Model(s)				
2007	1	2	125.7	0	0.57	Prop Agriculture (500m)	-0.89	0.86	-2.36	0.58
						Prop Grassland (500m)	**-3.16**	**0.78**	**-4.50**	**-1.82**
	2	1	127.6	1.9	0.22	**Prop Hostile Habitat (500m)**	**2.25**	**0.61**	**1.20**	**3.30**
	3	3	127.7	2	0.21	Prop Agriculture (500m)	-3.02	4.18	-10.18	4.14
						Prop Grassland (500m)	-5.47	4.57	-13.29	2.36
						Prop Hostile Habitat (500m)	-2.16	4.17	-9.30	4.98
2008	1	0	193.4	0	0.38	NA	–	–	–	–
	2	1	193.5	0.1	0.36	Prop Hostile Habitat (500m)	0.82	0.57	-0.16	1.79
	3	2	194.9	1.5	0.18	Prop Agriculture (500m)	-0.49	0.79	-1.84	0.86
						Prop Grassland (500m)	-1.20	0.71	-2.41	0.01
						Best Patch Only Model(s)				
2007	1	2	127.1	0	0.74	**Natural log of Area**	**-0.37**	**0.09**	**-0.52**	**-0.22**
						Quality	-0.17	0.38	-0.81	0.48
2008	1	0	193.4	0	0.51	NA	–	–	–	–
	2	2	194.5	1.1	0.30	Natural log of Area	-0.16	0.09	-0.31	0.00
						Quality	-0.15	0.35	-0.75	0.44
						Best Vegetation Only Model(s)				
2007	1	3	97.9	0	0.68	Robel reading	-0.40	0.27	-0.86	0.06
						Litter depth	-0.03	0.08	-0.17	0.11
						Maximum height	**0.28**	**0.11**	**0.08**	**0.47**
2008	1	3	144	0	0.36	Robel reading	0.09	0.21	-0.27	0.45
						Litter depth	0.04	0.06	-0.06	0.14
						Maximum height	0.07	0.10	-0.10	0.25
	2	2	144.5	0.5	0.28	Native species richness	-0.03	0.09	-0.18	0.12
						Non-native species richness	-0.10	0.20	-0.44	0.25
	3	3	146	2	0.13	Prop native vegetation cover	1.08	3.46	-4.83	6.99
						Prop non-native vegetation cover	0.81	3.37	-4.95	6.56
						Prop litter cover	-0.84	3.30	-6.49	4.81
						Best Landscape and Patch Model(s)				
2007	1	4	129.1	0	0.30	Prop Hostile Habitat (500m)	1.14	0.76	-0.16	2.44
						Natural log of Area	**-0.26**	**0.12**	**-0.45**	**-0.06**
						Quality	0.01	0.46	-0.78	0.80
						Mean Shape Index	-0.09	0.29	-0.58	0.41
	2	5	129.2	0.1	0.29	Prop Agriculture (500m)	-3.05	4.26	-10.32	4.23
						Prop Grassland (500m)	-5.01	4.75	-13.12	3.11
						Prop Hostile Habitat (500m)	-2.61	4.27	-9.91	4.69
						Natural log of Area	-0.20	0.12	-0.41	0.01
						Quality	0.15	0.42	-0.56	0.87
	3	5	129.5	0.4	0.25	Prop Agriculture (500m)	-0.46	0.90	-2.00	1.08
						Prop Grassland (500m)	**-2.24**	**1.13**	**-4.17**	**-0.31**
						Natural log of Area	-0.20	0.12	-0.41	0.01
						Quality	0.11	0.46	-0.68	0.90
						Mean Shape Index	0.03	0.31	-0.50	0.55
2008	1	0	193.4	0	0.87	NA	–	–	–	–
						Best Patch and Vegetation Model(s)				
2007	1	4	91.5	0	0.49	**Natural log of Area**	**-0.47**	**0.13**	**-0.70**	**-0.25**
						Quality	-0.05	0.51	-0.92	0.82
						Native species richness	0.12	0.10	-0.06	0.30
						Non-native species richness	0.19	0.25	-0.23	0.62

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
2008	1	5	144.2	0	0.24	Natural log of Area	-0.17	0.11	-0.36	0.02
						Quality	-0.51	0.43	-1.24	0.22
						Robel reading	0.20	0.21	-0.16	0.57
						Litter depth	0.05	0.06	-0.05	0.15
						Maximum height	0.04	0.12	-0.16	0.24
	2	5	144.9	0.7	0.17	Quality	-0.33	0.48	-1.16	0.50
						Mean Shape Index	-0.40	0.30	-0.92	0.11
						Robel reading	0.09	0.20	-0.24	0.43
						Litter depth	0.06	0.06	-0.04	0.16
						Maximum height	0.13	0.10	-0.05	0.31
	3	6	145.8	1.6	0.11	Natural log of Area	-0.15	0.11	-0.34	0.04
						Quality	-0.29	0.48	-1.11	0.52
						Mean Shape Index	-0.31	0.30	-0.82	0.21
						Robel reading	0.20	0.21	-0.17	0.56
						Litter depth	0.06	0.06	-0.04	0.15
						Maximum height	0.06	0.12	-0.14	0.26
	4	5	146.1	1.9	0.09	**Natural log of Area**	**-0.22**	**0.11**	**-0.40**	**-0.03**
						Quality	-0.23	0.43	-0.97	0.51
						Prop native vegetation cover	2.14	3.32	-3.54	7.82
						Prop non-native vegetation cover	2.04	3.35	-3.70	7.77
						Prop litter cover	-0.72	3.03	-5.90	4.47
						Best Landscape and Vegetation Model(s)				
2007	1	5	91.7	0	0.20	Prop Agriculture (500m)	-0.61	0.93	-2.19	0.98
						Prop Grassland (500m)	**-3.65**	**1.01**	**-5.38**	**-1.91**
						Prop native vegetation cover	-3.98	3.64	-10.21	2.26
						Prop non-native vegetation cover	-5.49	3.68	-11.78	0.80
						Prop litter cover	-3.62	3.40	-9.45	2.20
	1	5	91.7	0	0.20	Prop Agriculture (500m)	-0.77	1.01	-2.50	0.95
						Prop Grassland (500m)	**-3.21**	**1.02**	**-4.96**	**-1.46**
						Robel reading	-0.12	0.28	-0.61	0.36
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	0.19	0.12	-0.01	0.39
	2	4	92.4	0.7	0.14	Prop Hostile Habitat (500m)	2.15	0.78	0.83	3.48
						Robel reading	-0.07	0.27	-0.54	0.40
						Litter depth	-0.02	0.09	-0.18	0.14
						Maximum height	0.19	0.12	0.00	0.39
	2	3	92.4	0.7	0.14	**Prop Hostile Habitat (500m)**	**2.26**	**0.73**	**1.01**	**3.52**
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.22	-0.55	0.19
	3	5	93.5	1.8	0.08	Prop Agriculture (500m)	-2.15	6.41	-13.12	8.82
						Prop Grassland (500m)	-4.94	6.89	-16.72	6.84
						Prop Hostile Habitat (500m)	-1.37	6.41	-12.34	9.61
						Native species richness	0.04	0.10	-0.13	0.21
						Non-native species richness	-0.18	0.21	-0.55	0.18
2008	1	4	142.2	0	0.42	Prop Hostile Habitat (500m)	1.45	0.69	-1.94	2.36
						Robel reading	**0.26**	**0.22**	**-2.38**	**-0.43**
						Litter depth	0.06	0.06	-0.21	0.21
						Maximum height	**0.02**	**0.10**	**0.36**	**1.03**

Le Conte's Sparrow

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	5	97.1	0	0.44	**Natural log of Area**	**0.75**	**0.25**	**0.32**	**1.17**
						Quality	**1.29**	**0.54**	**0.37**	**2.22**
						Mean Shape Index	**-0.70**	**0.27**	**-1.16**	**-0.24**
						Native species richness	-0.10	0.11	-0.28	0.08
						Non-native species richness	0.15	0.22	-0.23	0.54
2008	1	5	80	0	0.24	**Natural log of Area**	**0.52**	**0.26**	**0.07**	**0.97**
						Quality	0.55	0.54	-0.39	1.48
						Robel reading	0.35	0.38	-0.30	1.00
						Litter depth	**0.18**	**0.09**	**0.03**	**0.33**
						Maximum height	**-0.42**	**0.21**	**-0.78**	**-0.05**
	2	5	81.3	1.3	0.12	Prop Agriculture (500m)	0.22	1.30	-2.00	2.45
						Prop Grassland (500m)	**2.83**	**1.34**	**0.53**	**5.12**
						Robel reading	0.33	0.38	-0.31	0.97
						Litter depth	**0.17**	**0.09**	**0.03**	**0.32**
						Maximum height	**-0.36**	**0.19**	**-0.69**	**-0.03**
	3	4	81.5	1.5	0.11	**Hostile500**	**-1.89**	**0.99**	**-3.59**	**-0.20**
						Robel reading	0.23	0.39	-0.44	0.90
						Litter depth	0.09	0.08	-0.04	0.23
						Maximum height	-0.27	0.19	-0.60	0.06
						Best Landscape Only Model(s)				
2007	1	1	140	0	0.63	**Hostile500**	**-1.88**	**0.69**	**-3.06**	**-0.71**
	2	3	142	1.9	0.24	Prop Agriculture (500m)	-3.04	1.99	-6.44	0.37
						Prop Grassland (500m)	**-4.16**	**2.40**	**-8.28**	**-0.05**
						Hostile500	-5.05	1.97	-8.42	-1.68
2008										
	1	1	118	0	0.59	**Prop Agriculture (500m)**	**-1.93**	**0.73**	**-3.18**	**-0.68**
	2	3	119	1.6	0.27	Prop Agriculture (500m)	-3.22	2.13	-6.86	0.42
						Prop Grassland (500m)	-2.65	2.51	-6.96	1.65
						Hostile500	**-4.43**	**2.03**	**-7.91**	**-0.95**
						Best Patch Only Model(s)				
2007	1	3	134	0	0.87	**Natural log of Area**	**0.77**	**0.23**	**0.39**	**1.16**
						Quality	0.55	0.37	-0.08	1.19
						Mean Shape Index	**-0.67**	**0.24**	**-1.08**	**-0.26**
2008	1	2	118	0	0.71	**Natural log of Area**	**0.51**	**0.20**	**0.16**	**0.85**
						Quality	-0.06	0.32	-0.60	0.48
						Best Vegetation Only Model(s)				
2007	1	4	107	0	0.37	Prop forb cover	6.15	4.42	-1.41	13.70
						Prop grass cover	4.07	5.22	-4.86	13.01
						Prop shrub cover	-3.61	6.40	-14.56	7.34
						Prop litter cover (FGS)	2.02	3.96	-4.76	8.80
	2	2	108	0.9	0.23	Native species richness	0.08	0.10	-0.09	0.25
						Non-native species richness	0.23	0.20	-0.11	0.57
	3	3	108	1	0.22	Robel reading	0.44	0.29	-0.06	0.94
						Litter depth	0.03	0.07	-0.09	0.16
						Maximum height	-0.20	0.14	-0.44	0.04
2008	1	3	83	0	0.71	Robel reading	0.42	0.35	-0.18	1.01
						Litter depth	0.14	0.07	0.01	0.26
						Maximum height	**-0.32**	**0.17**	**-0.62**	**-0.02**

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Patch Model(s)										
2007	1	4	135	0	0.60	Hostile500	-0.99	0.72	-2.21	0.24
						Natural log of Area	**0.70**	**0.24**	**0.29**	**1.11**
						Quality	0.26	0.41	-0.45	0.97
						Mean Shape Index	**-0.56**	**0.25**	**-0.99**	**-0.13**
2008	1	4	119	0	0.55	**Hostile500**	**-1.59**	**0.84**	**-3.02**	**-0.15**
						Natural log of Area	0.38	0.23	-0.03	0.78
						Quality	-0.40	0.51	-1.27	0.48
						Mean Shape Index	0.17	0.28	-0.31	0.66
	2	5	121	1.8	0.22	Prop Agriculture (500m)	-2.34	2.28	-6.24	1.55
						Prop Grassland (500m)	-2.48	2.70	-7.10	2.15
						Hostile500	-3.45	2.13	-7.10	0.21
						Natural log of Area	0.37	0.23	-0.03	0.77
						Quality	-0.09	0.37	-0.71	0.54
Best Patch and Vegetation Model(s)										
2007	1	5	97.1	0	0.55	**Natural log of Area**	**0.75**	**0.25**	**0.32**	**1.17**
						Quality	**1.29**	**0.54**	**0.37**	**2.22**
						Mean Shape Index	**-0.70**	**0.27**	**-1.16**	**-0.24**
						Native species richness	-0.10	0.11	-0.28	0.08
						Non-native species richness	0.15	0.22	-0.23	0.54
2008	1	5	80	0	0.45	**Natural log of Area**	**0.52**	**0.26**	**0.07**	**0.97**
						Quality	0.55	0.54	-0.39	1.48
						Robel reading	0.35	0.38	-0.30	1.00
						Litter depth	0.18	0.09	0.03	0.33
						Maximum height	**-0.42**	**0.21**	**-0.78**	**-0.05**
Best Landscape and Vegetation Model(s)										
2007	1	3	99.6	0	0.65	**Hostile500**	**-2.64**	**0.86**	**-4.10**	**-1.18**
						Native species richness	0.08	0.10	-0.09	0.24
						Non-native species richness	**0.48**	**0.23**	**0.10**	**0.87**
2008	1	5	81.3	0	0.31	Prop Agriculture (500m)	0.22	1.30	-2.00	2.45
						Prop Grassland (500m)	**2.83**	**1.34**	**0.53**	**5.12**
						Robel reading	0.33	0.38	-0.31	0.97
						Litter depth	**0.17**	**0.09**	**0.03**	**0.32**
						Maximum height	**-0.36**	**0.19**	**-0.69**	**-0.03**
	2	4	81.5	0.2	0.28	**Hostile500**	**-1.89**	**0.99**	**-3.59**	**-0.20**
						Robel reading	0.23	0.39	-0.44	0.90
						Litter depth	0.09	0.08	-0.04	0.23
						Maximum height	-0.27	0.19	-0.60	0.06
	3	3	82.7	1.4	0.16	**Hostile500**	**-2.60**	**0.97**	**-4.25**	**-0.94**
						Native species richness	0.11	0.28	-0.27	0.13
						Non-native species richness	0.11	0.28	-0.37	0.58

Red-winged blackbird

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	6	53.5	0	0.55	**Natural log of Area**	**1.60**	**0.72**	**0.37**	**2.83**
						Quality	**2.03**	**0.99**	**0.33**	**3.72**
						Prop forb cover	-3.92	12.76	-25.74	17.91
						Prop grass cover	-1.92	13.78	-25.50	21.66
						Prop shrub cover	22.95	14.91	-2.56	48.47
						Prop litter cover (FGS)	-18.73	12.24	-39.67	2.20
2008	1	5	43.4	0	0.53	Quality	-0.23	1.32	-2.49	2.02
						Mean Shape Index	**3.18**	**1.41**	**0.77**	**5.59**
						Robel reading	**1.50**	**0.78**	**0.16**	**2.84**
						Litter depth	-0.20	0.21	-0.56	0.17
						Maximum height	0.32	0.40	-0.36	1.01
						Best Landscape Only Model(s)				
2007	1	1	97.3	0	0.43	Prop Hostile Habitat (500m)	-1.75	1.23	-3.85	0.34
	2	0	97.5	0.2	0.39	NA				
2008	1	2	83.9	0	0.42	Prop Agriculture (500m)	3.30	2.47	-0.93	7.52
						Prop Grassland (500m)	6.36	2.74	1.66	11.05
	2	1	84.2	0.3	0.36	**Prop Hostile Habitat (500m)**	**-4.42**	**2.20**	**-8.18**	**-0.65**
	3	3	85.6	1.7	0.18	Prop Agriculture (500m)	8.56	7.62	-4.47	21.60
						Prop Grassland (500m)	12.14	8.37	-2.17	26.46
						Prop Hostile Habitat (500m)	5.53	7.39	-7.12	18.18
						Best Patch Only Model(s)				
2007	1	2	96.7	0	0.47	**Natural log of Area**	**0.41**	**0.23**	**0.01**	**0.81**
						Quality	0.57	0.57	-0.40	1.55
	2	0	97.5	0.8	0.32	NA				
	3	3	98.3	1.6	0.21	Natural log of Area	0.34	0.24	-0.07	0.75
						Quality	0.16	0.69	-1.02	1.35
						Mean Shape Index	0.31	0.39	-0.35	0.97
2008	1	2	77.9	0	0.73	Quality	0.25	0.77	-1.06	1.56
						Mean Shape Index	**1.16**	**0.45**	**0.40**	**1.93**
						Best Vegetation Only Model(s)				
2007	1	4	60	0	0.39	Prop forb cover	1.65	10.84	-16.90	20.20
						Prop grass cover	4.96	12.33	-16.13	26.06
						Prop shrub cover	13.34	13.31	-9.43	36.11
						Prop litter cover (FGS)	-8.28	10.25	-25.81	9.25
	2	3	60.8	0.8	0.26	Prop native vegetation cover	0.06	10.47	-17.85	17.97
						Prop non-native vegetation cover	-2.15	9.96	-19.18	14.89
						Prop litter cover	-11.10	10.42	-28.93	6.72
2008	1	3	50.7	0	0.66	Robel reading	0.86	0.51	-0.02	1.74
						Litter depth	0.06	0.13	-0.16	0.27
						Maximum height	0.37	0.26	-0.08	0.82

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Landscape and Patch Model(s)				
2007	1	0	97.5	0	0.46	NA				
	2	5	99.2	1.7	0.20	Prop Agriculture (500m)	2.00	1.37	-0.34	4.35
						Prop Grassland (500m)	-1.17	1.65	-4.00	1.66
						Natural log of Area	0.44	0.28	-0.04	0.91
						Quality	-0.06	0.71	-1.28	1.17
						Mean Shape Index	0.64	0.43	-0.09	1.37
2008	1	5	78.2	0	0.43	**Prop Agriculture (500m)**	**4.13**	**1.92**	**0.85**	**7.41**
						Prop Grassland (500m)	**4.38**	**2.43**	**0.23**	**8.53**
						Natural log of Area	-0.26	0.33	-0.83	0.30
						Quality	-0.01	0.76	-1.31	1.29
						Mean Shape Index	**1.37**	**0.48**	**0.54**	**2.19**
	1	4	78.2	0	0.43	Prop Hostile Habitat (500m)	-3.50	1.74	-6.49	0.52
						Natural log of Area	-0.27	0.30	-0.79	0.24
						Quality	0.12	0.76	-1.19	1.43
						Mean Shape Index	**1.32**	**0.45**	**0.55**	**2.09**
						Best Patch and Vegetation Model(s)				
2007	1	6	53.5	0	0.61	**Natural log of Area**	**1.60**	**0.72**	**0.37**	**2.83**
						Quality	**2.03**	**0.99**	**0.33**	**3.72**
						Prop forb cover	-3.92	12.76	-25.74	17.91
						Prop grass cover	-1.92	13.78	-25.50	21.66
						Prop shrub cover	22.95	14.91	-2.56	48.47
						Prop litter cover (FGS)	-18.73	12.24	-39.67	2.20
2008	1	5	43.4	0	0.57325	Quality	-0.23	1.32	-2.49	2.02
						Mean Shape Index	**3.18**	**1.41**	**0.77**	**5.59**
						Robel reading	**1.50**	**0.78**	**0.16**	**2.84**
						Litter depth	-0.20	0.21	-0.56	0.17
						Maximum height	0.32	0.40	-0.36	1.01

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Landscape and Vegetation Model(s)				
2007	1	5	60.7	0	0.36	Prop Hostile Habitat (500m)	-2.87	2.26	-6.74	0.99
						Prop forb cover	2.68	11.86	-17.61	22.96
						Prop grass cover	6.02	13.38	-16.87	28.90
						Prop shrub cover	17.56	14.49	-7.23	42.35
						Prop litter cover (FGS)	-6.05	10.49	-24.00	11.90
	2	5	61.5	0.8	0.24	Prop Agriculture (500m)	2.32	2.37	-1.73	6.37
						Prop Grassland (500m)	3.22	2.86	-1.68	8.12
						Prop forb cover	9.06	6.55	-2.15	20.27
						Prop grass cover	11.86	8.81	-3.20	26.93
						Prop shrub cover	**24.08**	**10.57**	**6.00**	**42.16**
	3	4	62.7	2	0.13	Prop Hostile Habitat (500m)	-1.46	2.03	-4.94	2.01
						Prop native vegetation cover	-0.01	10.96	-18.75	18.73
						Prop non-native vegetation cover	-1.78	10.28	-19.37	15.81
						Prop litter cover	-10.92	10.65	-29.15	7.31
2008	1	6	49.9	0	0.40	Prop Agriculture (500m)	124.33	82.10	-16.13	264.78
						Prop Grassland (500m)	131.21	84.22	-12.88	275.31
						Prop Hostile Habitat (500m)	125.00	82.24	-15.71	265.71
						Robel reading	0.97	0.68	-0.19	2.14
						Litter depth	-0.01	0.17	-0.31	0.28
						Maximum height	0.39	0.33	-0.18	0.96
	2	5	51.5	1.6	0.18	Prop Agriculture (500m)	-0.33	2.15	-4.00	3.34
						Prop Grassland (500m)	3.19	2.07	-0.35	6.73
						Robel reading	0.82	0.62	-0.24	1.88
						Litter depth	0.39	0.30	-0.13	0.91
						Maximum height	0.39	0.30	-0.12	0.91

Savannah sparrow

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	5	160	0	0.23	**Natural log of Area**	**0.19**	**0.11**	**0.00**	**0.37**
						Quality	-0.54	0.39	-1.21	0.12
						Mean Shape Index	**-0.66**	**0.28**	**-1.13**	**-0.19**
						Native species richness	0.12	0.07	-0.01	0.24
						Non-native species richness	0.16	0.15	-0.09	0.42
	2	4	160	0.5	0.18	Quality	-0.63	0.39	-1.30	0.05
						Mean Shape Index	**-0.55**	**0.28**	**-1.02**	**-0.07**
						Native species richness	**0.17**	**0.07**	**0.05**	**0.29**
						Non-native species richness	**0.29**	**0.13**	**0.06**	**0.51**
	2	6	160	0.5	0.18	**Natural log of Area**	**0.26**	**0.11**	**0.07**	**0.44**
						Quality	-0.34	0.38	-0.99	0.32
						Mean Shape Index	**-0.71**	**0.27**	**-1.18**	**-0.25**
						Prop native vegetation cover	0.77	3.20	-4.70	6.23
						Prop non-native vegetation cover	0.95	3.11	-4.36	6.26
						Prop litter cover	-2.36	2.99	-7.48	2.77
2008	1	5	150	0	0.42	Quality	-0.44	0.38	-1.09	0.22
						Mean Shape Index	**-0.64**	**0.30**	**-1.15**	**-0.13**
						Prop native vegetation cover	-0.45	2.50	-4.74	3.83
						Prop non-native vegetation cover	1.83	2.43	-2.32	5.98
						Prop litter cover	**-5.08**	**2.38**	**-9.16**	**-1.01**
	2	6	151	0.9	0.27	Natural log of Area	0.13	0.10	-0.04	0.30
						Quality	-0.38	0.39	-1.04	0.28
						Mean Shape Index	**-0.68**	**0.29**	**-1.18**	**-0.18**
						Prop native vegetation cover	-1.04	2.64	-5.56	3.47
						Prop non-native vegetation cover	1.09	2.58	-3.32	5.50
						Prop litter cover	**-5.98**	**2.58**	**-10.39**	**-1.57**
						Best Landscape Only Model(s)				
2007	1	2	239	0	0.35	**Prop Agriculture (500m)**	**1.47**	**0.67**	**0.33**	**2.62**
						Prop Grassland (500m)	0.14	0.69	-1.04	1.32
	2	0	240	0.4	0.28	NA				
	3	1	240	0.6	0.26	Prop Hostile Habitat (500m)	-0.79	0.59	0.23	0.00
2008	1	3	234	0	0.53	Prop Agriculture (500m)	-3.86	3.31	-9.51	1.80
						Prop Grassland (500m)	**-7.17**	**3.72**	**-13.54**	**-0.81**
						Prop Hostile Habitat (500m)	**-5.88**	**3.33**	**-11.58**	**-0.17**
	2	2	234	0.8	0.36	**Prop Agriculture (500m)**	**1.96**	**0.80**	**0.59**	**3.34**
						Prop Grassland (500m)	-0.71	0.82	-2.12	0.69
						Best Patch Only Model(s)				
2007	1	3	227	0	0.82	**Natural log of Area**	**0.29**	**0.09**	**0.13**	**0.45**
						Quality	-0.43	0.28	-0.92	0.06
						Mean Shape Index	**-0.51**	**0.20**	**-0.85**	**-0.16**
2008	1	3	227	0	0.53	Natural log of Area	0.22	0.11	0.03	0.40
						Quality	**-1.01**	**0.41**	**-1.70**	**-0.31**
						Mean Shape Index	**-0.52**	**0.28**	**-1.01**	**-0.04**
	2	2	228	1	0.32	**Natural log of Area**	**0.20**	**0.12**	**0.01**	**0.40**
						Quality	**-1.46**	**0.39**	**-2.13**	**-0.79**

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Vegetation Only Model(s)				
2007	1	2	166	0	0.50	**Native species richness**	**0.13**	**0.07**	**0.01**	**0.26**
						Non-native species richness	**0.41**	**0.14**	**0.16**	**0.65**
	2	3	167	1.5	0.23	Prop native vegetation cover	0.15	3.03	-5.05	5.34
						Prop non-native vegetation cover	1.45	2.98	-3.65	6.55
						Prop litter cover	-3.40	2.83	-8.24	1.43
2008	1	3	156	0	0.81	Prop native vegetation cover	-1.00	2.59	-5.44	3.43
						Prop non-native vegetation cover	1.89	2.53	-2.45	6.22
						Prop litter cover	**-6.10**	**2.50**	**-10.38**	**-1.83**
						Best Landscape and Patch Model(s)				
2007	1	6	227	0	0.44	Prop Agriculture (500m)	1.90	2.06	-1.62	5.42
						Prop Grassland (500m)	0.63	2.24	-3.20	4.45
						Prop Hostile Habitat (500m)	0.98	2.04	-2.52	4.47
						Natural log of Area	0.32	0.10	0.49	0.00
						Quality	**-0.50**	**0.26**	**-0.93**	**-0.06**
						Mean Shape Index	-0.32	0.19	-0.65	0.01
	2	5	228	0.6	0.33	Prop Agriculture (500m)	2.24	2.01	-1.20	5.69
						Prop Grassland (500m)	0.60	2.21	-3.17	4.37
						Prop Hostile Habitat (500m)	1.08	2.01	-2.35	4.52
						Natural log of Area	0.30	0.09	0.14	0.46
						Quality	**-0.75**	**0.21**	**-1.11**	**-0.38**
	3	4	229	1.3	0.23	Prop Hostile Habitat (500m)	-0.36	0.39	-1.03	0.31
						Natural log of Area	**0.25**	**0.10**	**0.09**	**0.42**
						Quality	**-0.50**	**0.28**	**-0.99**	**-0.02**
						Mean Shape Index	**-0.49**	**0.20**	**-0.83**	**-0.15**
2008	1	6	218	0	0.49	**Prop Agriculture (500m)**	**-3.48**	**1.80**	**-6.56**	**-0.40**
						Prop Grassland (500m)	-5.98	2.03	-5.83	0.46
						Prop Hostile Habitat (500m)	**-4.59**	**1.78**	**-7.64**	**-1.54**
						Natural log of Area	0.25	0.09	0.10	0.40
						Quality	**-0.89**	**0.28**	**-1.38**	**-0.41**
						Mean Shape Index	-0.43	0.26	-0.88	0.02
	2	5	219	0.4	0.40	Prop Agriculture (500m)	-2.69	1.84	-5.83	0.46
						Prop Grassland (500m)	**-5.67**	**2.20**	**-9.43**	**-1.91**
						Prop Hostile Habitat (500m)	**-4.03**	**1.86**	**-7.21**	**-0.85**
						Natural log of Area	0.26	0.10	0.09	0.43
						Quality	**-1.11**	**0.28**	**-1.58**	**-0.63**
						Best Patch and Vegetation Model(s)				
2007	1	5	160	0	0.25	Natural log of Area	0.19	0.11	0.00	0.37
						Quality	-0.54	0.39	-1.21	0.12
						Mean Shape Index	**-0.66**	**0.28**	**-1.13**	**-0.19**
						Native species richness	0.12	0.07	-0.01	0.24
						Non-native species richness	0.16	0.15	-0.09	0.42
	2	6	160	0.5	0.20	Natural log of Area	0.26	0.11	0.07	0.44
						Quality	-0.34	0.38	-0.99	0.32
						Mean Shape Index	**-0.71**	**0.27**	**-1.18**	**-0.25**
						Prop native vegetation cover	0.77	3.20	-4.70	6.23
						Prop non-native vegetation cover	0.95	3.11	-4.36	6.26
						Prop litter cover	-2.36	2.99	-7.48	2.77
	2	4	160	0.5	0.20	Quality	-0.63	0.39	-1.30	0.05
						Mean Shape Index	**-0.55**	**0.28**	**-1.02**	**-0.07**
						Native species richness	0.17	0.07	0.05	0.29
						Non-native species richness	0.29	0.13	0.06	0.51

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
2008	1	5	150	0	0.51	Quality	-0.44	0.38	-1.09	0.22
						Mean Shape Index	**-0.64**	**0.30**	**-1.15**	**-0.13**
						Prop native vegetation cover	-0.45	2.50	-4.74	3.83
						Prop non-native vegetation cover	1.83	2.43	-2.32	5.98
						Prop litter cover	**-5.08**	**2.38**	**-9.16**	**-1.01**
	2	6	151	0.9	0.32	Natural log of Area	0.13	0.10	-0.04	0.30
						Quality	-0.38	0.39	-1.04	0.28
						Mean Shape Index	**-0.68**	**0.29**	**-1.18**	**-0.18**
						Prop native vegetation cover	-1.04	2.64	-5.56	3.47
						Prop non-native vegetation cover	1.09	2.58	-3.32	5.50
						Prop litter cover	**-5.98**	**2.58**	**-10.39**	**-1.57**
						Best Landscape and Vegetation Model(s)				
2007	1	5	164	0	0.26	Prop Agriculture (500m)	3.04	3.18	-2.41	8.48
						Prop Grassland (500m)	1.70	3.43	-4.17	7.57
						Prop Hostile Habitat (500m)	1.41	3.16	-3.99	6.81
						Native species richness	0.11	0.06	0.00	0.22
						Non-native species richness	**0.45**	**0.12**	**0.24**	**0.66**
	2	8	165	1.1	0.15	**Prop Agriculture (500m)**	**2.04**	**0.58**	**1.06**	**3.03**
						Prop Grassland (500m)	0.59	0.71	-0.62	1.80
						Robel reading	0.20	0.22	-0.17	0.57
						Litter depth	**-0.16**	**0.06**	**-0.32**	**-0.06**
						Maximum height	-0.15	0.09	-0.31	0.01
						Prop native vegetation cover	3.57	3.05	-1.64	8.79
						Prop non-native vegetation cover	5.22	3.07	-0.03	10.47
						Prop litter cover	0.82	2.56	-3.57	5.20
	2	5	165	1.1	0.15	**Prop Agriculture (500m)**	**1.92**	**0.63**	**0.85**	**3.00**
						Prop Grassland (500m)	-0.18	0.65	-1.29	0.93
						Robel reading	0.27	0.20	-0.08	0.61
						Litter depth	**-0.15**	**0.06**	**-0.24**	**-0.05**
						Maximum height	**-0.19**	**0.09**	**-0.34**	**-0.04**
	3	3	166	1.7	0.11	Prop Hostile Habitat (500m)	-0.88	0.55	-1.82	0.06
						Native species richness	0.12	0.07	0.00	0.24
						Non-native species richness	**0.45**	**0.14**	**0.21**	**0.69**
2008	1	5	155	0	0.25	**Prop Agriculture (500m)**	**1.36**	**0.58**	**0.37**	**2.35**
						Prop Grassland (500m)	0.27	0.72	-0.97	1.51
						Prop native vegetation cover	-2.32	2.56	-6.70	2.06
						Prop non-native vegetation cover	0.73	2.48	-3.51	4.97
						Prop litter cover	**-5.70**	**2.34**	**-9.71**	**-1.69**
	2	4	155	0.3	0.22	**Prop Hostile Habitat (500m)**	**-0.97**	**0.51**	**-1.84**	**-0.11**
						Prop native vegetation cover	-1.40	2.62	-5.88	3.08
						Prop non-native vegetation cover	1.95	2.51	-2.34	6.24
						Prop litter cover	**-5.95**	**2.43**	**-10.11**	**-1.79**
	3	8	156	1.4	0.12	Prop Agriculture (500m)	2.14	0.64	1.04	3.24
						Prop Grassland (500m)	0.43	0.80	-0.94	1.79
						Robel reading	0.13	0.22	-0.24	0.50
						Litter depth	**-0.10**	**0.05**	**-0.19**	**-0.01**
						Maximum height	-0.13	0.09	-0.29	0.02
						Prop native vegetation cover	0.25	2.96	-4.81	5.30
						Prop non-native vegetation cover	3.35	2.98	-1.74	8.44
						Prop litter cover	-3.88	2.46	-8.09	0.34

Sedge wren

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Overall Model(s)				
2007	1	4	40.1	0	0.35	**Natural log of Area**	**1.88**	**0.80**	**0.52**	**3.24**
						Quality	**-3.20**	**1.64**	**-6.00**	**-0.40**
						Native species richness	0.05	0.31	-0.48	0.58
						Non-native species richness	-0.82	0.71	-2.03	0.40
	2	6	40.7	0.6	0.26	**Natural log of Area**	**1.83**	**0.96**	**0.19**	**3.46**
						Quality	-2.12	1.49	-4.67	0.44
						Prop forb cover	10.35	16.91	-18.58	39.27
						Prop grass cover	23.10	18.41	-8.40	54.61
						Prop shrub cover	-7.67	26.92	-53.72	38.38
						Prop litter cover (FGS)	8.31	14.40	-16.33	32.95
2008	1	5	89.9	0	0.37	**Natural log of Area**	**0.80**	**0.26**	**0.35**	**1.24**
						Quality	**-1.72**	**0.82**	**-3.12**	**-0.33**
						Mean Shape Index	**0.70**	**0.36**	**0.09**	**1.31**
						Native species richness	0.00	0.11	-0.19	0.19
						Non-native species richness	**-0.87**	**0.37**	**-1.50**	**-0.24**
	2	6	91.5	1.6	0.17	**Natural log of Area**	**0.74**	**0.25**	**0.30**	**1.17**
						Quality	**-1.64**	**0.82**	**-3.04**	**-0.24**
						Mean Shape Index	0.80	0.38	0.14	1.46
						Prop native vegetation cover	-7.45	5.35	-16.60	1.70
						Prop non-native vegetation cover	**-11.53**	**5.18**	**-20.38**	**-2.68**
						Prop litter cover	-7.66	5.35	-16.81	1.49
	2	4	91.5	1.6	0.17	**Natural log of Area**	**0.95**	**0.31**	**0.42**	**1.49**
						Quality	-0.47	0.58	-1.47	0.52
						Native species richness	0.00	0.12	-0.20	0.21
						Non-native species richness	-0.67	0.40	-1.35	0.02
						Best Landscape Only Model(s)				
2007	1	0	60.4	0	0.57	NA				
	2	1	61.8	1.4	0.28	Prop Hostile Habitat (500m)	-1.75	2.10	-5.35	1.85
2008	1	2	134	0	0.46	Prop Agriculture (500m)	1.35	1.58	-1.36	4.06
						Prop Grassland (500m)	4.73	1.71	1.80	7.66
	2	1	135	0.8	0.31	**Prop Hostile Habitat (500m)**	**-3.26**	**1.42**	**-5.68**	**-0.84**
	3	3	136	1.7	0.20	Prop Agriculture (500m)	-1.69	4.21	-8.90	5.51
						Prop Grassland (500m)	1.26	4.75	-6.87	9.39
						Prop Hostile Habitat (500m)	-3.08	4.10	-10.10	3.93
						Best Patch Only Model(s)				
2007	1	2	54.6	0	0.70	**Natural log of Area**	**1.44**	**0.67**	**0.30**	**2.57**
						Quality	**-2.15**	**1.18**	**-4.16**	**-0.13**
2008	1	2	132	0	0.51	**Natural log of Area**	**0.87**	**0.33**	**0.31**	**1.43**
						Quality	0.38	0.50	-0.47	1.23
	2	3	132	0.3	0.44	**Natural log of Area**	**0.67**	**0.31**	**0.14**	**1.20**
						Quality	-0.47	0.79	-1.83	0.89
						Mean Shape Index	0.63	0.47	-0.18	1.43

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
						Best Vegetation Only Model(s)				
2007	1	4	46.3	0	0.56	Prop forb cover	20.37	14.98	-5.26	46.00
						Prop grass cover	**31.14**	**17.64**	**0.95**	**61.33**
						Prop shrub cover	1.85	20.96	-34.02	37.71
						Prop litter cover (FGS)	13.84	12.65	-7.80	35.49
	2	2	48.2	1.9	0.21	Native species richness	0.19	0.25	-0.23	0.61
						Non-native species richness	0.30	0.49	-0.54	1.14
2008	1	2	99.2	0	0.45	Native species richness	0.13	0.12	-0.08	0.33
						Non-native species richness	-0.18	0.35	-0.77	0.41
	2	3	100	1.1	0.26	Robel reading	0.46	0.31	-0.06	0.98
						Litter depth	-0.01	0.09	-0.16	0.15
						Maximum height	-0.03	0.16	-0.30	0.25
						Best Landscape and Patch Model(s)				
2007	1	5	56.1	0	0.48	Prop Agriculture (500m)	18.52	12.67	-3.16	40.20
						Prop Grassland (500m)	18.62	12.80	-3.28	40.51
						Prop Hostile Habitat (500m)	10.32	7.74	-2.92	23.56
						Natural log of Area	4.49	2.87	-0.42	9.39
						Quality	-0.42	9.39	-6.48	-0.67
	2	4	57.9	1.8	0.19	Prop Hostile Habitat (500m)	-1.98	2.00	-5.41	1.45
						Natural log of Area	**1.75**	**0.91**	**0.18**	**3.31**
						Quality	-3.05	2.14	-6.71	0.61
						Mean Shape Index	0.17	1.27	-2.00	2.34
2008	1	4	130	0	0.61	Prop Hostile Habitat (500m)	-2.37	1.05	-4.16	-0.58
						Natural log of Area	**0.53**	**0.29**	**0.02**	**1.03**
						Quality	-0.73	0.64	-1.84	0.37
						Mean Shape Index	**0.72**	**0.36**	**0.09**	**1.34**
						Best Patch and Vegetation Model(s)				
2007	1	4	40.1	0	0.35	**Natural log of Area**	**1.88**	**0.80**	**0.52**	**3.24**
						Quality	**-3.20**	**1.64**	**-6.00**	**-0.40**
						Native species richness	0.05	0.31	-0.48	0.58
						Non-native species richness	-0.82	0.71	-2.03	0.40
	2	6	40.7	0.6	0.26	**Natural log of Area**	**1.83**	**0.96**	**0.19**	**3.46**
						Quality	-2.12	1.49	-4.67	0.44
						Prop forb cover	10.35	16.91	-18.58	39.27
						Prop grass cover	23.10	18.41	-8.40	54.61
						Prop shrub cover	-7.67	26.92	-53.72	38.38
						Prop litter cover (FGS)	8.31	14.40	-16.33	32.95
2008	1	5	89.9	0	0.40	**Natural log of Area**	**0.80**	**0.26**	**0.35**	**1.24**
						Quality	-1.72	0.82	-3.12	-0.33
						Mean Shape Index	**0.70**	**0.36**	**0.09**	**1.31**
						Native species richness	0.00	0.11	-0.19	0.19
						Non-native species richness	**-0.87**	**0.37**	**-1.50**	**-0.24**
	2	6	91.5	1.6	0.18	**Natural log of Area**	**0.74**	**0.25**	**0.30**	**1.17**
						Quality	**-1.64**	**0.82**	**-3.04**	**-0.24**
						Mean Shape Index	**0.80**	**0.38**	**0.14**	**1.46**
						Prop native vegetation cover	-7.45	5.35	-16.60	1.70
						Prop non-native vegetation cover	**-11.53**	**5.18**	**-20.38**	**-2.68**
						Prop litter cover	-7.66	5.35	-16.81	1.49
	2	4	91.5	1.6	0.18	**Natural log of Area**	**0.95**	**0.31**	**0.42**	**1.49**
						Quality	-0.47	0.58	-1.47	0.52
						Native species richness	0.00	0.12	-0.20	0.21
						Non-native species richness	-0.67	0.40	-1.35	0.02

Year	Rank	K	AICc	ΔAICc	w_i	Variables	β	SE	Confidence Interval	
Best Landscape and Vegetation Model(s)										
2007	1	5	48.8	0	0.35	Prop Hostile Habitat (500m)	0.18	2.08	-3.39	3.75
						Prop forb cover	20.28	14.90	-5.21	45.77
						Prop grass cover	**31.16**	**17.54**	**1.15**	**61.17**
						Prop shrub cover	13.88	12.62	-7.71	35.46
						Prop litter cover (FGS)	13.88	12.62	-7.71	35.46
	2	5	50	1.2	0.19	Prop Agriculture (500m)	-1.22	3.44	-7.10	4.67
						Prop Grassland (500m)	0.29	2.64	-4.23	4.81
						Prop forb cover	6.56	6.75	-5.00	18.11
						Prop grass cover	**15.20**	**8.59**	**0.50**	**29.90**
						Prop shrub cover	-13.72	17.15	-43.07	15.63
	3	3	50.5	1.7	0.15	Prop Hostile Habitat (500m)	-0.75	2.06	-4.28	2.78
						Native species richness	0.18	0.25	-0.25	0.62
						Non-native species richness	0.34	0.52	-0.56	1.24
2008	1	3	96.9	0	0.19	**Prop Hostile Habitat (500m)**	**-2.74**	**1.44**	**-5.21**	**-0.28**
						Native species richness	0.11	0.12	-0.09	0.31
						Non-native species richness	-0.06	0.35	-0.67	0.54
	2	5	97.1	0.2	0.17	Prop Agriculture (500m)	0.16	1.55	-2.50	2.81
						Prop Grassland (500m)	**3.66**	**1.53**	**1.04**	**6.29**
						Robel reading	0.36	0.30	-0.15	0.87
						Litter depth	0.01	0.09	-0.14	0.17
						Maximum height	-0.03	0.15	-0.29	0.23
	3	5	97.4	0.5	0.15	Prop Agriculture (500m)	0.88	1.53	-1.73	3.48
						Prop Grassland (500m)	**4.87**	**1.78**	**1.82**	**7.91**
						Prop forb cover	1.64	2.77	-3.10	6.37
						Prop grass cover	1.95	3.37	-3.83	7.72
						Prop shrub cover	6.44	4.74	-1.67	14.55
	4	5	97.7	0.8	0.13	Prop Agriculture (500m)	0.94	1.58	-1.77	3.65
						Prop Grassland (500m)	**4.64**	**1.89**	**1.41**	**7.87**
						Prop native vegetation cover	-1.42	5.06	-10.09	7.24
						Prop non-native vegetation cover	-1.69	5.11	-10.44	7.06
						Prop litter cover	-4.42	5.07	-13.09	4.26

Appendix G – Correlation table of all variables in GLMMs

	Area (ln)	Quality	MSI	PropAg500	PropGrass500	Hostile500	Robel_Ave	Litter_depth	Max_ht	NPropNatCov	NPropNonNatCov	NpropGround	Nprop_lit	Native_sp_rich	Non_Nat_sp_rich	Vprop_forb	Vprop_grass	Vprop_shrub	VpropGround	Vprop_lit
Area (ln)	**1.00**	0.22	0.37	-0.05	0.60	-0.52	0.20	0.18	-0.13	0.04	0.16	-0.14	-0.22	0.30	0.25	0.21	0.20	-0.14	-0.28	-0.21
p		0.00	0.62	<.000 1	<.000 1	0.14		0.18	0.34	0.79	0.22	0.31	0.09	0.02	0.06	0.11	0.13	0.30	0.02	0.12
Quality	0.22	**1.00**	0.71	-0.12	0.40	-0.26	0.40	0.22	0.47	0.39	-0.45	0.03	0.04	0.42	-0.44	0.09	0.02	-0.16	-0.17	-0.01
p	0.04		0.28	0.00	0.02	0.00		0.10	0.00	0.00	0.00	0.81	0.75	0.00	0.00	0.52	0.91	0.23	0.16	0.94
MSI	0.37	0.71 <.000	**1.00**	-0.31 <.000	0.47	-0.18	0.42	0.33	0.39	0.27	-0.27	-0.12	0.04	0.22	-0.26	0.00	0.17	-0.11	-0.28	0.00
p	0.00	1		1	0.10	0.00		0.01	0.00	0.04	0.04	0.39	0.76	0.09	0.05	0.97	0.20	0.43	0.02	0.97
PropAg500	-0.05	-0.12	-0.31	**1.00**	-0.31 <.000	-0.45	0.32	0.26	0.16	0.10	0.04	-0.05	-0.19	0.11	-0.07	0.25	-0.11	0.07	0.07	-0.19
p	0.62	0.28	0.00		1	0.01		0.04	0.23	0.44	0.75	0.69	0.15	0.41	0.63	0.06	0.41	0.63	0.53	0.16
PropGrass500	0.60 <.000	0.40	0.47 <.000	-0.31	**1.00**	-0.69	0.18	0.10	0.03	0.24	-0.32	0.10	0.06	0.26	-0.20	-0.10	0.30	-0.22	-0.13	-0.02
p	1	0.00	1	0.00		0.18		0.46	0.81	0.07	0.01	0.46	0.67	0.05	0.13	0.48	0.02	0.09	0.28	0.90
Hostile500	-0.52 <.000	-0.26	-0.18	-0.45 <.000	-0.69 <.000	**1.00**	-0.39	-0.31	-0.14	-0.26	0.21	-0.04	0.10	-0.28	0.21	-0.14	-0.15	0.16	0.05	0.15
p	1	0.02	0.10	1	1			0.02	0.31	0.05	0.11	0.77	0.47	0.04	0.12	0.30	0.26	0.23	0.70	0.25
Robel_Ave	0.20	0.40	0.42	0.32	0.18	-0.39	**1.00**	0.51 <.000	0.70 <.000	0.37	-0.24	-0.10	-0.17	0.27	-0.32	0.07	0.23	0.02	-0.12	-0.19
p	0.14	0.00	0.00	0.01	0.18	0.00		1	1	0.00	0.07	0.46	0.21	0.04	0.02	0.61	0.08	0.90	0.38	0.15
Litter_depth	0.18	0.22	0.33	0.26	0.10	-0.31	0.51 <.000	**1.00**	0.30	0.01	0.00	-0.32	0.14	-0.17	-0.19	-0.14	0.34	-0.16	-0.33	0.14
p	0.18	0.10	0.01	0.04	0.46	0.02	1		0.97	0.98	0.01	0.29	0.20		0.15	0.31	0.01	0.23	0.01	0.28
Max_ht	-0.13	0.47	0.39	0.16	0.03	-0.14	0.70 <.000	0.30	**1.00**	0.34	-0.35	0.01	-0.01	0.26	-0.43	-0.08	0.20	-0.08	0.02	-0.03
p	0.34	0.00	0.00	0.23	0.81	0.31	1	0.02		0.01	0.92	0.93	0.05		0.00	0.57	0.13	0.54	0.87	0.83
NPropNatCov	0.04	0.39	0.27	0.10	0.24	-0.26	0.37	0.01	0.34	**1.00**	-0.80	0.06	-0.37 <.000	0.76	-0.69 <.000	0.15	0.11	0.39	0.02	-0.48
p	0.79	0.00	0.04	0.44	0.07	0.05	0.00	0.97	0.01		0.67	0.00	1		1	0.25	0.40	0.00	0.89	0.00
NPropNonNatCov	0.16	-0.45	-0.27	0.04	-0.32	0.21	-0.24	0.00	-0.35	-0.80 <.000	**1.00**	-0.14	-0.18	-0.45	0.88 <.000	0.22	-0.03	-0.20	-0.11	-0.03
p	0.22	0.00	0.04	0.75	0.01	0.11	0.07	0.98	0.01	1		0.17	0.00		1	0.09	0.85	0.14	0.42	0.80
NpropGround	-0.14	0.03	-0.12	-0.05	0.10	-0.04	-0.10	-0.32	0.01	0.06	-0.14	**1.00**	-0.37	-0.05	-0.01	-0.18	0.06	0.14	1.00 <.000	-0.42
p	0.31	0.81	0.39	0.69	0.46	0.77	0.46	0.01	0.92	0.67	0.29		0.69		0.93	0.17	0.64	0.28	1	0.00
Nprop_lit	-0.22	0.04	0.04	-0.19	0.06	0.10	-0.17	0.14	-0.01	-0.37	-0.18	-0.37	**1.00**	-0.46	-0.24	-0.47	-0.16	-0.37	-0.36	0.98 <.000
p	0.09	0.75	0.76	0.15	0.67	0.47	0.21	0.29	0.93	0.00	0.17	0.00			0.07	0.00	0.22	0.00	0.01	1
Native_sp_rich	0.30	0.42	0.22	0.11	0.26	-0.28	0.27	-0.17	0.26	0.76 <.000	-0.45	-0.05	-0.46	**1.00**	-0.33	0.43	-0.04	0.22	-0.07	-0.50 <.000
p	0.02	0.00	0.09	0.41	0.05	0.04	0.04	0.20	0.05	1	0.00	0.69	0.00		0.01	0.00	0.79	0.10	0.59	1
Non_Nat_sp_rich	0.25	-0.44	-0.26	-0.07	-0.20	0.21	-0.32	-0.19	-0.43	-0.69	0.88	-0.01	-0.24	-0.33	**1.00**	0.29	-0.03	-0.24	0.01	-0.13

										<.000	<.000									
p	0.06	0.00	0.05	0.63	0.13	0.12	0.02	0.15	0.00	1	1	0.93	0.07	0.01		0.84	0.07	0.93	0.32	
Vprop_forb	0.21	0.09	0.00	0.25	-0.10	-0.14	0.07	-0.14	-0.08	0.15	0.22	-0.18	-0.47	0.43	0.29	**1.00**	-0.49	-0.20	-0.19	-0.44
p	0.11	0.52	0.97	0.06	0.48	0.30	0.61	0.31	0.57	0.25	0.09	0.17	0.00	0.00	0.03		0.13	0.15	0.00	
Vprop_grass	0.20	0.02	0.17	-0.11	0.30	-0.15	0.23	0.34	0.20	0.11	-0.03	0.06	-0.16	-0.04	-0.03	-0.49	**1.00**	-0.12	0.05	-0.18
p	0.13	0.91	0.20	0.41	0.02	0.26	0.08	0.01	0.13	0.40	0.85	0.64	0.22	0.79	0.84	0.00		0.69	0.17	
Vprop_shrub	-0.14	-0.16	-0.11	0.07	-0.22	0.16	0.02	-0.16	-0.08	0.39	-0.20	0.14	-0.37	0.22	-0.24	-0.20	-0.12	**1.00**	0.14	-0.39
p	0.30	0.23	0.43	0.63	0.09	0.23	0.90	0.23	0.54	0.00	0.14	0.28	0.00	0.10	0.07	0.13	0.38		0.00	
VpropGround	-0.28	-0.17	-0.28	0.07	-0.13	0.05	-0.12	-0.33	0.02	0.02	-0.11	1.00	-0.36	-0.07	0.01	-0.19	0.05	0.14	**1.00**	-0.40
												<.000								
p	0.02	0.16	0.02	0.53	0.28	0.70	0.38	0.01	0.87	0.89	0.42	1	0.01	0.59	0.93	0.15	0.69	0.31		
Vprop_lit	-0.21	-0.01	0.00	-0.19	-0.02	0.15	-0.19	0.14	-0.03	-0.48	-0.03	-0.42	0.98	-0.50	-0.13	-0.44	-0.18	-0.39	-0.40	**1.00**
													<.000	<.000						
p	0.12	0.94	0.97	0.16	0.90	0.25	0.15	0.28	0.83	0.00	0.80	0.00	1	1	0.32	0.00	0.17	0.00	0.00	