

**Effects of twice-over rotation grazing on the relative abundances of grassland birds
in the mixed-grass prairie region of southwestern Manitoba**

By Cristina Lynn Ranellucci

A Thesis submitted to: The Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
for the Degree of

Masters of Natural Resources Management

Natural Resources Institute
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ABSTRACT

The mixed-grass prairie region of southwestern Manitoba is a hotspot for many endangered grassland birds. This region has been degraded to less than a quarter of its historical amount of mixed-grass prairie. Remaining prairie is primarily used for livestock grazing. The objective of this study was to evaluate the contribution of sustainable land management practices, such as rotational grazing, in the conservation of this region. In 2008 and 2009, I compared the abundances of grassland birds on two grazing regimes, twice-over rotation and season-long, to ungrazed fields. Bird surveys were done during the breeding season and were conducted using 100-m fixed-radius point-count plots. I determined the effects of treatment, landscape and vegetation characteristics on songbird abundances using generalized linear mixed models. Grassland birds selected grazed pastures over ungrazed fields in both years, and species richness of obligate grassland birds was significantly greater ($\alpha = 0.10$) on season-long than twice-over pastures ($\beta = 0.419$, $p = 0.032$, in 2008 and $\beta = 0.502$, $p = 0.043$ in 2009). Season-long grazing may actually benefit grassland bird communities by creating somewhat temporally stable areas of high use and low use within the pasture. However, nesting success studies and long-term monitoring are necessary to further understand how twice-over rotation grazing systems contribute to the conservation of grassland birds in southwestern Manitoba.

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1.0 LITERATURE REVIEW

1.1 Status of North American grassland birds

Continued exploitation of native prairie over the last century has converted grasslands into a globally at-risk ecosystem. The severe loss of North American grasslands is apparent at the species level, where many bird populations have been declining continuously for the past 35 years (Blancher 2003). Consequently, during the past 25 years, grassland birds have experienced greater declines in population sizes than any other group of North American birds (Robbins et al. 1993, Knopf 1994, Bird Studies Canada 2009). Many bird species depend on North American grasslands throughout the year as residents, for stopover sites during migration, or for breeding (Blancher 2003). Only nine North American bird species are considered endemic to the Great Plains, whereas about 20 bird species, both passerine and non-passerine, are considered secondary endemic grassland species, having a strong affiliation with the Great Plains (Knopf 1996). Of the nine grassland bird species endemic to North America, four are found in the mixed-grass prairies of southwestern Manitoba; Baird's sparrow (*Ammodramus bairdii*), chestnut-collared longspur (*Calcarius ornatus*), lark bunting (*Calamospiza melanocorys*), and Sprague's pipit (*Anthus spragueii*), (Knopf 1996).

Data from the Breeding Bird Survey indicate a decline in mean annual percent population sizes for 17 of the approximately 29 North American grassland bird specialists between 1966 and 2002, whereas only 3 species showed a significant increase (Sauer et al. 2003). In Manitoba, Savannah sparrows (*Passerculus sandwichensis*) have experienced a -2.8% rate of change in population size from 1997-2007, whereas horned larks (*Eremophila alpestris*) have experienced a more severe decline of 4.3% within the same

time period. The provincially threatened, Sprague's pipit has experienced a mean annual percent change of -4.5% from 1980-1996 continent wide, and a decline of 12.6% from 1988-2008 provincially. The loggerhead shrike (*Lanius ludovicianus*) has declined nationwide by 7.2%, and 12.3% provincially since 1968 (Breeding Bird Survey 2009). Although Baird's sparrows were once one of Manitoba's most common grassland birds (Thompson 1891 in Davis and Sealy 1998), today its range is restricted to the southwestern corner of the province (Rising 1996).

1.2 Grazing as a management tool

1.2.1 Grazing and grassland birds

Responses to grazing differ among grassland birds and the use of grazed habitats may be influenced by season, time of day, or specific activities such as foraging, roosting, displaying, or nesting (Saab et al. 1995). For instance, upland sandpipers (*Bartramia longicauda*) select sites with low vegetation for foraging and prefer moderately dense and tall vegetation for nesting (Rotenberry and Wiens 1980, Saab et al. 1995, Dechant et al. 1999a). By contrast, horned larks and burrowing owls (*Speotyto cunicularia*) consistently respond positively to heavy to moderately grazed pastures, whereas lark sparrows (*Chondestes grammacus*) respond positively to moderately grazed pastures (Kantrud 1981, Kantrud and Kologiski 1982, MacCracken et al. 1985, Bock et al. 1993).

Responses to land management strategies (Temple et al. 1999, Madden et al. 2000) and grazing (Kantrud and Kologiski 1982, Milchunas et al. 1998) may also vary among grassland birds depending on geographical area and species. Although research on

grasshopper sparrows (*Ammodramus sacannarum*) has indicated a positive response to moderate grazing in tall-grass prairies (Skinner 1975, Risser et al. 1981), it has shown a negative response in short-grass, semidesert, and some mixed-grass habitats (Ryder 1980, Kantrud and Kologiski 1982, Bock and Webb 1984), suggesting that they may prefer vegetation of an intermediate height and density. In addition, research conducted in the midwestern United States has found grasshopper sparrows prefer pastures grazed continuously over those grazed rotationally (Temple et al. 1999). Other species have shown weak or variable responses to grazing in different geographical areas, including clay-colored sparrow (*Spizella pallid*), brown-headed cowbird (*Molothrus ater*), vesper sparrow (*Pooecetes gramineus*), and Brewer's sparrow (*Spizella breweri*) (Saab et al. 1995).

Grazing can indirectly affect grassland birds by altering habitat structure, but also directly affect grassland birds by creating disturbances during the nesting season (Paine et al. 1996). Vegetation is a strong indicator of suitable nesting habitats. Effects of grazing on nesting success are inconsistent (Askins et al. 2007). Some studies have found no difference in nesting success between grazed and ungrazed fields (Zimmerman 1996, Klute et al. 1997), whereas others have found grazed pastures had lower nesting success than ungrazed fields (Temple et al. 1999, Sutter and Ritchison 2005).

Changes in vegetation structure due to grazing may influence the distribution and occurrences of grassland birds (Wiens 1981, Herkert 1994, Fondell and Ball 2003). For instance, chestnut collared-longspurs tend to select open prairie habitat with few shrubs (Arnold and Higgins 1986) and prefer grazed pastures over other grassland habitats

(Anstey et al. 1995, Dale 1983 and 1984, Davis et al. 1999, Faanes 1983, Fairfield 1968, Kantrud and Kologiski 1982 and 1983).

Changes in vegetation structure and impacts of grazing may also depend on the distribution of cattle on the pasture. For instance, cattle may select patches of preferred forage plants more than others, creating an uneven distribution of cattle on the field (Fuhlendorf and Engle 2001). Cattle use their environment on multiple scales, including at the landscape scale (their home range) (Howery et al. 1996) and at the patch scale (plant community) (Vallentine 2001). At the patch-scale, individual cattle may select native vegetation or preferred forage plants, whereas at the landscape scale, the herd may be influenced by the physical characteristics of the sites such as upland and riparian areas (Howery et al. 1996). Preferentially grazing of certain areas of the pastures may produce a patchy vegetation structure. Conversely, idle fields and rotational grazing systems may have a more uniform vegetation structure.

Pastures grazed season-long may produce patches of low vegetation cover and cause disturbances to nesting birds due to the constant presence of cattle. Therefore, season-long grazing may not produce suitable habitat for some grassland birds (Kirsch et al. 1978 reviewed in Salo 2003, Jensen et al. 1990). Given that pastures grazed season-long have no rest periods (Holechek et al. 1999), these pastures may be more heavily grazed than twice-over grazed pastures, which have cattle-free periods during the grazing season. Overgrazed pastures may not be used by some grassland birds, such as Savannah sparrows and Sprague's pipits (Kantrud 1981, Davis et al. 1999) because of the increased area of exposed bare ground and decreased amount of litter and vegetation cover. In contrast, horned larks typically use continuously grazed pastures (Temple et al. 1999),

and prefer low vegetation cover (Rotenberry and Wiens 1980, Dale 1983, Prescott and Murphy 1996). Differences in habitat requirements among grassland birds and management factors such as stocking rates and grazing intensities can produce variation in responses to grazing (Holechek et al. 1999). Having evolved with large grazing mammals, many endemic species have high densities on grazed pastures, such as chestnut-collared longspur (Kantrud 1981, Knopf 1996). Therefore, well managed grazing regimes may benefit both livestock and wildlife (Barker et al. 1990). Grazing programs that promote lower stocking rates may be more beneficial to prairie habitat.

In comparison to many grazing programs, twice-over rotation systems have closely monitored stocking rates to prevent overgrazing while aiming to maximize economic return (Biondini and Manske 1996). To evaluate the success of different grazing management practices, the influences of grassland condition on grassland bird habitats must be better understood.

1.2.2 Rotational grazing

In the late 1890s, ranchers were encouraged to adopt rotational grazing methods to improve rangelands on the Great Plains (Smith 1895 in Heady 1961, Coughenour 1991, Holechek et al. 1998). Although range managers experimented with grazing systems from 1920-1950 (Coughenour 1991, Holechek et al. 1998), interest in specialized grazing systems increased around the 1970s because of their potential for rangeland improvement and beef production (Barker et al. 1990). Many forms of specialized grazing systems are practiced in North America; some of the most common include deferred-rotation, rest-rotation, and short-duration/high-intensity (Holechek et al. 1998).

Rotational grazing systems claim to be more beneficial than traditional grazing systems for three main reasons (Briske et al. 2008). First, they claim to increase plant productivity and species composition by allowing for periods of rest between grazing events. The second assumption is that stocking rates can be increased to control selective grazing by cattle in order to use forage more uniformly and, finally, the increased fencing supposedly improves cattle distribution on the field (the dispersion of livestock within a pasture). Although the management and logistics of each rotational method vary, including number of paddocks, cattle stocking rates, and length of rest time between grazes, specialized grazing systems in general aim to produce higher yields and weights of cattle (Briske et al. 2008).

Rotational grazing systems involve alternating among paddocks for grazing, allowing each paddock a period of rest during the grazing season (Briske et al. 2008). The rest period characteristic of rotational grazing systems is considered an important phase for vegetative growth and seed production. The seedlings and new plant growth increase the amount of forage available for livestock (Savory 1988).

The rest period of rotational grazing also has the potential to be more compatible with nesting birds because some pastures are left cattle-free during May and June, which coincides with important breeding seasons of many grassland birds (Barker et al. 1990, Severson 1990, Pease 2003). Pastures left free from cattle disturbances may also benefit other wildlife (Holechek et al. 1999) by leaving breeding areas free from trampling and grazing for a period. However, because cattle are confined to a smaller area in rotational grazing systems than in season-long, the higher density of cattle may produce a greater disturbance to nesting birds than season-long grazing. Additionally, the second

assumption of rotational grazing systems is that stocking rates can increase sustainably by 1.5-2 times that of traditional grazing systems such as season-long (Savory 1988), which results in an increase in stocking density (animals per unit land) (Briske et al. 2008). Forage plants may mature with long rest periods at low stocking densities, making them less palatable and favourable to grazers, therefore an increase in stocking rate may improve utilization of forage on the field (Briske et al. 2008). As stocking rates may not remain consistent, the increased density of cattle per paddock may have further impacts on nesting grassland birds. However, nesting success studies may provide more information on the effects of rotational grazing systems on the breeding success of grassland birds.

The final assumption is that the increased field divisions improve the distribution of the herd creating a more uniform grazing pattern (Heady 1961), which may result in a more homogeneous landscape with fewer patches of high use and of lowered use (Bock et al. 1993, Saab et al. 1995). Although controlling the distribution of cattle on the pasture and increasing stocking densities may limit selective grazing (Savory 1988), individuals may be influenced by animal interactions within the herd (Coughenour 1991, Howery et al. 1996, Provenza 2009) and may still graze selectively at the patch scale. This may produce a heterogeneous environment at the patch-scale but a homogeneous habitat at the landscape scale. Many endemic grassland birds evolved within a heterogeneous landscape that supports a range of vegetation structures and habitats (Knopf 1996). Therefore grazing patterns that generate homogeneous landscapes may not produce the variety of habitats required to support a diversity of grassland birds.

1.3 Twice-over grazing systems

The twice-over rotation grazing system differs from other forms of rotational grazing in that it is based on the growing cycle of native grasses and aims to increase productivity of native plants. The increased productivity of native vegetation is believed to increase the aboveground herbage biomass, amount of vegetative cover, and decrease the number of bare patches. The increase in aboveground herbage biomass may permit landowners to increase stocking rates on twice-over pastures (Manske 2004). Proportion of native vegetation may be good indicators of the densities of some grassland birds, such as Baird's sparrows, bobolinks (*Dolichonyx oryzivorus*), and grasshopper sparrows (Madden et al. 2000). Grasslands dominated by introduced vegetation may be less attractive for many granivorous birds because of the reduced plant diversity and consequently low seed diversity (Wilson and Belcher 1989).

Three to six paddocks are required for the twice-over rotation system and each paddock is grazed twice during the grazing season. The grasses are grazed for the first time once they have reached the three-leaf stage and before they begin to flower, to increase tillering (the production of shoots, leaves, and roots) and, consequently, increase new grass production (Milchunas et al. 1988, Briske 1991, Briske and Richards 1994 and 1995). The removal of the axillary bud and apical dominance permits the shoots to grow and increase plant density (Holechek et al. 1998, Taiz and Zeiger 2002). The new grass produced, or 'second growth', is then available for grazing during the second rotation. Similarly, it is important to graze before the grasses begin to produce seeds (boot-stage), when much of the available protein will be allocated to the seeds and will no longer benefit the grazers (Pitt 1986).

The timing of the reproductive phase depends on the plant species, which is often before 21 June for many cool-season plants (C₃-plants) and after 21 June for many warm-season plants (C₄-plants) (Manske 2004). Therefore, twice-over rotation grazing systems require landowners to follow a schedule to ensure the optimal amount of time is allocated to both the grazing period and recovery period.

For a pasture to qualify for a twice-over agreement with the Manitoba Habitat Heritage Corporation (MHHC), it must contain a minimum of 30% native grass species composition and has likely not been cultivated since the 1950s or with no evidence of cultivation (K. Murray, Manitoba Conservation, personal communication). Pastures that qualify for the twice-over rotation system must have a minimum of a C grade, which is based on a standard set by Manitoba Conservation Data Center for mixed-grass grading guidelines. This guideline is also based on the amount of non-native species present on the pasture (Greenall 1996). Since the amount of native and non-native vegetation may influence bird abundances (Davis and Duncan 1999), all season-long pastures selected for this study also had a certain degree of native vegetation. Native vegetation may be more beneficial to grassland wildlife than non-native vegetation. Fletcher and Koford (2002) have found that restored grasslands in the Midwest containing few endemic vegetation species did not have the same level of diversity or structure of native grasslands (Fletcher and Koford 2002). Additionally, non-native vegetation, such as leafy spurge (*Euphorbia esula*), may influence the availability and diversity of seeds and insectivorous prey preferred by grassland birds (Wilson and Belcher 1989). Therefore, if twice-over rotation grazing systems can increase the productivity of native grasses, it may provide suitable habitat for native grassland birds.

1.4 Habitat preferences of prairie birds

Understanding the habitat requirements of grassland birds may help determine the causes of declines in grassland bird populations (Askins et al. 2007). Grassland birds use a variety of vegetation and landscape cues in habitat selection such as vegetation cover and structure (Sutter and Brigham 1998, Davis et al. 1999). These vegetation characteristics have been used as cues for habitat selection by many grassland birds (Patterson and Best 1996, Vickery and Gill 1999, Fondell and Ball 2003). For instance, the proportion of grass may influence the abundances of some grassland birds such as Savannah sparrows and grasshopper sparrows (Schneider 1998). Sprague's pipits tend to prefer habitat with little to no shrubs, (Robbins and Dale 1999, Madden et al. 2000), tall, relatively dense vegetation, and little bare ground (Dechant et al. 1998*d*). Vegetation structure can also provide shelter for nests for many grassland birds, such as vesper sparrows, which prefer taller vegetation to conceal nest sites (Ehrlich et al. 1988).

2.0 INTRODUCTION

2.1 Definition of terms

Grazing is defined here as the consumption of grasses and forbs by livestock. Browsing is the consumption of leaves and twigs from trees and shrubs. Livestock both graze and browse (Holechek et al. 1998, Provenza 2009).

Cattle grazed season-long are pastured for the duration of the growing season. In southwestern Manitoba, this is typically from late May to early October, or as long as the weather permits. As continuous grazing may be interpreted as cattle pastured yearlong on a range unit (Heady 1961, Holechek et al. 1998), season-long grazing is used here instead of continuous grazing because producers in southwestern Manitoba may practice different grazing methods during the winter. Some producers graze their cattle on separate pastures reserved for winter where they provide bales of hay for feeding. Pastures with a relatively high degree of forested area are preferred for overwintering in Manitoba because they provide shelter for cattle. The twice-over rotation system reviewed in this study involves spring and summer grazing only. Producers must remove cattle from twice-over pastures by 15 October; therefore, pastures grazed seasonally and not during the winter were a suitable comparison.

I used the definition of stocking rate proposed by Holechek et al. (1998), who defines stocking rate as the number of animal units grazed on an area of land during a month (AUM/acre) or for the grazing season. An animal unit is defined as one mature cow (1,000 lbs) with or without a calf up to approximately 6 months old (Society for Range Management 1989, Holechek et al. 1998). I calculated stocking rates and not

stocking densities (defined as the number of animal units on a specific section of land, such as a paddock, for a particular grazing period (Manitoba Conservation 2010)).

Specialized grazing systems refer to all forms of rotation and deferred grazing that involve moving cattle among a minimum of two paddocks, such as rotation, deferred, rest-rotation, and deferred-rotation grazing (Heitshmidt and Taylor 1991, Briske et al. 2008). A rest period in the twice-over program refers to the amount of time that a paddock is left cattle-free during a grazing season, whereas generally a rest period may refer to a pasture left livestock-free for the entire length of the season in a rest-rotation (Holechek et al. 1998). Normally the aim of cattle-free periods is to allow the vegetation time to recover (Holechek et al. 1998).

Idle fields in this study are defined as fields that are unmanaged, in other words they are not actively grazed, mowed, burned, or cultivated. The idle fields surveyed in this study have been left unmanaged for a minimum of 5 years.

To evaluate the contribution of twice-over rotation grazing systems to grassland habitat for grassland birds, I categorize songbirds into three groups according to the classification of grassland birds proposed by Vickery et al. (1999): obligate grassland birds, facultative grassland birds, and non-grassland birds. Obligate grassland birds require grassland habitat to carry out at least part of their life history, whereas facultative grassland birds are not dependent on grasslands for their life histories, but use them regularly. Although both groups of grassland birds may be affected by loss of suitable prairie habitat, obligate grassland birds are likely to be affected more severely, and would become extirpated from the region if grassland habitat was entirely eliminated (Vickery et al. 1999). Any bird that did not fall into one of these two categories was classified as a

non-grassland bird. Since the encroachment of woody vegetation in southwestern Manitoba is common on all sites and especially those that are left unmanaged, this primarily consisted of forest birds, including wood-warblers, woodpeckers, and flycatchers.

Species richness refers to the total number of species within a community (Krebs 1999). However, I referred to species richness here as the number of species surveyed within a point-count plot (3.2 ha), sometimes defined elsewhere as species density. I define relative abundance here as the total number of individuals of each species per point-count plot, and the total bird abundance as the total number of individuals of all species per plot. I defined species diversity as the number of species including their relative abundances observed per point-count plot (Wiens 1989).

2.2 Background

Grasslands were once the most extensive ecosystem in North America (Johnson and Igl 2001). Today, native prairie regions have experienced vast reduction in their area continent-wide, from 30-99% (Samson and Knopf 1994) relative to historical prairie extents. The loss and degradation of native prairie habitat has likely contributed to reductions in grassland bird populations (Johnson and Igl 2001), which have experienced severe declines over the last 50 years (Knopf 1996). In recent decades, pesticides, invasion of woody vegetation, and habitat fragmentation of North American grasslands, caused by the conversion of native grassland to crop lands, farm lands, and urban developments (Knopf 1994, Vickery et al. 1994, Peterjohn and Sauer 1999, Madden et al. 2000), has had significant impacts on native grassland bird populations (Herkert 1994, Igl

and Johnson 1997). However, sustainable land management in the remaining prairies may help to reduce the effects of declines in grassland bird breeding habitat (Herkert 1994, Johnson and Igl 2001).

Historical “ecological drivers” that maintained the mixed-grass prairies were drought, grazing, and fire (Knopf and Samson 1997, Askins et al. 2007), all of which have played a significant role in the evolution of grassland species (Knopf and Samson 1997). Fire played a critical role in suppressing the encroachment of woody vegetation on moist mixed-grass prairies, while grazing helped to maintain prairie vegetation composition and structure (Askins et al. 2007). These processes are termed ‘drivers’ because they were relatively continuous, common, and frequent, and are required for maintaining the grassland ecosystem (Askins et al. 2007). However, current land management practices that suppress burns, control drought, and remove grazers actually cause disturbance to the grassland ecosystem because they inhibit or alter these natural processes (Knopf and Samson 1997, Askins et al. 2007).

Grazing by livestock is a primary use of native prairie grassland. Historically, native grazers of the mixed-grass prairie included a number of large ungulates and smaller mammals, such as bison (*Bison bison*) and prairie dogs (*Cynomys* spp.) (Askins et al. 2007). Although the prairies were grazed by free-roaming bison herds, due to differences in morphology and behaviour, grazing by cattle may have very different effects on the land (Hartnett et al. 1997, Johnson and Igl 2001). The removal of native grazers and the introduction of grazing systems by domestic livestock altered the historical grazing pressure and likely had large effects on grassland bird habitats (Samson et al. 2004). Free-roaming bison once numbered in the tens of millions (Knopf and

Samson 1997), however, now only re-introduced herds of plains bison (*Bison bison bison*) exist in the province in captivity, for instance in Riding Mountain National Park. Although not native to Manitoba, one herd of introduced wood bison (*Bison bison athabascaae*) exists in Manitoba at Chitek Lake (Manitoba Conservation 2009a) and the species is now considered protected under the Manitoba Wildlife Act (Wildlife Act 2009).

Many grassland bird species may have adapted to the grazing patterns of nomadic bison herds and to the habitats this grazing produces (Knopf 1996, Fuhlendorf and Engle 2001). The grazing cycles of free-roaming bison contrast with regional patterns of grazing by livestock, as traditionally cattle are grazed each year in one pasture for the duration of the spring-fall season; often referred to as season-long grazing. However, grazing patterns similar to historical ones, where vegetation is grazed heavily early in the season followed by a period of rest and recovery, may increase the productivity of grassland vegetation (Frank and McNaughton 1993). Although twice-over grazing may benefit native grasses and livestock (Manske 2004), to the best of my knowledge, no research has been conducted on the effects of twice-over rotation on grassland songbirds in the mixed-grass prairie region of southwestern Manitoba.

2.3 Problem statement

The historical extent of Canada's mixed-grass prairies covered approximately 24 million ha, whereas presently it covers less than a quarter of that amount (Manitoba Conservation 2009b). Less than 18% of the historical amount of native vegetation remains in the southwestern part of the province (Nernberg and Ingstrup 2005). Land

improvement strategies, such as mowing, burning, and grazing, may encourage the growth of native vegetation and control the invasion of non-native vegetation. Grassland bird habitats on both the breeding and wintering grounds have been affected by the conversion of grassland habitat to cropland or urban developments, and by the alteration of historical grazing patterns, and the suppression of fire (Askins et al. 2007).

The mixed-grass prairie of southwestern Manitoba is a critical area for grassland birds (DeSmet and Conrad 1991, Davis and Sealy 1998), particularly for many rare prairie birds whose northern edge of their range is within Canada (Bird Studies Canada 2009). Of these are the nationally and provincially endangered burrowing owl, the nationally and provincially threatened Ferruginous hawk (*Buteo regalis*) and Sprague's pipit; the nationally threatened and provincially endangered loggerhead shrike; the nationally threatened chestnut-collared longspur (as of November 2009), and the provincially endangered Baird's sparrow (COSEWIC 2009, Manitoba Conservation 2009c). Although Baird's sparrow is no longer considered at risk nationally, it is close to becoming extirpated from Manitoba (Manitoba Conservation 2009c).

2.4 Research objectives

The overall goal of this project was to identify the effects of twice-over rotation grazing on native grassland birds. This was achieved by evaluating the diversity and densities of grassland birds on twice-over rotationally grazed pastures in comparison with pastures grazed season-long and ungrazed "idle" fields. In addition, a long-term goal of this study was to provide information regarding habitat requirements of grassland birds and their responses to grazing practices.

My objectives were:

1. To compare the diversity and densities of breeding grassland bird species present on twice-over rotation grazed pastures, pastures grazed season-long, and idle fields.
2. To determine the effects of grazing management on vegetation structure.
3. To determine the extent to which grazed pastures are used by threatened and vulnerable species.

2.5 Hypotheses

2.5.1 Occurrences and abundances of grassland bird species

The twice-over rotation grazing system claims to promote the growth of native vegetation through increased tillering, and to produce suitable habitat for wildlife (MHHC 2002, Manske 2004). Therefore, if native vegetation is preferred by grassland birds (Wilson and Belcher 1989), my first prediction was that species richness and abundances of grassland birds would be greater on twice-over rotation sites than sites grazed season-long. The twice-over rotation grazing system also claims to increase the productivity of native grasses (Manske 2004); therefore, if native vegetation influences habitat structure or increases the abundance of preferred food items such as invertebrate prey or seeds, then it would be expected that native grasses would produce preferred habitat for grassland birds.

Grazing and other ecological disturbances help produce and maintain prairie habitats for grassland birds, for instance by controlling the expansion of woody vegetation in the mixed-grass prairie region of southwestern Manitoba. Therefore, I also

tested the hypothesis that grazed sites would have a higher species richness and abundance of grassland birds than ungrazed fields.

2.5.2 Effects of management on vegetation

I also predicted that differences among the management regimes would produce different habitat structures thus supporting different avian communities, which would be reflected by different vegetation structure and bird species composition among treatments. Specifically, rotational grazing claims that the cattle-free periods allow for more vegetative growth (Savory 1988). Therefore I predicted the vegetation would be denser and taller on the twice-over rotation sites with less exposed bare ground than sites grazed season-long sites. Twice-over rotation grazing also claims to increase above ground herbage biomass through increased tillering of native grasses (Manske 2004); therefore, I also tested the hypothesis that twice-over rotation sites would have more grass cover than sites grazed season-long.

2.5.3 Effects of management on species at risk

The species at risk found in southwestern Manitoba are obligate and facultative grassland birds that require grassland habitat for all or some of their life history requirements. Therefore, to evaluate the contribution each management regime has in providing habitat to vulnerable and at risk species, I tested the hypothesis that grazed sites would support a higher proportion of at-risk grassland birds than ungrazed fields if high-quality prairie habitat is maintained through grazing.

2.6 Contributions

This study aims to further our knowledge and understanding of prairie conservation, native prairie birds, and grazing practices. The comparison between traditionally grazed pastures to twice-over rotation grazing systems will provide the opportunity for landowners to make informed choices towards sustainability. This is the first study to look at the effects of twice-over rotation grazing on the grassland bird communities and their habitat; therefore, results from this project will improve our understanding of the contribution of twice-over rotation grazing on the conservation of grassland birds in southwestern Manitoba. Additionally, the results from this study will contribute to the development of more sustainable land-use management programs and grazing regimes. It will also provide information on habitat preferences for the species at risk in this study, which will help further our conservation efforts to support threatened and vulnerable prairie bird species.

2.7 Limitations

Reproductive success may not be correlated with grassland bird densities (Vickery et al. 1992a); therefore, conclusions about reproductive success cannot be made. Studies based on nest-searching and bird-banding data can provide more direct information about source and sink dynamics or breeding success (Van Horne 1983). However, studies based on breeding behaviours (i.e., New Reproductive Index, Vickery et al. 1992b) were not feasible for the scope of this study. Given the large size of the study area and number of species of interest, species abundance data are the most cost- and-time effective approach (Madden et al. 2000).

Other factors influencing the occurrence of specific bird species on particular pastures could be due to microhabitats within fields, the presence or absence of marshes, wetlands, streams, and ponds; edge effects, such as proximity to forests, topography of the field (i.e., lowland or highland areas), soil composition; and vegetation structure, including species composition and density. However, to minimize these effects, treatments were dispersed across the landscape and throughout the study area, and the effects of landscape characteristics on bird abundances were determined. In addition, each rural municipality contained at least 1 pasture from each grazing treatment, to maximize dispersion and minimize bias among treatments that might result from differences in topography, geography, or vegetative characteristics among sites. I also used ground truthing data to omit non-grassland habitats, such as ponds and marshes, from sites of all treatments to calculate the total amount of grassland per site. The proportions of forested area and amount of edge were calculated for each site to determine the effects of landscape characteristics on bird abundances and to control for variation in these characteristics among pastures.

3.0 METHODS

3.1 Study area

My study area was located within the Aspen Parkland ecoregion of southwestern Manitoba, extending from the Saskatchewan and North Dakota borders (49°02'81.78"N, 101°25'74.17"W), to approximately 145 kilometers north (50°17'74.57" N, 101°23'91.46"W), and about 106 kilometers east (49°89'96.54"N, 100°40'76.44"W). The area is situated within the mixed-grass prairie ecosystem of Manitoba and the riparian zone of the Assiniboine River. The mixed-grass prairie ecosystem is composed of species found in both the tall-grass and short-grass prairie ecosystems (Bragg and Steuter, 1996). The landscape is heterogeneous, consisting of valleys, riparian zones, and both upland and lowland areas. Although most of the area is grasslands, small aspen stands and forests are scattered throughout the area. Overall, the study area consisted primarily of grazed pastures and agricultural fields.

Native grass species commonly found within the study area included northern wheatgrass (*Elymus lanceolatus*), western wheatgrass (*Pascopyrum smithii*), slender wheatgrass (*Elymus trachycaulus*), big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), blue grama (*Bouteloua gracilis*), sedges (*Carex* spp.), salt grass (*Distichlis spicata*), switch grass (*Panicum virgatum*), and needle and thread (*Hesperostipa comata*). Common non-native grass species were crested wheatgrass (*Agropyron cristatum*), quack grass (*Elymus repens*), smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*) (Flora of North America 2007, USDA 2010).

A variety of native and non-native forb and shrub species inhabited the area. Prairie crocus (*Anemone patens*), pasture sage (*Artemisia frigida*), pussytoes (*Antennaria* spp.), three-flowered avens (*Geum triflorum*), and vetchling (*Lathyrus* spp.) were common native forb species. Leafy spurge was a common non-native forb species. The most common native shrubs were western snowberry (*Symphoricarpos occidentalis*) and wolf willow (*Elaeagnus commutata*), both of which are cool season plants (USDA 2010). Wolf willow grows in areas of high moisture and was found in dense stands on many of the sites sampled. Western snowberry, also called wolfberry, is one of the most widespread and common shrubs found in pastures in southwestern Manitoba, where it grows primarily on dry pastures and hillsides (Moore 2003).

Only pastures subjected to one of two grazing systems, twice-over rotation or season-long, were studied. Producers who graze their cattle season-long generally start grazing in May and remove cattle from pastures by the end of October. In the twice-over program, cattle are pastured between 1 June and 15 October of each year (MHHC, 2002). Study sites were interspersed throughout the rural municipalities of Albert, Archie (2008 only), Arthur, Cameron, Daly, Edward, Pipestone, Sifton, Wallace, and Woodworth, in southwestern Manitoba (Figure 1).

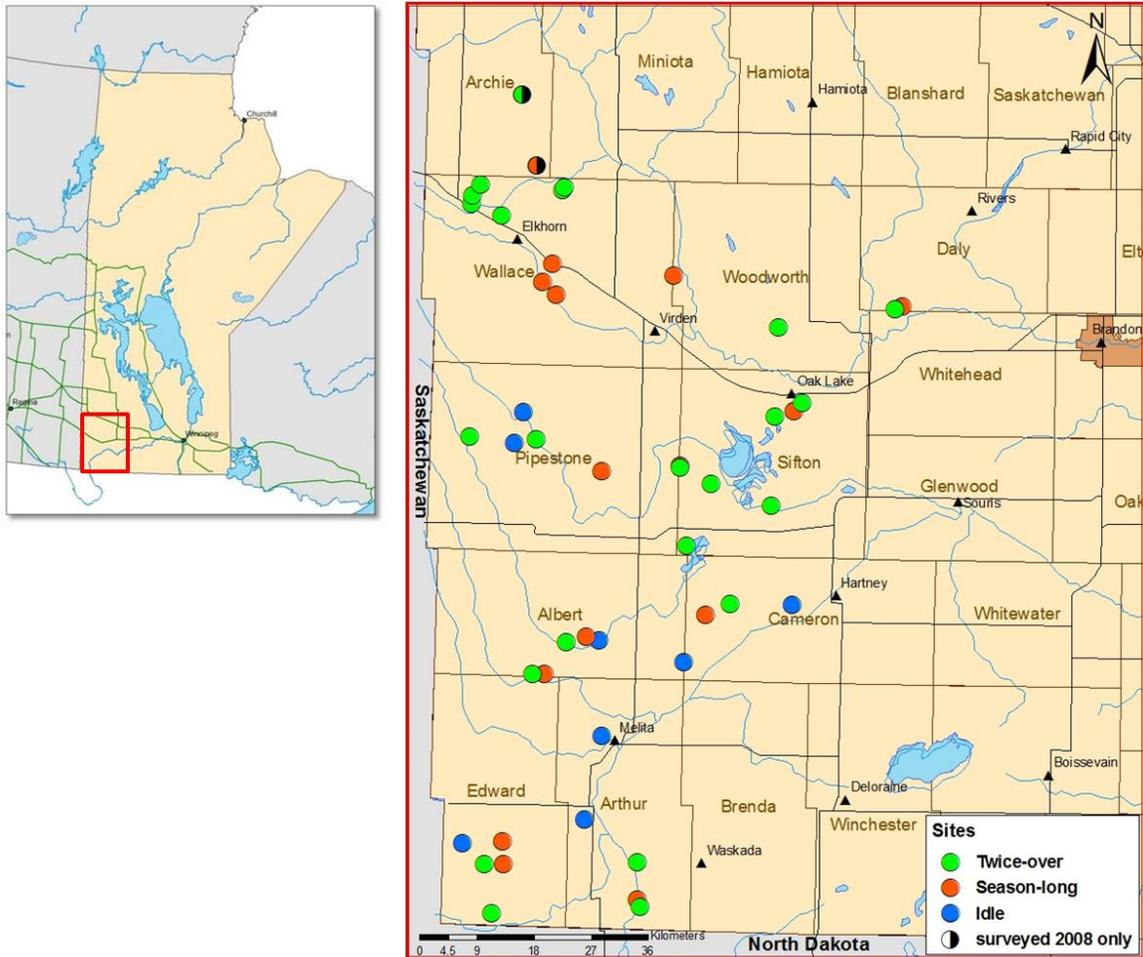


Figure 1: Study site locations in southwestern Manitoba for 2008 and 2009, identified by treatment.

3.2 Experimental design

I evaluated bird population densities and habitat selection in pastures grazed using twice-over or season-long systems, and idle fields. Farmers rotated cattle between three-to-six paddocks in the twice-over system, whereas pastures grazed season-long were not divided into paddocks, and cattle grazed the entire field during the season. Approximately 75% of the idle fields surveyed were Provincial Wildlife Management Areas (WMAs) owned and managed by Manitoba Conservation.

I surveyed 45 and 43 study sites during the 2008 and 2009 field seasons, respectively. Sites ranged from 0.65 to 2.6 square km (65 ha to 260 ha). Twenty-two sites were grazed following the twice-over rotation system, 15 were grazed continuously (in 2008), and 8 sites were idle. Two sites, with a total of 14 point-count plots, were omitted from the 2009 surveys in the RM of Archie, one from each grazing regime due to a change in management by the landowner. The rotational pastures surveyed in this study had been in the twice-over system for 2-7 years and had a mixed-grass prairie inventory grade of B to C+ according to the Manitoba Conservation Data Center guidelines. The idle sites remained the same for both field seasons. I had planned to survey 10 idle sites, but only 8 suitable sites could be found within the study area. Wherever possible, study sites were located 1-4 kilometers apart to ensure pastures were not spatially correlated. However, this was not possible for 11 of the sites because the availability of pastures grazed season-long was limited.

3.3 Effects of grazing management on songbird habitat and community structure

To evaluate differences among grazing management regimes and help control for other variation in cattle management, I used management information on stocking densities and dates the cattle were pastured for both season-long and twice-over rotational grazing sites to calculate relative stocking rates for both surveying years. I multiplied the number of cow-calf pairs by the number of months they were pastured and divided by the total site area to give the animal unit months per acre (AUM/acre) (Holechek et al. 1998), then I compared actual stocking rates between grazing regimes. I used this information to determine whether there was a significant difference in stocking rates between sites grazed season-long and sites grazed twice-over rotationally.

3.3.1 Determination of songbird occurrences and abundances

Songbird surveys were conducted within 4-8 randomly placed 100-m fixed-radius point-counts plots in each site. Point-count surveys were chosen because they provide a good indication of the relative abundances of songbirds at the time of survey (Bibby et al. 1992), and enable sampling of large study areas in a relatively short amount of time. Although point-count surveys may over or under estimate population densities, for instance by failing to detect non-breeding individuals, it is estimated that over 95% of grassland songbirds can be detected up to a distance of 125 m from the observer (Ralph et al. 1995).

Point-counts were conducted from sunrise to 1000 hrs in May, but end time was gradually shifted to 0900 hrs as temperatures rose towards the end of June, and songbird activity, for instance singing, begins to decline (Ralph et al. 1995, Lynch 1995). Surveys were not conducted during rain and wind \geq 16-km/hr (Robbins 1981).

Four observers conducted two rounds of point-counts from 22 May to 27 June 2008, and from 21 May to 20 June 2009. Observers sampled sites from each of the three treatments to minimize effects of observer bias. The second round of songbird surveys was conducted immediately after the first round ended. In 2009, 3 sites were heavily flooded in early May and were left until later in the sampling period to allow time for the flood water to recede.

Point-count periods can be divided into intervals to allow for removal sampling, which may compensate for variability in detection among bird species (Farnsworth et al. 2002). Therefore, point-counts were divided into 4 periods; the first two were 2 minutes long and the last two were 1 minute each for a total of 6 minutes. Observers started each period facing north, and recorded all the birds seen and heard singing or calling within the point-count area, including birds flying overhead. Also recorded were behaviours such as singing, calling, flying, conflict, roosting, foraging, and carrying nesting material. The sex of the individuals of sexually dimorphic species was noted, and all singing individuals were assumed to be male.

Point-count plots should be set up such that the radius is as large as possible while still allowing a reasonably accurate detection of all birds of interest within the area (Hutto et al. 1986). Because the openness of the grasslands enabled a large detection area (Cody 1985), all point-counts had a fixed radius of 100 m, with interplot distances a minimum of 300-400 m apart from adjacent point-count centers to avoid recounting individuals and to maximize coverage of the field (Bibby et al. 1992). Point-count plots were positioned in a random systematic grid (Quinn and Keough 2002), a minimum of 50 m from roads and the edges of the field. The first plot was located by walking a random

distance from 50-100 m, generated by a random numbers table, in the north-south direction, and again in the east-west direction from the edges of the field. Subsequent plots were arranged systematically from the first plot location to avoid observer bias in selecting plot locations (Pendleton 1995). Plot locations formed two linear transects parallel to each other along the length of the field. I collected data in 2008 from a total of 301 plots (3.2 ha): 178 plots in twice-over rotation pastures, 102 in pastures grazed season-long, and 21 in idle fields. Idle fields had the lowest number of plots because of the high degree of woody vegetation encroachment and small amount of suitable grassland habitat present on the sites. Twenty-seven point-count plots had to be omitted during the 2009 surveys due to flooding, mowing, burning, cultivation, or grazing by horses: 15 plots on twice-over grazing treatments, 8 plots on season-long sites and 4 plots on idle fields.

Features such as dugouts, roads, wooded areas, fences bordering the edges of the fields, and bodies of water (marshes, streams and ponds) were avoided to maximize the amount of grassland sampled. If necessary, point-count locations were shifted from the stratified grid pattern to ensure fixed structures were not included within the area. If it was not possible to avoid non-grassland habitats within point-count plots, ground truthing data were taken to calculate the total area of grassland sampled. The presence of marshes on site was recorded because this would influence the species composition of both the birds and the vegetation, and may affect grazing habits of the cattle (Wiens 1969, Vallentine 2001).

3.3.2 Determination of vegetation structure

Vegetation surveys were conducted between 22 May 2008 and 14 June 2008, and 20 May and 5 June 2009, which is the period that coincides with most species of grassland songbirds selecting and establishing breeding territories (Wiens 1969). Vegetation for each site was sampled 1-4 days after the avian survey. In 2008, 2 vegetation plots were surveyed within each point-count plot, at a random distance of 0-100 m along two randomly chosen cardinal directions. However, 4 vegetation plots per point-count plot were surveyed in 2009 to better represent the vegetation structure within each plot, one in each cardinal direction at a random distance of 0-100 m from the point-count plot centre. Vegetation surveys included several vertical and horizontal structural measurements.

Litter depth and vegetation height were measured using a meter stick, and visual obstruction measurements (VOM) were taken to determine vertical cover using a Robel pole (Robel et al. 1970). For this study, dead plant material lying on the ground was considered litter (Facelli and Pickett 1991). A visual estimate for percent cover of shrubs (all woody vegetation), forb species, litter, standing grasses (dead and alive), and bare ground within a 1-m by 1-m square located at the vegetation plot center, was based on methods by Daubenmire (1959). Percent cover of rocks and cow patties was also recorded. Distances from the centre of the quadrat to trees, shrubs, streams, roads, dug outs, and cow patties were visually estimated by the observer.

3.3.3 Determination of landscape characteristics

Sites were composed of either 100% open area or contained varying amounts of forest cover. Open areas were grass and forb dominated areas with few shrubs and no forest patches. Ground truth data were collected during the 2009 field season to

determine the ratio of open-to-forest area within each pasture. Open areas were measured by marking the perimeters of the grassland patch using a hand-held GPS unit (Garmin GPSmap 60). These points were digitized into polygons in ArcMap version 9.3. Polygon areas were calculated to determine the proportions of open and treed areas present on the site, and polygon perimeters were calculated to determine the length of tree edge for the site. Wooded areas, ponds, streams, oil rigs, or other obstructions were ground truthed in the field or clipped out in ArcMap. The proportion of open area, proportion of trees, length of tree edge, and total site area was then calculated for each site. Surveyed sites were surrounded by a variety of matrix habitats including woodlands, cultivated fields, or pastures.

3.4 Data analysis

After speaking with landowners in 2009, it was discovered that a few season-long producers were grazing their cattle rotationally and not season-long as expected (SE, SW 2-11-22W, 6 point-count plots total, and NW 19-11-27W, with 4 point-count plots total). These sites were therefore omitted from analysis. In addition, although all producers participating within the twice-over rotation program were expected to follow the protocol accordingly, there was evidence of some variability in stocking rates and rotation dates among producers within the twice-over rotation program. Since this study was concerned with how the twice-over grazing system would be implemented by landowners, it was appropriate to include these data in the analysis.

Only songbird species were considered for analysis. Although recorded during surveys, waterfowl, herons, cranes, and goatsuckers were omitted from analysis.

Songbirds were separated into three groups based on their degree of association to grassland habitats: obligate, facultative, and non-grassland birds (see section 2.1).

I also modeled effects of management on the following ten grassland birds as they were common and were present on sites of all treatments in both years. Six species were obligate grassland birds: bobolink, Le Conte's sparrow (*Ammodramus leconteii*), Savannah sparrow, vesper sparrow, western meadowlark (*Sturnella neglecta*), and Sprague's pipit; and 4 species were facultative grassland birds: clay-colored sparrow, eastern kingbird (*Tyrannus tyrannus*), red-winged blackbird (*Agelaius phoeniceus*), and brown-headed cowbird. Many grassland birds may be suitable hosts for brown-headed cowbirds, making this species also of management concern (Davis and Sealy 2000).

Species richness was calculated as the total number of species recorded per point-count plot (3.2 ha). Measurements of heterogeneity were calculated using the Shannon-Wiener heterogeneity index because it is sensitive to the rare species in the community (Wiens 1992, Krebs 1999). Rare species were of interest because these may include species at risk in southwestern Manitoba.

Similarity tests (Sørensen's indices) were conducted on all bird species observed during surveys to determine whether species composition differed among treatments. Sørensen's coefficients were determined between each pair-wise treatment to determine the number of species in common among treatments. Since there was an unequal number of sites and point-count plots among the three treatments and Sørensen's index is sensitive to sample size (Wolda 1981), I randomly selected an equal number of sites and plots from each treatment for analysis. The idle treatment had the lowest number of sites (8) and plots (21 in 2008 and 17 in 2009) compared with season-long and twice-over

sites, therefore I selected 8 sites at random from both grazing regimes, each with 21 plots in 2008 and 17 plots in 2009.

Sørensen's index (also called Dice's Coefficient) is a type of binary coefficient because it compares presence-absence data among treatments, whereas Sørensen's Quantitative index (also known as Czekanowski index) takes the species' relative abundances into consideration (Bloom 1981, Wolda 1981, Lyman 2008) (see Appendix IX). Sørensen's binary index emphasizes similarities between samples, whereas other similarity indices, such as Jaccard's index, emphasizes differences (Magurran 2004). Sørensen's qualitative index shows how the communities differ in species richness, whereas Sørensen's quantitative index indicates how the communities differ in species diversity. The quantitative index may, therefore, provide a more precise estimate of community structure among treatments. Sørensen's quantitative index gives among the most accurate representation of species overlap in a community when compared to other similarity indices (Bloom 1981, Southwood and Henderson 2000, Magurran 2004). Both Sørensen's quotients, binary and quantitative, were calculated for each pair-wise combination of treatments.

I calculated the relative abundance for each species and the total bird abundance per plot. Data were analyzed at the plot-scale to control for variation in number of plots among sites of each treatment. Calculations of species richness, species diversity, similarity indices, and relative and total abundances were conducted in MS Excel 2007.

I used generalized linear mixed models (GLMMs), in SAS version 9.2, (PROC GLIMMIX), to determine the relationships among treatment, landscape characteristics, vegetation characteristics, and bird abundances. GLMMs were suitable for this study for

a number of reasons. First, GLMMs are extensions of fixed effects models that accommodate for random and mixed effects, allowing inferences to be made beyond the sites surveyed (Bolker et al. 2008). In this study, the random factors were the study sites with the point-count plots and the fixed factors were the grazing treatments (twice-over rotational grazing, season-long grazing, and idle fields). GLMMs also combine characteristics of both linear mixed models, such as random effects, and generalized linear models (GLMs), to accommodate for non-normal distributions of the response variable (Littell et al. 2006). In my study, my response variables were bird abundances, which were non-normally distributed count data. In addition, GLMMs can handle both categorical and continuous data, which were treatment and bird data respectively (Littell et al. 2006). GLMMs were also suitable for this study because they accommodate samples that may be correlated with each other, which may occur when observations are taken from the same site or are nested (Bolker et al. 2008). Since I had multiple point-count plots per site and a number of sites per treatment, observations could have been correlated due to similarities among plots within pastures, such as the herd, topography, and other geographical factors. Sub-samples (point-count plots) in a hierarchical data set are treated as replicates instead of averaging by site, which would result in a loss of information allowing for analysis at the plot-scale since point-count plots within a pasture cannot be treated independently from each other (Koper and Schmiegelow 2006a).

An alpha value of 0.10 was set as the level of significance to reduce the risk of committing a Type II error. Although many biological studies use an alpha level of 0.05 to minimize the risk of committing a Type I error, for studies involving environmental monitoring, conservation, and impact assessment, committing a Type II error may be

more critical; failing to detect an effect when there is one may lead to increased environmental degradation (Quinn and Keough 2002).

I used GLMMs to determine the effects of management regimes on vegetation characteristics and on species richness, diversity, and abundance of grassland birds. I also compared the site characteristics, vegetation characteristics, and bird abundances among treatments using GLMMs. Season-long and idle sites were compared with twice-over sites for both years. I compared stocking rates, site area, proportion of wooded area and the proportion of grassland per site among the three treatments. Then I evaluated effects of management on bird species richness, diversity, and abundances. I also determined the effects of management regimes on vegetation height, litter depth, vertical density of vegetation (VOM), proportion of shrubs, forbs, standing grass (dead and alive), and amount of exposed bare ground (see Appendix X for interpretation). Again, both season-long and idle sites were compared to twice-over rotation sites. At the site scale, I looked at possible effects of proportion of wooded area, open area, and site area on bird species richness, diversity and abundance. The natural logarithm of site area was used over the total site area, which is typical for species-area relationships (Begon et al. 1996). The natural logarithm of site area has also been found to be a good predictor of bird species richness (Howe 1984) because larger site areas can potentially support a larger number of species. I also compared effects of vegetation height, litter depth, vertical density of vegetation (VOM), proportion of shrubs, forbs, standing grass (dead and alive), and bare ground on bird species richness, diversity, and abundances among treatments. The relationship between grassland birds and their habitats may be scale dependent (Wiens 1989), and grazing may influence habitat structure at different spatial scales (Ricketts et

al. 1999). Therefore, evaluating a number of factors at both the landscape and local levels enabled me to determine any effects of grazing management on grassland bird species richness and abundance at different spatial scales.

I used abundances of birds summed over both rounds for GLMM analysis in SAS because the software requires discrete data for the analysis of count data. The Gaussian, Poisson, and binomial distributions of the exponential family were used for the GLMMs. The distribution of the response variable was determined using generalized linear models (GLMs) in SAS. (PROC GENMOD). These distributions were then used for analysis using generalized linear mixed-models. Correlated vegetation variables ($r > |0.7|$) were not included in the same models to avoid collinearity.

4.0 RESULTS

4.1 Management and site characteristics

4.1.1 Comparison of management characteristics among grazing regimes

Stocking rates were calculated for 7 season-long pastures in 2008 and 6 season-long pastures in 2009, and for 20 of the twice-over rotation pastures. Eight of the season-long producers did not provide management details, and stocking rates could not be determined for the 3 twice-over sites within the Kirkella community pasture in the rural municipality of Wallace. Stocking rates (AUM/acre) for season-long sites were slightly higher than twice-over rotation sites in both years (Tables 1 and 2).

Table 1: Summary of average stocking rates and range of stocking rates (AUM/acre) between grazing treatments for both years in southwestern Manitoba.

Treatment	AvgStockingRate (AUM/acre)		Range (AUM/acre)	
	2008	2009	2008	2009
Season-long	0.872 ± 0.35	0.883 ± 0.41	0.355 - 1.631	0.355 - 1.631
Twice-over	0.772 ± 0.34	0.741 ± 0.25	0.113 - 2.378	0.300 - 1.487

Table 2: Comparison of stocking rates between grazing treatments in southwestern Manitoba, for both 2008 and 2009. A negative value of β (beta) indicates higher stocking rates on twice-over rotation sites, while a positive value of β indicates higher stocking rates on season-long sites. Significant p -values ($\alpha = 0.10$) are highlighted.

Stocking rates		Twice-over vs. Season-long		
	Family	β	SE	p
2008				
AUM/acre	Gaussian	0.100	0.062	<.0001
2009				
AUM/acre	Gaussian	0.142	0.057	<.0001

Although season-long producers may put cattle to pasture in early May, six of the season-long pastures surveyed in this study started grazing 1 June in both years and only one pasture started earlier. I could not obtain management information for 6 of the season-long pastures so the grazing dates for these pastures are unknown.

4.1.2 Comparison of landscape characteristics among treatments

Season-long sites had a significantly larger proportion of open area per site (0.70 – 1.00 in both years) than twice-over sites (0.44 - 1.00 in 2008, and 0.45 - 1.0 in 2009) in both years. However, the proportion of treed area per site did not differ significantly between sites grazed season-long (0.00 - 0.30 in both years), and sites grazed twice-over rotationally (0.00 - 0.55 in both years). Although idle sites had a significantly higher amount of woodland area per site (0.001 - 0.56 for both years) than twice-over rotation sites (0.00 - 0.55 in both years), the total proportion of open area available on idle (0.44 - 1.00 in both years) and twice-over sites (0.44 - 1.00 in 2008, and 0.45 - 1.0 in 2009) was not significantly different (Table 3).

Table 3: Comparison of landscape variables at the site scale in southwestern Manitoba for both 2008 and 2009 surveying years. The proportion of open area and wooded areas (proportion treed) per site, and the natural logarithm of the total site area (LnArea) were compared among treatments. A negative value of β (beta) indicates higher abundances on twice-over rotation sites, while a positive value of β indicates higher abundances on season-long or idle sites. Significant p -values ($\alpha = 0.10$) are highlighted.

Landscape variables	Family	Twice-over vs. Season-long			Twice-over vs. Idle		
		β	SE	p	β	SE	p
<i>2008</i>							
Prop.Open Area	Gaussian	0.119	0.031	0.000	-0.007	0.057	0.897
Prop.Treed Area	Gaussian	-0.012	0.016	0.469	0.114	0.030	0.000
LnArea	Gaussian	-0.207	0.071	0.006	-0.795	0.132	<.0001
<i>2009</i>							
Prop.Open Area	Gaussian	0.125	0.033	0.001	-0.027	0.050	0.592
Prop.Treed Area	Gaussian	-0.023	0.016	0.152	0.129	0.024	<.0001
LnArea	Gaussian	-0.340	0.073	<.0001	-0.687	0.110	<.0001

4.2 Effects of grazing management on grassland birds

4.2.1 Bird species composition

A total of 101 species was observed during surveys in 2008 and 2009 combined: 60 species were observed in 2008 and 93 species in 2009 (Appendices III, IV, and V).

The most abundant grassland birds recorded during point-count surveys were: clay-colored sparrows, western meadowlarks, Savannah sparrows, red-winged blackbirds, brown-headed cowbirds, and eastern kingbirds. In addition, the following four obligate grassland birds had relatively high abundances in both surveying years: Sprague’s pipits, bobolinks, vesper sparrows, and Le Conte’s sparrows (Appendices I and II).

Most songbird species were observed on both grazed and ungrazed fields in both years: 48% of all songbird species in 2008 and 42% of all songbird species in 2009 (see Appendices III, IV, and V).

Both binary and quantitative similarity indices showed a higher species overlap between grazed treatments in both years and a lower species overlap between ungrazed fields and both grazing regimes (Tables 4 and 5). The quantitative index demonstrated that treatments were less similar in species composition when the relative abundances are taken into consideration, in contrast to comparing presence-absence data. Although grazing had little effect on species richness, the similarity indices suggest that slightly different avian communities were found in grazed and idle fields. Results of Sørensen's quantitative index suggest that idle and twice-over had more species in common than between idle and season-long sites in both years.

Table 4: Similarity indices and number of species overlap in southwestern Manitoba, represented as a percentage, between treatment pairs in 2008. Sørensen's binary index determines the percent of similarity based on presence-absence data, whereas Sørensen's quantitative index compares relative abundance of species among treatments.

2008	Season- Twice- No.Sp. in			Season- No.Sp. in			Twice- No.Sp. in		
	long	over	common	Idle	long	common	Idle	over	common
<i>Tot. No. Species</i>	49	35	32	34	49	28	34	35	25
<u><i>%similarity:</i></u>									
<i>Sørensen's</i>									
<i>Binary index</i>			76.19			67.47			72.46
<i>Quantitative index</i>			63.92			40.12			52.28

Table 5: Similarity indices and number of species overlap in southwestern Manitoba, represented as a percentage, between treatment pairs in 2009. Sørensen’s binary index determines the percent of similarity based on presence-absence data, whereas Sørensen’s quantitative index compares relative abundance of species among treatments.

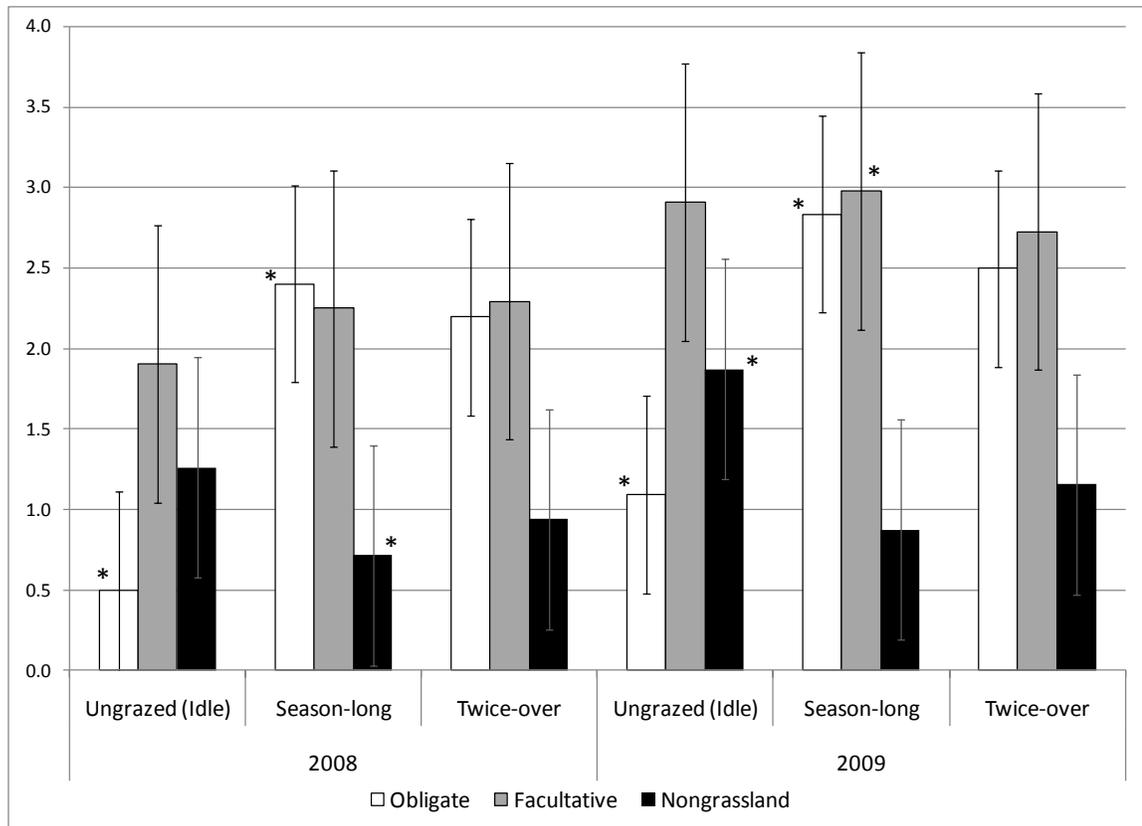
2009	Season- Twice- No.Sp. in			Season- No.Sp. in			Twice- No.Sp. in		
	long	over	common	Idle	long	common	Idle	over	common
<i>Tot. No. Species</i>	49	40	33	46	49	31	46	40	28
<i>%similarity:</i>									
<i>Sørensen's</i>									
<i>Binary index</i>			74.16			65.26			65.12
<i>Quantitative index</i>			60.06			40.36			44.93

4.2.2 Species richness

Species richness, diversity, and abundance of obligate grassland birds were significantly higher on grazed sites than ungrazed fields in both years. Idle fields supported fewer obligate and facultative grassland birds, but a greater number of non-grassland birds than either grazing regime in both years (Figures 2 and 3, and Tables 6 and 7).

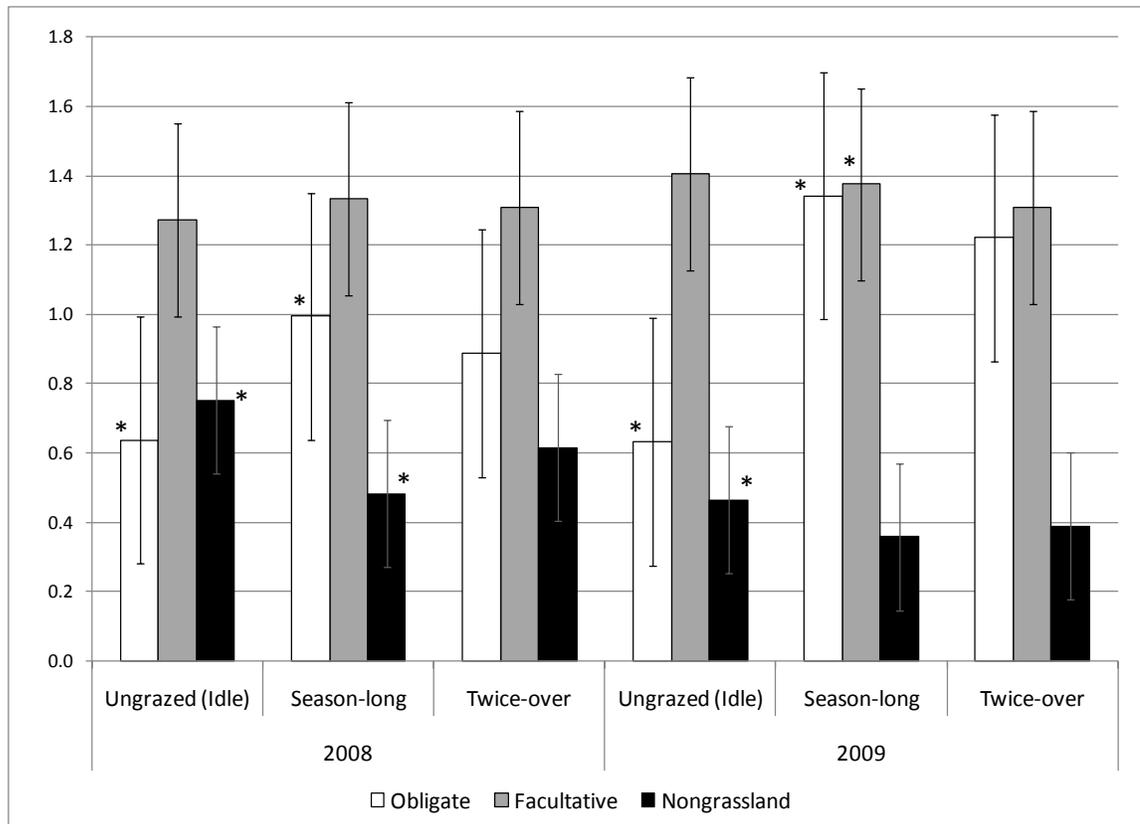
The magnitude of the difference between species richness, diversity, and bird abundances of obligate and facultative grassland birds was larger between twice-over and idle sites than between twice-over and season-long sites (Tables 6 and 7). For instance, species richness of obligate grassland birds was greater on season-long than idle sites by about 0.42 species per 3.2 ha, and by 2.00 species per 3.2 ha on twice-over than idle sites in 2008 (Table 6).

Although the responses were inconsistent between years, season-long sites tended to support more grassland birds than twice-over sites in both years (Figures 2 and 3, and Tables 6 and 7).



* Significantly different from twice-over rotation sites, ($\alpha = 0.10$)

Figure 2: Species richness of grassland birds observed in southwestern Manitoba in both 2008 and 2009, separated by treatment. Error bars represent standard deviations.



* Significantly different from twice-over rotation sites, ($\alpha = 0.10$)

Figure 3: Shannon index of grassland birds observed in southwestern Manitoba in 2008 and 2009, separated by treatment. Error bars represent standard deviations.

4.2.3 Relative abundances of grassland birds

Bobolinks, an obligate grassland bird, had higher abundances on season-long than twice-over sites in 2008, by approximately 0.654 individuals per point-count plot (Table 6), but abundances did not differ significantly among treatments in 2009 (Table 7).

Savannah sparrow was the only obligate grassland species to have significantly higher relative abundances on twice-over than season-long sites in 2009, whereas western meadowlark was the only obligate grassland bird with higher abundances on season-long than twice-over sites in 2009. Two obligate grassland birds, Savannah sparrow and western meadowlark, had significantly higher abundances on twice-over than idle sites in

2008, while three obligate grassland birds, Savannah sparrow, Sprague's pipit, and western meadowlark, had higher abundances on twice-over sites than idle sites in 2009. Although the relative abundances of facultative grassland birds did not differ significantly among treatments in 2008, brown-headed cowbird and clay-colored sparrow had higher abundances on idle than twice-over sites in 2009.

Table 6: Effects of management on songbird species in southwestern Manitoba in 2008. A negative value of β (beta) indicates higher abundances on twice-over rotation sites, while a positive value of β indicates higher abundances on season-long or idle sites. Significant p -values ($\alpha = 0.10$) are highlighted.

2008 Species	Family	Twice-over vs. Season-long			Twice-over vs. Idle		
		β	SE	p	β	SE	p
<i>All birds</i>							
Richness	Gaussian	-0.145	0.304	0.636	-1.603	0.565	0.007
Diversity	Gaussian	-0.089	0.080	0.273	-0.253	0.149	0.097
<i>Obligate grassland birds</i>							
Species Richness	Gaussian	0.319	0.184	0.090	-1.994	0.342	<.0001
Total Abundance	Gaussian	0.678	0.615	0.276	-6.576	1.142	<.0001
Species Diversity	Gaussian	0.106	0.048	0.032	-0.534	0.089	<.0001
Bobolink	Binomial	0.739	0.315	0.023	0.648	0.559	0.252
Le Conte's sparrow	Binomial	-0.371	0.322	0.256	-1.013	0.769	0.194
Savannah sparrow	Gaussian	0.086	0.297	0.772	-2.748	0.552	<.0001
Sprague's pipit	Binomial	-0.164	0.269	0.547	-21.708	16808.000	0.999
Vesper sparrow	Binomial	-0.012	0.308	0.969	-0.454	0.654	0.491
Western meadowlark	Gaussian	-0.198	0.253	0.439	-2.583	0.470	<.0001
<i>Facultative grassland birds</i>							
Species Richness	Gaussian	-0.022	0.171	0.898	-0.024	0.319	0.941
Total Abundance	Gaussian	0.132	0.692	0.849	-0.320	1.282	0.804
Species Diversity	Gaussian	0.026	0.045	0.570	-0.035	0.083	0.676
Brown-headed cowbird	Binomial	0.101	0.260	0.699	-0.019	0.478	0.968
Clay-colored sparrow	Gaussian	-0.340	0.321	0.294	-0.208	0.596	0.728
Eastern kingbird	Binomial	0.180	0.257	0.487	0.092	0.478	0.849
Red-winged blackbird	Binomial	0.048	0.262	0.857	-0.507	0.467	0.283
<i>Non-grassland birds</i>							
Species Richness	Gaussian	-0.442	0.191	0.025	0.415	0.354	0.247
Total Abundance	Gaussian	-3.117	2.918	0.291	-1.343	5.422	0.806
Species Diversity	Gaussian	-0.112	0.050	0.029	0.227	0.092	0.018

Table 7: Effects of management on songbird species in southwestern Manitoba in 2009. A negative value of β (beta) indicates higher abundances on twice-over rotation sites, while a positive value of β indicates higher abundances on season-long or idle sites. Significant p -values ($\alpha = 0.10$) are highlighted.

2009 Species	Family	Twice-over vs. Season-long			Twice-over vs. Idle		
		β	SE	p	β	SE	p
<i>All birds</i>							
Richness	Gaussian	0.525	0.340	0.130	-0.032	0.517	0.950
Diversity	Gaussian	0.084	0.065	0.204	-0.044	0.099	0.658
<i>Obligate grassland birds</i>							
Species Richness	Gaussian	0.502	0.229	0.034	-1.886	0.348	<.0001
Total Abundance	Gaussian	1.443	0.756	0.063	-6.476	1.148	<.0001
Species Diversity	Gaussian	0.161	0.075	0.039	-0.588	0.120	<.0001
Bobolink	Binomial	0.645	0.362	0.081	0.889	0.500	0.082
Le Conte's sparrow	Binomial	-0.244	0.442	0.584	-1.319	1.051	0.216
Savannah sparrow	Gaussian	-0.741	0.290	0.014	-2.325	0.440	<.0001
Sprague's pipit	Binomial	-0.003	0.277	0.991	-2.981	1.037	0.006
Vesper sparrow	Binomial	0.342	0.296	0.254	-0.255	0.497	0.610
Western meadowlark	Gaussian	0.418	0.341	0.227	-2.409	0.518	<.0001
<i>Facultative grassland birds</i>							
Species Richness	Gaussian	0.338	0.219	0.130	0.294	0.332	0.381
Total Abundance	Gaussian	0.613	0.834	0.467	1.099	1.267	0.391
Species Diversity	Gaussian	0.067	0.061	0.277	0.097	0.092	0.298
Brown-headed cowbird	Binomial	-0.174	0.285	0.544	0.956	0.431	0.032
Clay-colored sparrow	Gaussian	-0.716	0.375	0.063	1.486	0.570	0.012
Eastern kingbird	Binomial	0.034	0.285	0.906	0.653	0.420	0.127
Red-winged blackbird	Binomial	0.037	0.275	0.893	-0.062	0.417	0.882
<i>Non-grassland birds</i>							
Species Richness	Gaussian	-0.317	0.226	0.169	1.151	0.344	0.002
Total Abundance	Gaussian	-1.386	0.503	0.008	2.484	0.764	0.002
Species Diversity	Gaussian	-0.002	0.035	0.963	0.168	0.053	0.003

4.3 Effects of management on local vegetation structure

At the plot scale, vegetation height and density was on average significantly higher on idle than twice-over sites in both years, and litter depth was significantly greater on idle than twice-over sites in 2009 (Table 8). Litter depth, vegetation height and density did not differ significantly between twice-over rotation and season-long sites in either year.

Season-long sites had a significantly higher percent cover of forbs and grass than twice-over sites in both years and a higher proportion of exposed bare ground than twice-over sites in 2008. The percent cover of litter, however, was significantly higher on twice-over sites than season-long in 2009. Idle sites had a higher percent cover of shrubs than twice-over sites in both years (Table 8)

Table 8: Effects of management on vegetation variables at the plot scale (litter depth, vegetation height, visual obstruction measurements (VOM), and percent cover of shrubs, forbs, grass, and exposed bare ground) in southwestern Manitoba for both surveying years. A negative value of β (beta) indicates higher abundances on twice-over rotation sites, while a positive value of β indicates higher abundances on season-long or idle sites. Significant p -values ($\alpha = 0.10$) are highlighted.

Local vegetation variables		Twice-over vs. Season-long			Twice-over vs. Idle		
		β	SE	p	β	SE	p
<i>2008</i>							
Litter depth	Gaussian	-0.228	0.245	0.356	0.707	0.454	0.127
Vegetation height	Gaussian	-3.062	3.389	0.371	14.331	6.296	0.028
VOM	Gaussian	0.028	0.064	0.667	0.465	0.120	0.000
PropShrubs	Gaussian	0.006	0.005	0.223	0.073	0.009	<.0001
PropForbs	Gaussian	0.014	0.008	0.080	0.009	0.015	0.562
PropGrass	Gaussian	0.119	0.031	0.000	-0.007	0.057	0.897
PropLitter	Gaussian	0.003	0.014	0.839	-0.284	0.025	<.0001
PropBare ground	Gaussian	0.016	0.009	0.075	0.001	0.016	0.972
<i>2009</i>							
Litter depth	Gaussian	0.051	0.137	0.714	0.608	0.208	0.005
Vegetation height	Gaussian	-0.219	0.738	0.769	4.797	1.121	0.000
VOM	Gaussian	0.125	0.091	0.177	1.006	0.139	<.0001
PropShrubs	Gaussian	0.001	0.001	0.515	0.008	0.002	0.000
PropForbs	Gaussian	0.006	0.002	0.003	-0.001	0.003	0.810
PropGrass	Gaussian	0.125	0.033	0.001	-0.027	0.050	0.592
PropLitter	Gaussian	-0.009	0.004	0.021	-0.019	0.006	0.002
PropBare ground	Gaussian	0.000	0.000	0.593	0.000	0.000	0.424

4.4 Grassland bird responses to local vegetation structure

4.4.1 Species richness and diversity

The vegetation variables that had the strongest effect on species richness and diversity in both years were vegetation height, percent cover of shrubs, percent cover of grass, and percent cover of litter (Tables 9 and 10). As the percent cover of shrubs increased, the species richness, total abundance, and species diversity of obligate grassland birds decreased in both years (Tables 9 and 10). For instance, with each percent increase of shrubs per 1 m² species richness of obligate grassland birds decreased by approximately 7.0 species per 3.2 ha in 2008 and by 39.7 species in 2009. However, the total abundance and species diversity of facultative grassland birds increased as percent cover of shrubs increased in both years. The species richness of facultative grassland birds increased by about 4.86 species per 3.2 ha as percent cover of shrubs increased per 1 m² in 2008. Similarly, the species richness of non-grassland birds increased as the percent cover of shrubs increased in both years, and species diversity of non-grassland birds increased as percent cover of shrubs increased in 2008.

Vegetation height had a significant effect on the richness, diversity, and total abundance of facultative grassland birds, though the response was inconsistent between years. Species richness of non-grassland birds was positively associated with vegetation height, density and proportion cover of litter. Proportion cover of grass, however, negatively influenced species richness and diversity of non-grassland birds in both years. Obligate grassland birds species richness, diversity, and total abundance increased with proportion cover of grass in both years.

4.4.2 Relative abundances of grassland birds

Grassland bird responses to local vegetation characteristics were inconsistent between years. Vegetation structure generally had a strong influence on relative bird abundances. The most influential vegetation characteristics were percent cover of shrubs, percent cover of grass, and percent cover of litter in both years (Tables 9 and 10).

Vesper sparrow abundances decreased as litter depth increased in 2008 and Savannah sparrow abundances decreased as litter depth increased in 2009. Clay-colored sparrow abundances increased as litter depth increased in 2009. The abundances of Savannah sparrows increased as vegetation height increased, whereas the abundances of clay-colored sparrows decreased with increasing vegetation height in 2008. Both bobolink and red-winged blackbird abundances increased as vegetation height increased, whereas vesper sparrow abundances decreased in 2009. Bobolinks, Le Conte's sparrows, and vesper sparrows tended to select denser vegetation (VOM) in 2008, and clay-colored sparrows used sites with denser vegetation in both years. However, abundances of red-winged blackbirds and brown-headed cowbirds were negatively associated with vegetation density in 2008, and western meadowlark abundances were negatively associated with vegetation density in both years.

Percent cover of shrubs influenced the most number of birds in both years. For instance, with every percent increase of woody vegetation per 1 m², Sprague's pipit and Le Conte's sparrow densities decreased by approximately 19 individuals in 2008 and Savannah sparrow densities decreased by approximately 24.5 individuals in 2009 (Tables 9 and 10, but see Appendix X for interpretation). By contrast, with every percent increase of woody vegetation per 1 m² clay-colored sparrows densities increased by approximately

31.5 individuals and eastern kingbird densities increased by approximately 20.5 individuals in 2009. Red-winged blackbirds were the only facultative grassland bird negatively associated with percent cover of shrubs in 2009

Most species responded inconsistently to percent cover of forbs, grass, litter, and exposed bare ground between years. Two obligate grassland birds were negatively associated with percent cover of forbs: Sprague's pipit in 2008 and Savannah sparrows in 2009. With each percent increase in grass cover per 1 m², Sprague's pipit densities increased by approximately 7.84 individuals per 3.2 ha in 2008, and by 2.34 individuals in 2009. The abundance of bobolinks, however, increased as percent cover of forbs increased in 2008. Red-winged blackbird and brown-headed cowbird abundances increased as percent cover of grass increased in 2008, although red-winged blackbird abundances decreased as percent cover of grass increased in 2009. The relative abundances of Sprague's pipits and western meadowlarks were positively associated with percent cover of grass in both years. However, clay-colored sparrow abundances decreased as percent cover of grass increased in both years.

One obligate grassland bird, western meadowlark, and two facultative grassland birds, clay-colored sparrow and red-winged blackbird, increased in abundance as the percent cover of litter increased in 2008. In 2009, bobolink, clay-colored sparrow, and eastern kingbird abundances were positively associated with percent cover of litter. In 2008, the proportion of exposed bare ground had a positive influence on the abundances of Savannah sparrows and eastern kingbirds and a negative influence on the abundance of brown-headed cowbirds. Savannah sparrow densities increased by about 6.1 individuals and eastern kingbird abundances increased by about 3.38 individuals per 3.2 ha with each

percent increase of exposed bare ground per 1 m². In 2009, however, there was no significant response in grassland bird abundances to the proportion of exposed bare ground.

Table 9: Effects of local vegetation variables (litter depth, vegetation height, visual obstruction measurements (VOM), and percent cover of shrubs, forbs, grass, and exposed bare ground) on songbird species observed during surveys in southwestern Manitoba in 2008 modeled using generalized linear mixed-models. Significant responses, parameters with $p \leq 0.10$, are highlighted.

Local vegetation variables 2008	Family	Litter depth (cm)			Vegetation height (cm)			VOM (cm)			PropShrubs		
		β	SE	p	β	SE	p	β	SE	p	β	SE	p
<i>All birds</i>													
Species Richness	Gaussian	-0.146	0.073	0.047	-0.010	0.005	0.065	0.079	0.280	0.777	9.051	3.731	0.016
Species Diversity	Gaussian	-0.017	0.020	0.382	-0.002	0.001	0.250	-0.045	0.075	0.553	1.460	1.005	0.148
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-0.057	0.045	0.209	0.000	0.003	0.948	-0.042	0.172	0.806	-6.918	2.293	0.003
Total Abundance	Gaussian	-0.144	0.150	0.339	0.004	0.011	0.692	0.093	0.574	0.872	-22.542	7.647	0.004
Species Diversity	Gaussian	-0.004	0.012	0.761	0.000	0.001	0.819	-0.038	0.046	0.405	-1.615	0.612	0.009
Bobolink	Binomial	-0.076	0.131	0.565	-0.010	0.013	0.431	0.747	0.327	0.023	1.778	5.164	0.731
Le Conte's sparrow	Poisson	-0.201	0.127	0.115	0.003	0.003	0.226	1.011	0.274	0.000	-38.933	12.767	0.003
Savannah sparrow	Gaussian	0.043	0.074	0.559	0.015	0.005	0.006	0.112	0.281	0.691	-13.997	3.745	0.000
Sprague's pipit	Binomial	0.055	0.123	0.659	0.004	0.005	0.485	-0.053	0.343	0.876	-38.443	12.627	0.003
Vesper sparrow	Binomial	-0.247	0.151	0.103	-0.016	0.015	0.288	1.157	0.340	0.001	-8.844	6.364	0.166
Western meadowlark	Gaussian	0.026	0.061	0.668	-0.003	0.004	0.562	-0.416	0.234	0.077	-4.400	3.123	0.160
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	-0.017	0.042	0.685	-0.008	0.003	0.012	0.050	0.160	0.757	4.860	2.131	0.023
Total Abundance	Gaussian	-0.206	0.167	0.216	-0.037	0.021	0.079	1.943	0.651	0.003	20.144	8.655	0.021
Species Diversity	Gaussian	0.010	0.011	0.364	-0.001	0.001	0.061	0.000	0.042	0.995	0.988	0.563	0.080
Brown-headed cowbird	Binomial	0.078	0.098	0.425	-0.003	0.005	0.585	-0.585	0.276	0.035	7.419	4.722	0.117
Clay-colored sparrow	Gaussian	0.002	0.075	0.977	-0.013	0.005	0.018	1.090	0.288	0.000	9.418	3.833	0.015
Eastern kingbird	Binomial	-0.012	0.071	0.863	-0.007	0.007	0.298	0.257	0.251	0.307	3.024	3.534	0.393
Red-winged blackbird	Binomial	0.026	0.061	0.668	-0.003	0.004	0.562	-0.416	0.234	0.077	-4.400	3.123	0.160
<i>Non-grassland birds</i>													
Species Richness	Gaussian	-0.053	0.044	0.238	-0.001	0.003	0.774	0.067	0.169	0.692	10.899	2.258	<.0001
Total Abundance	Gaussian	-0.348	0.728	0.633	-0.022	0.052	0.674	-3.124	2.778	0.262	24.792	37.042	0.504
Species Diversity	Gaussian	-0.011	0.012	0.328	0.000	0.001	0.623	-0.017	0.044	0.699	2.853	0.593	<.0001

Effects of twice-over rotation grazing on the abundances of grassland birds

Table 9 continued.

Local vegetation variables		PropForbs			PropGrass			PropLitter			PropBare ground		
2008	Family	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>
<i>All birds</i>													
Species Richness	Gaussian	-0.939	2.334	0.688	-0.192	0.555	0.730	4.699	1.205	0.000	-2.921	2.242	0.194
Species Diversity	Gaussian	-0.354	0.629	0.574	-0.168	0.150	0.262	0.665	0.325	0.042	-0.692	0.604	0.253
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-0.186	1.435	0.897	1.458	0.341	<.0001	2.327	0.741	0.002	-0.063	1.378	0.964
Total Abundance	Gaussian	-2.957	4.784	0.537	4.616	1.137	<.0001	8.075	2.470	0.001	6.470	4.595	0.160
Species Diversity	Gaussian	0.065	0.383	0.865	0.316	0.091	0.001	0.654	0.198	0.001	0.522	0.368	0.157
Bobolink	Binomial	7.525	2.376	0.002	0.965	0.732	0.189	1.249	1.670	0.456	-0.834	2.908	0.775
Le Conte's sparrow	Poisson	-3.232	2.825	0.254	-0.997	0.418	0.018	0.968	1.098	0.379	-4.714	4.233	0.267
Savannah sparrow	Gaussian	-1.350	2.343	0.565	0.551	0.557	0.324	1.669	1.210	0.169	6.066	2.251	0.008
Sprague's pipit	Binomial	-7.641	3.536	0.032	7.841	1.782	<.0001	-1.776	1.448	0.221	-3.056	2.883	0.290
Vesper sparrow	Binomial	-0.030	2.382	0.990	-0.083	0.577	0.886	1.718	1.604	0.285	1.875	2.424	0.440
Western meadowlark	Gaussian	-2.391	1.954	0.222	1.820	0.464	0.000	3.754	1.009	0.000	1.811	1.877	0.335
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	-1.118	1.333	0.402	-0.365	0.317	0.251	1.236	0.688	0.074	-0.208	1.281	0.871
Total Abundance	Gaussian	6.446	5.305	0.226	0.014	1.260	0.991	6.327	2.921	0.031	0.421	5.180	0.935
Species Diversity	Gaussian	-0.375	0.352	0.288	-0.049	0.084	0.560	0.288	0.182	0.115	-0.039	0.338	0.909
Brown-headed cowbird	Binomial	-2.444	2.277	0.284	0.851	0.491	0.084	0.791	1.091	0.469	-7.549	2.851	0.009
Clay-colored sparrow	Gaussian	3.318	2.398	0.168	-1.369	0.570	0.017	2.723	1.238	0.029	-1.738	2.304	0.451
Eastern kingbird	Binomial	-1.642	2.174	0.451	0.292	0.507	0.566	1.583	1.214	0.193	3.376	2.106	0.110
Red-winged blackbird	Binomial	-2.391	1.954	0.222	1.820	0.464	0.000	3.754	1.009	0.000	1.811	1.877	0.335
<i>Non-grassland birds</i>													
Species Richness	Gaussian	0.090	1.412	0.949	-1.407	0.336	<.0001	1.201	0.729	0.101	-2.386	1.357	0.080
Total Abundance	Gaussian	2.959	23.171	0.899	1.988	5.507	0.718	9.181	11.965	0.444	-12.187	22.259	0.585
Species Diversity	Gaussian	0.194	0.371	0.601	-0.376	0.088	<.0001	0.154	0.192	0.422	-0.868	0.356	0.016

Table 10: Effects of local vegetation variables (litter depth, vegetation height, visual obstruction measurements (VOM), and percent cover of shrubs, forbs, grass, and exposed bare ground) on songbird species in southwestern Manitoba in 2009 modeled using generalized linear mixed-models. Significant responses, parameters with $p \leq 0.10$, are highlighted.

Local vegetation variables		Litter depth (cm)			Vegetation height (cm)			VOM (cm)			PropShrubs		
2009	Family	β	SE	p	β	SE	p	β	SE	p	β	SE	p
<i>All birds</i>													
Species Richness	Gaussian	0.173	0.168	0.303	0.050	0.031	0.103	0.206	0.261	0.431	1.870	17.297	0.914
Species Diversity	Gaussian	0.014	0.033	0.662	0.008	0.006	0.158	0.029	0.050	0.571	-1.059	3.353	0.752
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-0.008	0.115	0.946	-0.030	0.021	0.151	-0.145	0.178	0.417	-39.724	11.846	0.001
Total Abundance	Gaussian	-0.273	0.378	0.471	-0.112	0.069	0.104	-0.536	0.587	0.362	-109.790	38.961	0.005
Species Diversity	Gaussian	-0.052	0.035	0.144	-0.006	0.007	0.414	-0.072	0.055	0.192	-13.046	3.755	0.001
Bobolink	Binomial	-0.112	0.201	0.577	0.079	0.034	0.021	0.454	0.305	0.138	-76.891	30.812	0.013
Le Conte's sparrow	Poisson	0.099	0.193	0.610	0.012	0.039	0.760	0.056	0.330	0.867	-57.134	35.941	0.113
Savannah sparrow	Gaussian	-0.239	0.146	0.102	-0.014	0.027	0.603	-0.306	0.226	0.177	-49.082	15.032	0.001
Sprague's pipit	Binomial	0.007	0.150	0.963	-0.017	0.028	0.536	-0.275	0.242	0.257	-14.150	17.337	0.415
Vesper sparrow	Binomial	0.169	0.156	0.281	-0.096	0.034	0.004	0.331	0.237	0.164	-11.713	17.668	0.508
Western meadowlark	Gaussian	-0.040	0.173	0.818	-0.020	0.031	0.525	-0.490	0.269	0.070	8.897	17.844	0.619
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	0.011	0.108	0.918	0.041	0.020	0.039	0.035	0.168	0.834	14.270	11.169	0.203
Total Abundance	Gaussian	0.179	0.403	0.657	0.221	0.073	0.003	-0.476	0.626	0.448	111.570	41.592	0.008
Species Diversity	Gaussian	0.021	0.030	0.475	0.009	0.005	0.101	-0.013	0.046	0.786	8.352	3.078	0.007
Brown-headed cowbird	Binomial	0.224	0.143	0.120	-0.004	0.026	0.877	-0.162	0.227	0.477	21.554	14.843	0.148
Clay-colored sparrow	Gaussian	0.325	0.176	0.067	0.008	0.032	0.802	0.474	0.274	0.085	62.735	18.165	0.001
Eastern kingbird	Binomial	-0.076	0.150	0.612	-0.020	0.027	0.454	0.248	0.227	0.276	40.681	15.912	0.011
Red-winged blackbird	Binomial	0.123	0.145	0.398	0.048	0.027	0.075	0.075	0.229	0.745	-31.464	15.665	0.046
<i>Non-grassland birds</i>													
Species Richness	Gaussian	0.155	0.103	0.133	0.038	0.019	0.042	0.315	0.159	0.049	20.396	10.586	0.055
Total Abundance	Gaussian	0.193	0.241	0.423	0.094	0.044	0.033	0.561	0.374	0.135	35.325	24.813	0.156
Species Diversity	Gaussian	0.028	0.017	0.100	0.007	0.003	0.029	0.021	0.026	0.423	2.766	1.746	0.115

Effects of twice-over rotation grazing on the abundances of grassland birds

Table 10 continued.

Local vegetation variables		PropForbs			PropGrass			PropLitter			PropBare ground		
2009	Family	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>
<i>All birds</i>													
Species Richness	Gaussian	8.825	11.965	0.462	-1.474	0.603	0.019	6.563	6.133	0.286	130.970	173.080	0.450
Species Diversity	Gaussian	0.025	2.319	0.992	-0.263	0.117	0.030	0.116	1.189	0.922	-18.692	33.552	0.578
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-17.661	8.194	0.032	1.620	0.413	0.000	-1.366	4.200	0.745	-18.045	118.540	0.879
Total Abundance	Gaussian	-30.390	26.951	0.261	6.063	1.358	<.0001	1.311	13.814	0.925	44.813	389.870	0.909
Species Diversity	Gaussian	-7.698	2.538	0.003	0.648	0.128	<.0001	-1.942	1.317	0.142	25.323	45.728	0.580
Bobolink	Binomial	16.041	13.093	0.222	1.516	1.100	0.175	-11.489	7.018	0.103	-75.302	206.100	0.715
Le Conte's sparrow	Poisson	2.375	14.906	0.874	0.634	0.930	0.499	1.428	8.397	0.865	53.255	168.710	0.753
Savannah sparrow	Gaussian	-18.800	10.398	0.072	-0.517	0.524	0.330	-3.775	5.330	0.480	-129.810	150.420	0.389
Sprague's pipit	Binomial	-13.664	11.701	0.244	2.345	0.738	0.003	2.923	5.595	0.602	-350.390	242.510	0.150
Vesper sparrow	Binomial	5.884	10.991	0.593	0.114	0.557	0.839	7.426	6.150	0.229	40.404	161.590	0.803
Western meadowlark	Gaussian	-5.087	12.344	0.681	2.702	0.622	<.0001	3.893	6.327	0.539	-11.914	178.560	0.947
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	14.998	7.726	0.054	-0.608	0.389	0.126	0.120	3.960	0.976	36.129	111.760	0.747
Total Abundance	Gaussian	72.492	28.771	0.013	-1.887	1.450	0.200	27.427	14.747	0.064	340.520	416.200	0.414
Species Diversity	Gaussian	4.274	2.129	0.046	-0.084	0.107	0.439	0.709	1.092	0.516	3.175	30.803	0.918
Brown-headed cowbird	Binomial	13.984	10.212	0.172	0.859	0.564	0.134	0.858	5.276	0.871	61.144	144.680	0.673
Clay-colored sparrow	Gaussian	7.249	12.565	0.565	-2.682	0.633	0.000	17.296	6.441	0.008	169.170	181.770	0.353
Eastern kingbird	Binomial	9.374	10.565	0.376	-0.673	0.515	0.198	10.703	5.870	0.070	83.770	145.590	0.566
Red-winged blackbird	Binomial	14.638	10.698	0.173	-1.710	0.591	0.006	-3.425	5.361	0.524	-45.510	149.610	0.761
<i>Non-grassland birds</i>													
Species Richness	Gaussian	8.720	7.322	0.235	-2.448	0.369	<.0001	6.740	3.753	0.074	58.076	105.930	0.584
Total Abundance	Gaussian	8.884	17.164	0.605	-4.669	0.865	<.0001	15.752	8.798	0.075	-114.820	248.300	0.644
Species Diversity	Gaussian	1.039	1.208	0.391	-0.148	0.061	0.019	0.083	0.619	0.894	-0.245	17.475	0.989

4.5 Grassland bird responses to landscape characteristics

The size of treed area and total tree edge on each site were correlated ($r > |0.7|$), therefore these two variables were not included together in the same model (Table 11). Because the calculation of amount of tree edge considered only tree patches found within the site and not within the surrounding matrix, or along the edge of the field, this variable was omitted from the following models.

Table 11: Correlation matrix of landscape variables taken at the site scale for both 2008 and 2009. Correlation coefficients between each pairwise variable are shown. Variables with high coefficient values ($r > |0.7|$) are highlighted.

	<i>Y_PROJ</i>	<i>TreePerimeter</i>	<i>PropGrass</i>	<i>PropTrees</i>	<i>InArea</i>
<i>Y_PROJ</i>	1.000				
<i>TreePerimeter</i>	0.022	1.000			
<i>PropGrass</i>	-0.382	-0.184	1.000		
<i>PropTrees</i>	0.047	0.759	-0.304	1.000	
<i>InArea</i>	0.053	0.280	-0.286	-0.032	1.000

4.4.1 Species richness and diversity

Species richness, diversity, and abundance of obligate grassland birds were negatively associated with the proportion of trees on the site in both years. Although the proportion of trees had no significant influence on the species richness, diversity, or total abundance of facultative grassland birds, the species diversity of non-grassland birds increased with proportion of trees in both years. Non-grassland bird species richness increased with proportion of trees in 2008 and the total abundance of non-grassland birds increased with proportion of trees in 2009 (Tables 12 and 13).

Table 12: Effects of landscape variables on songbird species observed during surveys in southwestern Manitoba in 2008 modeled using generalized linear mixed-models. Significant responses, parameters with $p \leq 0.10$, are highlighted.

Landscape variables 2008	Family	PropTree			PropOpen			Ln Area			Northing		
		β	SE	p	β	SE	p	β	SE	p	β	SE	p
<i>All birds</i>													
Species Richness	Gaussian	-0.482	1.145	0.674	-0.207	0.670	0.758	0.396	0.247	0.109	5.00×10^{-7}	4.08×10^{-6}	0.903
Species Diversity	Gaussian	0.010	0.301	0.973	-0.140	0.176	0.426	0.050	0.065	0.436	5.01×10^{-7}	1.07×10^{-6}	0.640
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-3.742	0.677	<.0001	0.989	0.396	0.013	0.082	0.146	0.577	9.09×10^{-7}	2.41×10^{-6}	0.707
Total Abundance	Gaussian	-14.369	2.205	<.0001	3.228	1.290	0.013	0.222	0.475	0.640	7.39×10^{-6}	7.85×10^{-6}	0.348
Species Diversity	Gaussian	-1.106	0.178	<.0001	0.179	0.104	0.086	-0.001	0.038	0.974	4.35×10^{-7}	0.00	<.0001
Bobolink	Binomial	1.096	1.434	0.445	1.766	1.076	0.102	-1.001	0.245	<.0001	2.20×10^{-5}	5.34×10^{-6}	<.0001
Le Conte's sparrow	Binomial	-1.082	1.210	0.372	-0.251	0.583	0.668	0.262	0.269	0.332	1.40×10^{-5}	4.73×10^{-6}	0.003
Savannah sparrow	Gaussian	-6.215	1.061	<.0001	1.058	0.620	0.090	0.231	0.228	0.312	1.60×10^{-5}	3.78×10^{-6}	<.0001
Sprague's pipit	Binomial	12.173	9568.29	0.999	21.450	9568.28	0.998	0.157	0.247	0.525	4.31×10^{-6}	3.97×10^{-6}	0.279
Vesper sparrow	Binomial	2.321	1.211	0.056	1.242	0.828	0.135	-0.265	0.242	0.274	1.60×10^{-5}	4.72×10^{-6}	0.001
Western meadowlark	Gaussian	-5.192	0.892	<.0001	0.794	0.522	0.130	0.445	0.192	0.021	-8.34×10^{-6}	3.18×10^{-6}	0.009
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	0.115	0.629	0.855	-0.552	0.368	0.135	0.296	0.136	0.030	5.04×10^{-6}	2.24×10^{-6}	0.026
Total Abundance	Gaussian	2.686	2.575	0.298	0.673	1.506	0.655	0.411	0.555	0.459	4.93×10^{-6}	9.18×10^{-6}	0.592
Species Diversity	Gaussian	0.190	0.164	0.246	-0.013	0.096	0.893	0.126	0.035	0.000	-1.06×10^{-6}	0.00	<.0001
Brown-headed cowbird	Binomial	1.861	0.994	0.062	0.682	0.559	0.223	0.504	0.212	0.018	-9.17×10^{-6}	3.68×10^{-6}	0.013
Clay-colored sparrow	Gaussian	5.253	1.144	<.0001	-0.322	0.669	0.631	0.274	0.246	0.266	2.87×10^{-6}	4.07×10^{-6}	0.482
Eastern kingbird	Binomial	-0.947	1.034	0.361	0.558	0.571	0.329	0.455	0.222	0.041	9.15×10^{-7}	3.47×10^{-6}	0.792
Red-winged blackbird	Binomial	-0.718	0.989	0.469	-0.178	0.608	0.770	-0.046	0.211	0.828	5.00×10^{-6}	3.46×10^{-6}	0.150
<i>Non-grassland birds</i>													
Species Richness	Gaussian	3.502	0.661	<.0001	-0.663	0.387	0.088	0.067	0.142	0.638	4.39×10^{-6}	2.36×10^{-6}	0.064
Total Abundance	Gaussian	0.625	10.915	0.954	-0.409	6.386	0.949	0.837	2.350	0.722	-3.00×10^{-5}	3.9×10^{-5}	0.395
Species Diversity	Gaussian	0.976	0.173	<.0001	-0.231	0.101	0.023	-0.024	0.037	0.528	7.95×10^{-7}	0.00	<.0001

Table 13: Effects of landscape variables songbirds observed during surveys in southwestern Manitoba in 2009 modeled using generalized linear mixed-models. Significant responses, parameters with $p \leq 0.10$, are highlighted.

Landscape variables 2009	Family	PropTreed			PropOpen			Ln Area			Northing		
		β	SE	p	β	SE	p	β	SE	p	β	SE	p
<i>All birds</i>													
Species Richness	Gaussian	2.693	1.279	0.041	-0.887	0.718	0.224	0.210	0.273	0.446	1.43×10^{-6}	4.28×10^{-6}	0.738
Species Diversity	Gaussian	0.602	0.244	0.018	-0.110	0.137	0.427	0.061	0.052	0.250	4.50×10^{-7}	0.00	<.0001
<i>Obligate grassland birds</i>													
Species Richness	Gaussian	-4.846	0.852	<.0001	1.160	0.478	0.020	0.327	0.182	0.079	-1.47×10^{-6}	2.85×10^{-6}	0.606
Total Abundance	Gaussian	-17.860	2.765	<.0001	3.551	1.552	0.027	0.433	0.590	0.467	-8.34×10^{-6}	9.24×10^{-6}	0.368
Species Diversity	Gaussian	-1.750	0.262	<.0001	0.490	0.148	0.002	0.067	0.057	0.250	2.16×10^{-8}	0.00	<.0001
Bobolink	Binomial	20.655	19121.00	0.999	21.215	19121.00	0.999	-0.817	0.270	0.004	1.60×10^{-5}	5.22×10^{-6}	0.003
Le Conte's sparrow	Binomial	-0.524	1.886	0.782	1.268	0.864	0.149	0.249	0.348	0.478	2.10×10^{-5}	6.35×10^{-6}	0.001
Savannah sparrow	Gaussian	-4.368	1.114	0.000	-0.400	0.625	0.526	0.023	0.238	0.924	1.00×10^{-5}	3.72×10^{-6}	0.006
Sprague's pipit	Binomial	-1.247	1.380	0.371	2.594	0.837	0.003	0.631	0.251	0.016	2.19×10^{-6}	3.66×10^{-6}	0.550
Vesper sparrow	Binomial	-0.354	1.268	0.781	0.945	0.650	0.153	0.660	0.277	0.022	7.10×10^{-6}	3.96×10^{-6}	0.074
Western meadowlark	Gaussian	-6.286	1.210	<.0001	1.406	0.679	0.045	0.790	0.258	0.004	-1.00×10^{-5}	4.05×10^{-6}	0.001
<i>Facultative grassland birds</i>													
Species Richness	Gaussian	1.136	0.828	0.177	-0.738	0.465	0.120	0.036	0.177	0.839	-4.43×10^{-6}	2.77×10^{-6}	0.111
Total Abundance	Gaussian	-2.541	3.143	-0.810	-4.008	1.765	-2.270	0.323	0.670	0.480	-2.00×10^{-5}	1.10×10^{-5}	-2.220
Species Diversity	Gaussian	0.086	0.227	0.705	-0.202	0.127	0.120	0.067	0.048	0.175	-2.36×10^{-6}	0.00	<.0001
Brown-headed cowbird	Binomial	1.433	1.157	0.222	0.060	0.738	0.936	-0.146	0.238	0.542	-2.00×10^{-5}	3.78×10^{-6}	<.0001
Clay-colored sparrow	Gaussian	4.011	1.395	0.006	-2.354	0.783	0.004	0.167	0.297	0.577	-2.70×10^{-6}	4.66×10^{-6}	0.564
Eastern kingbird	Binomial	0.080	1.071	0.941	-0.919	0.600	0.133	0.202	0.240	0.405	-5.13×10^{-6}	3.66×10^{-6}	0.162
Red-winged blackbird	Binomial	-0.308	1.157	0.791	-1.200	0.723	0.104	-0.318	0.232	0.178	1.30×10^{-5}	3.72×10^{-6}	0.000
<i>Non-grassland birds</i>													
Species Richness	Gaussian	5.371	0.745	7.210	-1.351	0.418	-3.230	-0.082	0.159	-0.520	7.53×10^{-6}	2.49×10^{-6}	3.020
Total Abundance	Gaussian	13.639	1.678	<.0001	-1.666	0.942	0.084	0.120	0.358	0.330	1.90×10^{-5}	5.61×10^{-6}	3.340
Species Diversity	Gaussian	0.731	0.125	<.0001	-0.069	0.070	0.333	-0.008	0.027	0.761	-2.08×10^{-7}	0.00	<.0001

The proportion of open area per site positively influenced species richness, diversity, and total abundance of obligate grassland birds in both years. The species diversity of non-grassland birds decreased as the proportion of open area increased in 2008 and the total abundance of non-grassland birds decreased as the proportion of open area increased in 2009. Species richness, diversity, and total abundance of facultative grassland birds were not significantly influenced by proportion of open area in either year.

The natural logarithm of site area (LnArea) had a positive influence on the species richness of facultative grassland birds in 2008. The species diversity of facultative grassland birds was also positively associated with the natural logarithm of site area in 2008. Although site area was positively associated with the species richness and diversity of facultative grassland birds in 2008, it did not influence diversity or abundance of obligate or non-grassland bird species.

Although responses (parameter estimates) were very small, a slight increase in species diversity of obligate grassland birds was observed with increasing latitude in both years. Species richness of facultative grassland birds and non-grassland birds, and non-grassland bird species diversity increased with latitude in 2008. However, species diversity of facultative and non-grassland birds slightly decreased with latitude.

4.4.2 Relative abundances of grassland birds

Responses of individual species abundances to landscape variables at the site scale were inconsistent between years (Tables 12 and 13). Savannah sparrows and western meadowlarks, however, consistently selected sites with a lower proportion of trees, whereas clay-colored sparrows selected sites with a higher proportion of trees in

both years. In addition, brown-headed cowbird and vesper sparrow abundances increased with proportion of trees in 2008. Although the total amount of open area on the site influenced abundances of a number of bird species, responses were variable between years. Bobolink and Savannah sparrow abundances both increased with proportion open area in 2008 but not in 2009. Sprague's pipit and western meadowlark abundances increased with proportion open area in 2009, while clay-colored sparrow and red-winged blackbird abundances decreased with the proportion of open area in 2009.

Bobolinks tended to select smaller sites in both years, while western meadowlarks tended to select larger sites in both years. In 2008, brown-headed cowbirds and eastern kingbird abundances were higher on larger sites, and in 2009, Sprague's pipit and vesper sparrow abundances were higher on larger sites.

Although responses to latitude were very small, the relative abundances of grassland birds to latitude were fairly consistent between years. Bobolink, Le Conte's sparrow, Savannah sparrow and vesper sparrow abundances all increased with latitude in both years, whereas western meadowlark and brown-headed cowbird abundances decreased with latitude in both years. Red-winged black bird abundances increased with latitude only in 2009.

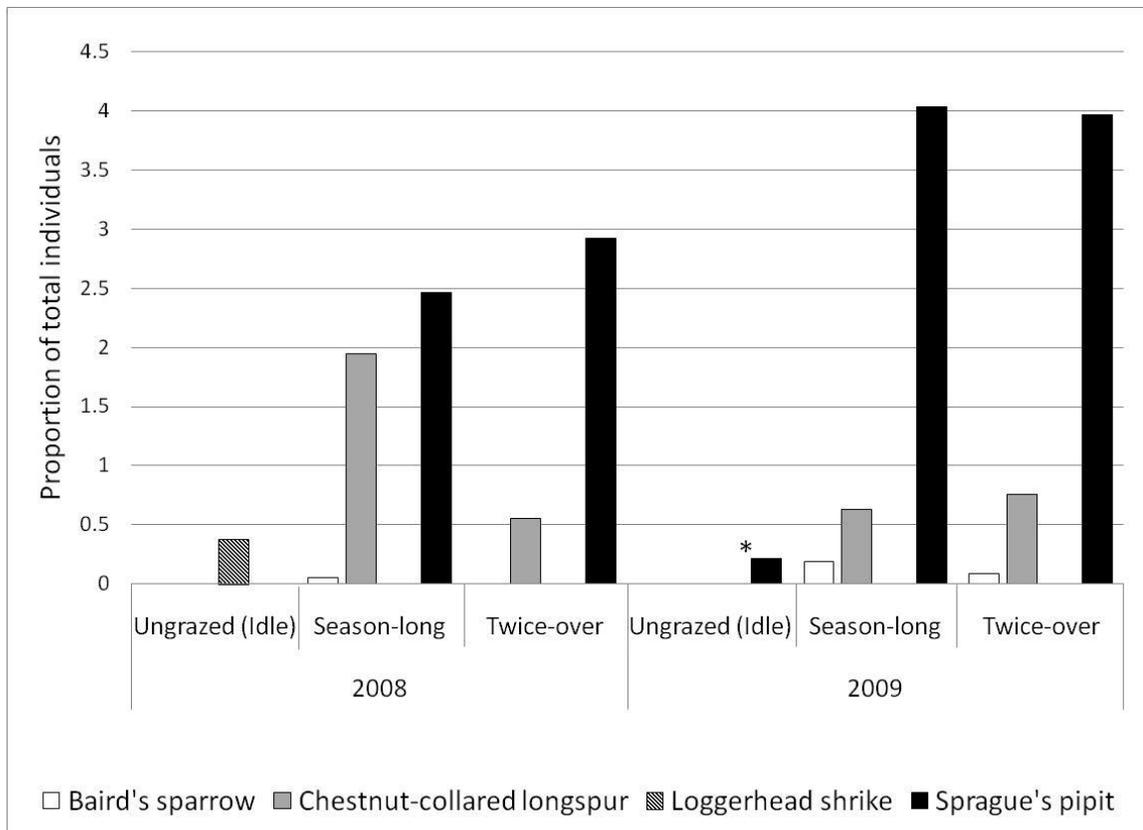
4.6 Influence of grazing management on species at risk

Previous surveys have demonstrated that the following species at risk can be found in southwestern Manitoba: ferruginous hawk, Sprague's pipit, burrowing owl, Baird's sparrow and loggerhead shrike (Environment Canada 2009). Three of the five species at risk in southwestern Manitoba were observed during surveys in 2008:

Sprague's pipit, Baird's sparrow and loggerhead shrike. Two species at risk were found in 2009: Sprague's pipit, and Baird's sparrow (Figure 4). Although Sprague's pipit abundances were significantly lower on idle fields in 2009 when compared to sites of both grazing regimes, abundances were not significantly different between season-long and twice-over sites (Table 14).

Although not considered a species at risk in Manitoba, the nationally threatened chestnut-collared longspur was also observed during both surveying years (Figure 4). Chestnut-collared longspurs occurred in higher densities on season-long than twice-over rotation sites in 2008 (Figure 4), however the relative abundances did not differ significantly between grazed sites in either year (Table 14).

There was only one occurrence of the loggerhead shrike, on an idle site, the Bernice WMA (NW 12-5-26W) (Figure 5). Ferruginous hawks were also observed outside of point-count plots within the study area on grazed pastures in both years.



* Significantly different from twice-over rotation sites, ($\alpha = 0.10$)

Figure 4: Proportions of species at risk relative to total number of individuals observed during surveys in southwestern Manitoba, separated by treatment and year.

Table 14: Effects of grazing management on species at risk in southwestern Manitoba for both 2008 and 2009. A negative value of β (beta) indicates higher abundances on twice-over rotation sites, while a positive value of β indicates higher abundances on season-long or idle sites. Significant p -values ($\alpha = 0.10$) are highlighted.

Species at Risk	Family	Twice-over vs. Season-long			Twice-over vs. Idle		
		β	SE	p	β	SE	p
<i>2008</i>							
Baird's sparrow	Poisson	0.749	0.850	0.383	-17.674	10290.000	0.999
Chestnut-collared longspur	Binomial	0.112	0.485	0.818	-19.846	16808.000	0.999
Sprague's pipit	Binomial	-0.164	0.269	0.547	-21.708	16808.000	0.999
<i>2009</i>							
Baird's sparrow	-						
Chestnut-collared longspur	Binomial	-0.373	0.567	0.515	-20.008	14597.000	0.999
Sprague's pipit	Binomial	-0.003	0.277	0.991	-2.981	1.037	0.006

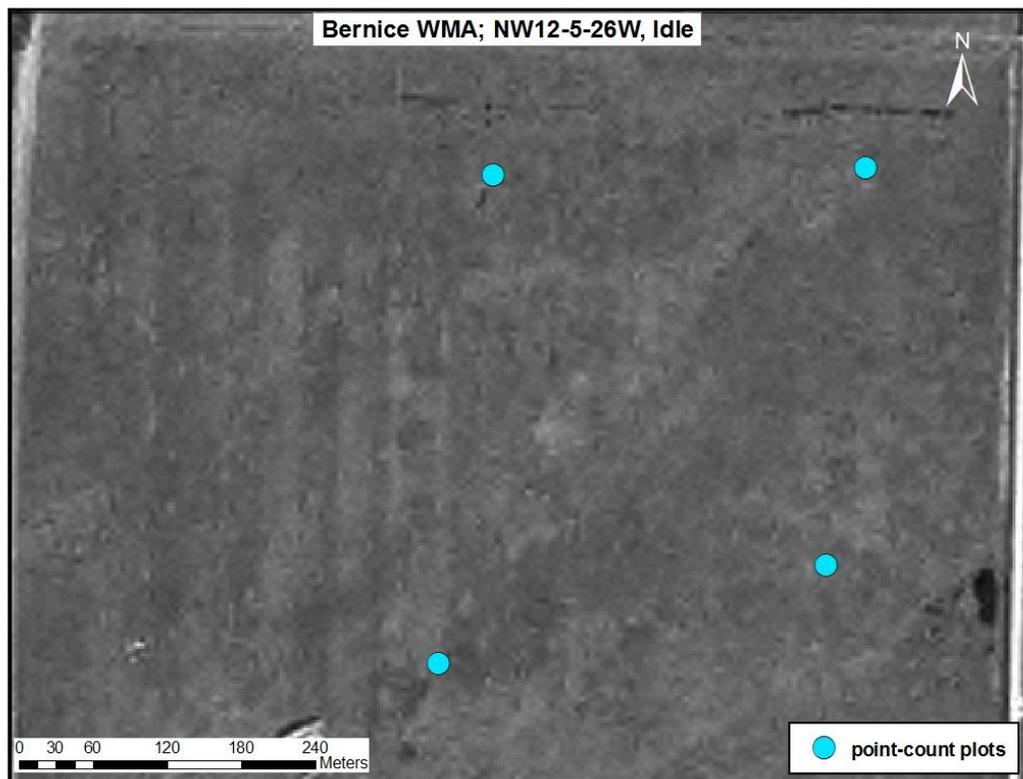


Figure 5: Idle site in southwestern Manitoba with a relatively high degree of open area. One occurrence of a loggerhead shrike was observed during point-count surveys in 2008 and outside of surveys in 2009 on this site.

5.0 DISCUSSION

To the best of my knowledge, this is the first study conducted in the mixed-grass prairie region of southwestern Manitoba to evaluate the effects of twice-over rotation grazing systems on the abundances of grassland songbirds. Another study compared the effects of deferred rotation and twice-over rotation on the abundances of non-game birds (Christie 1997). However, Christie (1997) evaluated the effects of managed grazing systems collectively on the abundances of non-game birds; therefore, it is not possible to determine the effects of twice-over rotation grazing independently from deferred rotation. In addition, Christie's (1997) study was conducted within the Aspen Parkland ecoregion of southwestern Manitoba, and was located approximately 30-56 km north-east of the northern limit of my study area; therefore, it reflected effects of management under different geographical and topographical characteristics.

Limited information exists on the effects of twice-over rotation grazing systems on grassland birds. Studies have included internal reports from the Dickinson Research Extension Centre of North Dakota State University (Manske 1995). To the best of my knowledge there are few peer-reviewed published articles on the effects of twice-over rotation grazing on the abundances or nesting success of grassland birds; studies have been conducted on waterfowl (Barker et al. 1990, Sedivec et al. 1990) and sharp-tailed grouse (*Tympanuchus phasianellus*) (Sedivec et al. 1990, Kirby and Grosz 1995). Although Kirby and Grosz (1995) found rotationally grazed fields increased nesting success of sharp-tailed grouse, season-long sites were not surveyed in this study, making it difficult to determine if rotational grazing would be more beneficial than traditional grazing regimes. Sedivec et al. (1990) also found duck nesting success was higher on

twice-over rotationally grazed pastures than other grazing regimes; however, the rest periods for these pastures were twice as long as those for the twice-over rotation sites surveyed in southwestern Manitoba, which may have been sufficient time to complete a nesting attempt.

A few studies, primarily from the Central Grasslands Research Extension Center in North Dakota, have evaluated the effects of twice-over rotation grazing on the densities and reproductive success of non-game birds, including: Messmer 1985 reviewed in Salo 2003, Messmer 1990, Kennedy 1994, and Salo 2003. However, the Barker et al. (1990) and Kennedy (1994) studies had few replicates and potentially low statistical power. Salo (2003) evaluated temporal effects of grazing systems on non-game bird abundances, but did not indicate whether bird abundances differed significantly among treatments, making it difficult to identify any effects of management over time.

This study is unique because it considers effects of twice-over rotation grazing independently from other rotational grazing systems, includes pastures of varying sizes, a large sample size, and takes place across a broad study area.

5.1 Influences of grazing regimes on grassland birds

5.1.1 Species richness and bird abundances

Differences in habitat structure between the two grazing regimes may have explained why season-long sites supported a greater number of grassland birds than twice-over rotation sites. For instance, the greater species richness, diversity and total abundance of grassland birds on season-long than twice-over sites in southwestern

Manitoba may have been because of the greater percent cover of grass and forbs on the season-long than twice-over sites. Salo (2003) also found greater bird densities on season-long than rotationally grazed pastures in North Dakota, even though species richness on the rotationally grazed pastures was higher. In contrast with Salo's (2003) study, Schneider (1998) found higher species richness on rotationally grazed sites than season-long sites in North Dakota, but only in one year of the study. However, the season-long sites surveyed in the Schneider (1998) study had a significantly higher proportion of shrubby vegetation than the rotational sites, which may have negatively influenced the suitability of grassland habitat for grassland birds on these sites.

Differences in landscape characteristics between the two grazing regimes may also have influenced the occurrences of species. For instance, the species richness, diversity, and total abundance of obligate grassland birds were positively correlated with total proportion of open area, which on average was significantly greater on season-long than twice-over sites in both years.

Twice-over rotation does not seem to provide better habitat for conserving grassland songbirds compared with more traditional grazing systems. Although some previous studies have found that some grassland birds may avoid continuously grazed pastures and select rotationally grazed pastures (Temple et al. 1999), most other studies have found no increase in bird nesting success or abundance among grazing systems (Kennedy 1994, Paine et al. 1996, Christie 1997, Schneider 1998, Lapointe et al. 2000, Buskness et al. 2001, Ignatiuk and Duncan 2001, Murphy et al. 2004, Koper and Schmiegelow 2006b, and Duran 2009). In addition, Messmer (1990) found densities of most grassland birds did not differ significantly between pastures grazed season-long and

twice-over rotationally in North Dakota, including for marbled godwit (*Limosa fedoa*), horned lark, lark bunting, grasshopper sparrow, killdeer (*Charadrius vociferous*), and common yellowthroat (*Geothlypis trichas*).

Rotational grazing may not enhance habitat quality as expected, which may have explained why twice-over sites did not improve species richness of grassland birds in southwestern Manitoba. A review of 60 years of research suggests that neither habitat quality nor livestock production is improved by rotational grazing (Briske et al. 2008). Differences in habitat structure among grazing treatments seem to be more strongly influenced by factors other than rotational grazing management, such as climate, stocking rates, or grazing intensity (Heady 1961, Hart and Samuel 1985, Hart et al. 1988, O'Reagain and Turner 1992, Fuhlendorf and Engle 2001, Vallentine 2001). Where rotational grazing seems to have helped improve range condition, this may be due to increased care of livestock, improved water and mineral distribution, more careful attention to stocking rates, brush control, and re-seeding rather than rotational grazing per se (Heady 1961).

The Savannah sparrow was the only grassland bird to prefer twice-over rotation over season-long pastures in southwestern Manitoba, and this pattern was only clear in the second year of the study. This contrast with Messmer's (1990) study, which found Savannah sparrow densities similar among sites grazed season-long, twice-over rotationally, short-duration, and idle fields. Savannah sparrows tend to use prairie habitats with tall and dense vegetation such as tall-grass prairie, idle fields, and lightly grazed mixed-grass prairie (Swanson 1998). Savannah sparrows may have responded positively to the higher percent litter cover on twice-over sites compared with season-long sites in

the second year, which is consistent with a study conducted in Minnesota where densities of Savannah sparrows were positively correlated with percent cover of litter (Tester and Marshall 1961 in Swanson 1998). Savannah sparrows require litter for concealing nests and tend to avoid fields with low cover of litter, such as recently burned fields (Johnson 1997).

Past studies conducted in North Dakota have found that western meadowlarks show no preference among short-duration, twice-over rotation, or season-long grazed sites (Renken 1983, Messmer 1990). However, I observed that western meadowlarks avoided ungrazed fields and preferred season-long over twice-over rotation sites in southwestern Manitoba. Season-long sites had a higher percent cover of forbs and grass than twice-over rotation sites, both of which western meadowlarks prefer (Sample 1989, Kimmel et al. 1992, Anstey et al. 1995, Madden 1996).

Temple et al. (1999) found bobolinks showed no preference among sites grazed rotationally, continuously, or idle fields on the Great Plains. In addition, bobolink densities did not differ significantly between sites grazed twice-over rotationally and season-long in North Dakota (Messmer 1990). However, bobolinks preferred season-long or idle sites over twice-over rotational sites in southwestern Manitoba. However, the stocking rates for both pastures grazed season-long and twice-over were much lower in southwestern Manitoba than in Temple et al.'s (1999) study. Perhaps at the lower stocking rates in southwestern Manitoba, season-long grazing was a suitable practice for creating habitat for these grassland birds. In southwestern Manitoba, bobolinks may have selected for season-long over twice-over sites because of the higher percent cover of forbs on the season-long sites.

Eastern kingbird, red-winged blackbird, vesper sparrow, and Le Conte's sparrow abundances were not significantly different among treatments in either year, perhaps because their habitat selection is influenced by habitat cues other than those affected by grazing management. Messmer (1990) also found densities of red-winged blackbirds, brown-headed cowbirds, and eastern kingbirds did not differ significantly between grazing regimes. By contrast, another study found vesper sparrows preferred continuously grazed pastures than either rotationally grazed pastures or idle fields (Temple et al. 1999). Other studies have also found vesper sparrows prefer habitat with some shrubs for perching (Dechant et al. 2000) such as habitats along parkland edges (Anstey et al. 1995). Vegetation height, density, and proportion of shrubs did not differ between season-long or twice-over pastures in southwestern Manitoba in either year, perhaps explaining why vesper sparrows inhabited season-long and twice-over sites at similar densities.

The amount of forested area on twice-over sites may have explained the greater abundance of non-grassland birds on these sites than on season-long pastures. Grassland and non-grassland birds tended to use different grazing treatments in southwestern Manitoba, suggesting that there are biologically significant differences in habitat structure between the two grazing regimes.

5.1.2 Bird species composition and community structure

Idle fields had fewer species in common with both grazing treatments, which may reflect differences in habitat structure between grazed and ungrazed fields. Habitat structure strongly influences grassland bird composition (Rotenberry and Wiens 1980). Since grazing stimulates aboveground plant productivity (Frank and McNaughton 1993),

plant species composition and vegetation structure may differ between grazed and ungrazed fields. For instance, ungrazed fields may have a higher proportion of cool-season plants and a low proportion of warm-season plants (Hughes 1983). Hughes (1983) found grazed pastures had a higher proportion of exposed bare ground while fields left ungrazed for a minimum of 14 years had taller and denser vegetation with a greater amount of litter and trees than grazed pastures. I also found the idle fields in southwestern Manitoba had taller vegetation, and higher vertical density, litter depth, and proportion of shrubs than the two grazing regimes. Species richness, diversity, and total abundance of non-grassland birds were positively associated with these vegetative characteristics in southwestern Manitoba, probably explaining why they occurred in higher densities on ungrazed than grazed fields. Additionally, clay-colored sparrows, a facultative grassland bird, selected dense, shrubby sites in southwestern Manitoba and occurred in higher densities on ungrazed than grazed sites, which is consistent with this species' habitat preferences (Dechant et al. 1998c, Madden et al. 2000). By contrast, many obligate grassland birds, such as chestnut-collared longspurs and horned larks, both of which occurred only on grazed pastures in both years, prefer short vegetation and no shrubs (Owens and Myres 1973, Dale 1983, Prescott and Murphy 1996).

Idle fields also had more trees than sites in either grazing regime. Species richness, diversity, and total abundance of obligate grassland birds were negatively correlated with proportion of trees in both years. Additionally, Savannah sparrow and western meadowlark abundances, two obligate grassland birds, were negatively associated with proportion of trees in southwestern Manitoba. Sprague's pipits were strongly negatively associated with percent cover of shrubs in southwestern Manitoba in

both years, which is consistent with another study (Davis 2005). However, western meadowlarks may select sites with some shrubs for perching (Zimmerman and Euliss 1999, Davis 2005).

Many native grassland plants tolerate grazing and may even require it (Bock et al. 1993), and many grassland birds prefer vegetation structure produced by grazing or periodic burns (Kantrud 1981, Renken 1987, Messmer 1990, Madden et al. 1999, Madden et al. 2000). Although grazing may produce a range of vegetation characteristics that can support multiple grassland birds, bird response to grazing can vary depending on environmental conditions and vegetation structure. For instance, avian community composition may be influenced by regional soil types, moisture, climate, and plant species composition in addition to management regimes (Madden et al. 2000). Although many grassland birds use grazed fields, some avoid them (Askins et al. 2007). For instance, upland sandpiper, grasshopper sparrow, western meadowlark, and horned lark densities may be positively associated with grazed pastures (Skinner et al. 1984, Powell 2006) while Henslow's sparrow (*Ammodramus henslowii*) and sedge wren (*Cistothorus platensis*) densities may be negatively influenced by grazing (Powell 2006). Ungrazed fields may support grassland birds in drier prairie regions (Dale 1983), however, they are quickly invaded by shrubby species in southwestern Manitoba and may produce unsuitable habitat for many grassland birds.

The higher species overlap between season-long and twice-over sites than between ungrazed and sites of either grazing regime is likely due to similarities in habitat structure promoted by grazing. Vegetation may respond positively to grazing, regardless of management regime (Frank and McNaughton 1993, Briske et al. 2008). For instance,

grazing may increase the photosynthetic ability and growth rate of many plants, remove accumulated dead material, and grazers add nutrients to the soil through their excretions (Frank and McNaughton 1993). Most of the grassland birds surveyed in southwestern Manitoba preferred grazed sites and the resulting habitat.

However, the avian community also differed slightly in both species richness and species diversity among grazing regimes in southwestern Manitoba, which is consistent with other studies that have found differences in species composition among sites grazed season-long, rotationally, and ungrazed fields (Messmer 1990, Temple et al. 1999, Salo 2003). Differences in species composition between season-long and twice-over sites may have reflected differences in range conditions resulting from the two grazing regimes (Holechek et al. 1998). Results of the quantitative similarity index suggested the avian communities between the two grazing regimes differed slightly, with 36% - 40% dissimilarity, suggesting the grazing treatments influenced grassland birds differently. Although nearly all the same species of birds occurred on sites of both grazing regimes, they differed in relative abundances. Some of the differences in avian community structure may have been due to the higher total abundances of obligate grassland birds found on season-long sites and the greater total abundances of non-grassland birds found on twice-over rotation sites.

Differences in vegetation structure and landscape characteristics between the two grazing regimes likely contributed to differences in habitat composition between season-long and twice-over sites. The vegetation cover on the season-long sites may have produced a mosaic of habitat structure preferred by many grassland birds (see section 5.4). For instance, sites with short to moderate grass height and sparse to moderate

amount of forb cover may support a number of obligate grassland birds such as bobolinks, Le Conte's sparrows, Baird's sparrows, Sprague's pipits, and western meadowlarks (Madden et al. 2000).

Although many studies have found continuous and rotational grazing systems have similar effects on plant production and standing crop biomass (Hughes 1983, Briske et al. 2008), my results suggest that season-long and twice-over rotational grazing had different effects on grassland bird habitat in southwestern Manitoba.

5.2 Comparison of management characteristics between grazing regimes

The main factors that distinguish range management regimes are stocking rates, the timing of grazing, and livestock distribution (Holechek et al. 1998). Typically, season-long and rotational grazing systems differ in stocking rates, and in the temporal and spatial manipulation of grazing (Savory 1988). Stocking rates may have the most influence on plant productivity than other grazing factors (Heady 1961, Heitschmidt et al. 1987, O'Reagain and Turner 1992, Holechek et al. 1998).

Although it has been proposed that the twice-over rotation grazing system may enable landowners to increase stocking rates as forage production on the pastures increase (Manske 2004), the stocking rates on the season-long pastures were slightly higher than the twice-over rotation pastures in southwestern Manitoba, which may explain some of the differences in local vegetation structure observed between the two grazing regimes.

In some ecosystems, high stocking rates may negatively impact grassland bird habitat (Newton 1998). Excessive defoliation can impair the plant's photosynthetic ability

and can stunt the growth of the root system below the ground, making it more difficult to obtain nutrients and minerals from the soil (Holechek et al. 1998). Although grazing, drought, and fire interact to produce and maintain grasslands, heavy grazing may be destructive to the prairie ecosystem (Holechek et al. 1998). For instance, overgrazing can remove the dead plant material (carryover) needed to protect the soil over the winter (Willms et al. 1990). Although high stocking rates can lead to overgrazed pastures, high stocking rates are not the only cause of overgrazing (Savory 1988). Properly managed season-long grazing, with controlled stocking rates, may be more sustainable than poorly managed rotation grazing systems (Briske et al. 2008). However, since I found more grassland birds using season-long than twice-over sites, the stocking rates for the season-long pastures in southwestern Manitoba may not be high enough to be destructive.

Previous studies found no difference in vegetation composition, litter biomass, or the quantity of forage among rotational and continuous grazing systems when the grazing intensities were equal (Gammon and Roberts 1978 in Heitschmidt et al. 1987, Hart et al. 1988). Therefore, grazing intensity may be more influential on local vegetation structure and grassland birds than grazing regime (Beck and Mitchell 2000). Grazing can influence the amount of grass, litter, and shrubby vegetation, as well as the height and density of above ground biomass (Askins et al. 2007). However, many plants differ in their responses to grazing and to grazing intensity (Heitschmidt et al. 1987). For instance, plants that have evolved with grazers are relatively resistant to grazing, and may increase in density with grazing, such as blue grama, which can quickly replenish the carbohydrate reserves lost during defoliation (Heitschmidt et al. 1987).

I also expected the grazing start dates for the season-long pastures to be earlier than 1 June, which is when cattle are pastured in the twice-over rotation system. Twice-over rotation sites begin grazing 1 June annually because grazing native prairie in early June may increase plant productivity and biomass, depending on the species and the climate (Sedivec 1992, Manske and Sedivec 1999). Pastures grazed earlier than 1 June in the season may have little vegetation cover and produce habitat that is less attractive for nesting birds than pastures grazed later in the season (Temple et al. 1999). However, the grazing start dates between the two grazing regimes were similar, which may also help explain why differences in vegetation structure between the two grazing regimes were fairly subtle (Biondini and Manske 1996).

The presence of cattle early in the season may also disturb birds establishing territories (Jensen et al. 1990). Although rotationally grazed fields may provide a refuge from cattle for nesting birds early in the season, they may be detrimental once a high density of cattle is moved into the paddock (Paine et al. 1996). If pastures are grazed twice annually in the twice-over rotation grazing system, it is possible this does not provide grassland birds enough time to complete a breeding attempt between rotations. Many grassland birds, such as Sprague's pipits, chestnut-collared longspurs, and Baird's sparrow, may produce two clutches a year (Maher 1973, Sutter et al. 1996, Davis and Sealy 1998, Dickinson and Dale 1999 in Robbins and Dale 1999), from approximately early to mid-May to approximately mid-July (Robbins and Dale 1999). The length of time between nesting attempts may be as soon as 6 days after the first brood has fledged for chestnut-collared longspurs (Hill and Gould 1997) and 5-8 days for Baird's sparrows in southwestern Manitoba (Davis and Sealy 1998). Given that the approximate time of

incubation for songbirds is 11 days (Ehrlich et al. 1988), and the rest period for the twice-over grazing sites surveyed in this study was about 28 days (K. Murray, Manitoba Conservation, personal communication), this may not be enough time for many grassland birds to complete both nesting attempts. However, this remains a hypothesis, and further studies on the effects of twice-over rotation grazing systems on the nesting success of grassland birds may determine if the length of the rest period is adequate for many grassland birds to successfully breed. Additionally, the rest phase may not be long enough for the habitat structure to recover between grazing periods, or for birds to move to preferred habitat types before the vegetation structure is again altered.

Rotational grazing regimes also manipulate the distribution of cattle on the pasture to improve rangelands (Savory 1988), usually through fencing. By limiting the movement of a herd to one paddock at a time, rotational grazing may force livestock to graze on less preferred plant species as alternatives (Coughenour 1991), which may generate a more homogeneous environment. However, rotational grazing may not completely eliminate selective grazing by cattle (Stuth et al. 1987, Walker et al. 1989), suggesting selective grazing occurs regardless of grazing system. Selective grazing causes non-uniform distribution of livestock on the landscape (Willms et al. 1990) creating areas of high use and areas of low use. However, selective grazing would occur within paddocks in a rotational grazing system but at the field scale for season-long grazing, which may increase the heterogeneity of the landscape. Season-long grazing can produce patchy environments due to selective grazing by cattle (Saab et al. 1995, Holechek et al. 1998). Brock et al. (1993) found that rotationally grazed pastures did not generate heavily grazed patches preferred by some grassland birds. Season-long grazing

may actually benefit grassland bird communities, by creating somewhat temporally stable areas of high use and low use within the same pasture.

A heterogeneous environment influences species diversity of wildlife (Wiens 1997) and is required to maintain a diverse grassland bird community (Fulhendorf and Engle 2001). Species richness and diversity of grassland birds was lower on twice-over rotation sites than season-long, perhaps because twice-over sites were more homogeneous, and therefore included fewer niche types, than season-long sites.

5.3 Effects of grazing regimes on local vegetation structure

Although the twice-over rotation system intends to increase plant production by promoting the growth of new shoots (Manske 2004), the percent cover of grass and forbs was higher on season-long sites than twice-over in both years, which is consistent with other studies that have found plant production from season-long grazing to be similar or greater than rotation grazing systems (Briske et al. 2008). Schneider (1998) also found higher percent cover of forbs on season-long pastures than on rotational grazing systems in North Dakota. Alternatively, a study conducted in northern Nevada found rotational grazing increased forb density and produced habitat used by greater sage-grouse (*Centrocercus urophasianus*) (Neel 1980 in Holechek et al. 1982). However, Neel (1980) found greater sage-grouse occurred in high densities on moderately grazed sites and were absent on overgrazed sites, suggesting habitat suitability may have been influenced more by grazing intensity than by grazing system. Continuous grazing was thought to result in overgrazing of desirable grass and forb species; however, few studies have documented this (Holechek et al. 1998, Briske 2008).

Vegetation can be an important indication of suitable nesting habitat for many grassland birds (Chapman et al. 2004). Madden et al. (2000) found both proportion of cover of grass and forbs positively influenced densities of many obligate grassland birds such as bobolinks, Sprague's pipits, western meadowlarks, Baird's sparrows, and Le Conte's sparrows. Bobolinks may select sites with a high density of forbs for nesting (Bollinger 1995), and were found in greater abundances on season-long than twice-over sites. Sprague's pipit abundances were positively correlated with percent cover of grass but negatively correlated with percent cover of forbs in southwestern Manitoba. Sutter (1997) also found Sprague's pipit densities positively associated with amount of grass and negatively with amount of forbs and exposed bare ground. In some ecosystems, Sprague's pipits may use sites with short, sparse vegetation cover (Madden et al. 2000). Although amount of forbs and exposed bare ground were higher on season-long sites than twice-over in southwestern Manitoba, pipit densities were not influenced by grazing regime, suggesting grazing may produce suitable habitat for Sprague's pipits in southwestern Manitoba, regardless of grazing system. Madden et al. (2000) found Sprague's pipit densities were negatively associated with vegetation density; however, vegetation density did not influence abundances of Sprague's pipits in southwestern Manitoba. Buskness et al. (2001) also found higher percent cover of exposed bare ground on continuously grazed than rotationally grazed pastures in North Dakota (Table 5, p. 255).

Effects of grazing regimes on vegetation structure may be variable (Heady 1961, Holechek et al. 1999). A review of 15 studies evaluating the effects of season-long versus rotation grazing on vegetation in North America suggested results were largely dependent

on ecosystem (Holechek et al. 1999). For instance, in arid or semiarid grasslands, the effects on vegetation between season-long or twice-over rotation grazing regimes generally did not differ. In contrast, research conducted in moist or humid grasslands found rotation grazing systems resulted in a 20-30% higher amount of forage production than season-long grazing (Holechek et al. 1999). Although studies from the northern Great Plains were evaluated, no study conducted in the mixed-grass prairie region of Manitoba was included in the Holechek et al. (1999) review.

Many studies have found no benefit of rotational grazing on above-ground biomass or plant species composition when compared to season-long grazing (Weltz and Wood 1986, Hart et al. 1988, Ignatiuk and Duncan 2001, Hart et al. 1993, Manley et al. 1997, Gillen et al. 1998, McCollum et al. 1999, Buckness et al. 2001, Derner and Hart 2007, Briske et al. 2008). Although the twice-over rotation grazing system differs from other rotational grazing regimes and may therefore have different effects on vegetation, Gillen et al. (1991) found no difference in standing crop biomass and species composition among three rotational grazing systems in the tallgrass prairie region of Oklahoma. The timing of cattle grazing in the twice-over system is aimed at grazing plants before they mature, when they are more nutritious (Manske 1999). However, bluebunch wheatgrass (*Pseudoroegneria spicata*) plants clipped during the pre-boot stage were no higher in nutritive value than non-clipped plants (Westenskow-Wall et al. 1994). By contrast, Pitt (1986) found the nutritive quality of boot-stage vegetation higher than post boot-stage vegetation; however, the amount of available forage was less. Additionally, a study conducted in western North Dakota, found that although plant species composition differed between grazed and ungrazed sites, there was no difference in plant species

composition between sites grazed twice-over rotationally and sites grazed season-long at moderate stocking rates (Biondini and Manske 1996). It is possible that external factors such as climate, precipitation, site characteristics, and grazing in general regardless of grazing system, effect plant species composition (Biondini and Manske 1996), suggesting that grazing management may not be influencing vegetation structure as much as expected (Briske et al. 2008).

Grazing at light to moderate intensities can increase plant productivity (the grazing optimization hypothesis) and influence plant species composition (Briske et al. 2008). The grazing optimization hypothesis suggests that vegetation will increase in biomass if grazed up to a certain intensity level. Beyond this threshold, plant productivity will decrease (McNaughton 1983, Milchunas and Lauenroth 1993). Although there is some controversy over whether or not grazing increases plant productivity, this is likely due to the scale at which the observations were made, the evolutionary history of the vegetation, or the grassland ecosystem (Milchunas and Lauenroth 1993). Therefore the vegetation composition and structure of grazed and ungrazed communities may be very different.

The tall, dense, and shrubby vegetation cover on the idle fields in southwestern Manitoba does not produce habitat preferred by many obligate grassland birds. Western meadowlarks, vesper sparrows, and Savannah sparrows were negatively associated with tall, dense vegetation and deep litter layers, which may have driven the low abundances of these birds on idle sites in southwestern Manitoba. In addition, the following obligate grassland birds observed in southwestern Manitoba have been negatively associated with woody vegetation in previous studies: Baird's sparrow, Le Conte's sparrow (Madden

1996), bobolink, Savannah sparrow (Wiens 1969, Johnson and Igl 2001), sedge wren, and western meadowlark (Sample 1989, Herkert 1994, Vickery et al. 1994). Facultative grassland birds may not be negatively influenced by the amount of woody vegetation, because they use habitats other than grassland for some part of their life cycle. For instance, mourning doves (*Zenaida macroura*), a facultative grassland bird, may be positively associated with woody vegetation (Tomlinson et al. 1994 in Johnson and Igl 2001).

Management practices, such as grazing systems, may influence vegetation structure at the spatial extent of individual territories. Grazing can influence vegetation structure in a number of ways. For example, changes in vegetation height and plant morphology influences vertical vegetation structure, and horizontal vegetation structure is altered by increased patchiness through selective grazing and trampling by livestock (Hartnett et al. 1997). As the preferred plant species are consumed, growth of the non-preferred plant species increases (Collins and Barber 1985). Although some introduced vegetation may not impact native vegetation negatively (Simberloff 1981), introduced vegetation can suppress the growth of native vegetation (Wilson 1989), and alter the native ecosystem (Simberloff 1981, Vitousek et al. 1987).

Another benefit of ecological disturbance is that grasslands left ungrazed generally accumulate standing dead vegetation. As more dead leaves accumulate, lower leaves become shaded, leading to a reduction in photosynthesis that eventually reduces growth. Grasses left ungrazed therefore experience a reduction in tillering (Brand and Goetz 1986, Briske and Richards 1995). Under these conditions, the proportion of native grasses tend to decrease and the proportion of shade-tolerant species, such as smooth

brome and Kentucky bluegrass, will increase. Shrubs can also inhibit grass growth by competing for sunlight (Kochy and Wilson 2000).

Wallwork (1976) referred to grasslands that require constant management to inhibit plant succession as 'managed grasslands'. The successional climax species of managed grasslands are woody vegetation and if left idle, these grasslands can succeed into forested areas (Wallwork 1976).

Although vegetation height and density were greater on ungrazed fields than on grazed sites, the average percent cover of litter was significantly greater on twice-over than idle and slightly greater than season-long sites in the last year of the study. Litter depth on idle sites was greater than on twice-over sites, which was expected because grazing by large mammals may reduce the amount of litter in grasslands (Sample 1989, Facelli and Pickett 1991). Some studies suggest that rotational grazing systems increase litter depth more than season-long grazing (Sedivec et al. 1990, Schneider 1998, Buskness et al. 2001). Alternatively, a study conducted on the Great Plains found rotationally grazed pastures had less litter accumulation than continuously grazed pastures (Heitschmidt et al. 1987). However, there was no significant difference in litter depth between twice-over rotation and season-long grazing regimes in southwestern Manitoba.

Vegetation structure is influenced by the accumulation of litter and standing dead vegetation (Vinton and Collins 1996), which will affect the habitat suitability for some grassland birds. Vegetative growth is either enhanced or inhibited by litter, depending on the plant species (Facelli and Pickett 1991). Litter layers can intercept sunlight creating a cooler environment by reducing the soil temperatures and shading seedlings, which can

negatively affect many plant species. In addition, litter can prevent many plant species from germinating (Facelli and Pickett 1991). Litter may also produce moister environment by absorbing rainfall before it percolates into the soil or by inhibiting water evaporation from the soil. Some plant species may benefit from the improved water conditions and may more easily become established with increased litter accumulation. Litter accumulation on grasslands may decrease the plant species richness and inhibit the growth of some forbs (Facelli and Pickett 1991). Litter decomposition requires nitrogen (Kochy and Wilson 1997) and may reduce the amount of nitrogen available for plant growth. Therefore, the greater percent cover of litter on the twice-over sites in southwestern Manitoba may have hindered the growth of forbs on these sites.

I found no effect of grazing regime on vegetation height, density, or litter depth in southwestern Manitoba, which may explain why I found no effect of grazing regime on relative abundances of facultative and some obligate grassland birds. A study conducted in North Dakota also found no difference in vegetation density between rotational and season-long grazing systems (Schneider 1998). However, Schneider (1998) found increased litter depth on rotational than season-long sites. In contrast, a study conducted on the Great Plains found that grassland birds tended to avoid continuously grazed pastures due to the low vegetation height and the lack of cover this provides for nests (Temple et al. 1999). The stocking rates on the continuously grazed pastures in the Temple et al. (1999) study were higher than those on the season-long pastures surveyed in southwestern Manitoba, which may have caused these fields to be overgrazed, thus explaining the low vertical density of the vegetation.

The twice-over rotation system claims to control the spread of non-native vegetation by increasing the aboveground biomass of native vegetation (MHHC 2002). However, the effects of introduced vegetation on avian communities are varied. A study conducted in Manitoba suggested the abundances of two grassland birds were positively correlated with sites dominated by non-native vegetation: clay-colored sparrows with smooth brome, and grasshopper sparrows with Kentucky bluegrass (Wilson and Belcher 1989). Abundances of other grassland birds were positively correlated with native vegetation, such as upland sandpiper with blue grama, Sprague's pipit with prairie junegrass (*Koeleria cristata*), and western meadowlark with little bluestem. Bobolinks were found to be negatively associated with native pastures in Alberta (Prescott and Murphy 1996), although were found on both native and tame sites in Manitoba and Saskatchewan (Hartley 1994). Sprague's pipit and upland sandpiper abundances have been negatively associated with tall non-native vegetation and positively with short native vegetation (Wilson and Belcher 1989). However, more research is needed to fully understand the effects of introduced plant species on grassland birds (Vitousek et al. 1987).

Native prairie may be more beneficial to grassland birds (Berkey et al. 1993, Sutter 1996) because the structure may provide more coverage and protection for nests than non-native vegetation. Smooth brome, for instance, grows in a mat (Moore 2003), providing little shelter for nesting birds. Upland sandpiper, western meadowlark, Baird's sparrow, Savannah sparrow, and Sprague's pipit, all obligate grassland birds, were positively associated with native vegetation in the mixed-grass prairies region of Manitoba (Wilson and Belcher 1989). Sprague's pipits are also positively associated with

native vegetation throughout their range (Kantrud 1981, Wilson and Belcher 1989, Dale et al. 1997). Chestnut-collared longspurs have also been positively associated with native pastures (Fairfield 1968, Owens and Myres 1973, Maher 1974, Stewart 1975, Faanes 1983, Anstey et al. 1995, Davis and Duncan 1999).

Conversely, some non-native plants may provide similar structure to native plants and may serve as suitable nesting sites. Clay-colored sparrows may use crested wheat/alfalfa (*Medicago sativa*) mixed fields (Davis and Duncan 1999), likely because alfalfa has a similar structure to many shrub species (Johnson and Schwartz 1993). Davis and Duncan (1999) found that some grassland birds, such as grasshopper sparrows, show little preference for native prairie. In addition, Madden et al. (2000) found bobolinks and grasshopper sparrows selected broad-leaved non-native grasses, such as smooth brome and quack grass, in northwestern North Dakota. Birds may use cues such as vegetation cover and structure for habitat selection rather than select for native versus non-native vegetation (Davis and Duncan 1999, Madden et al. 2000).

Non-native plants may also influence the seed diversity and availability for grassland birds (Wilson and Belcher 1989). Although I predicted granivorous grassland birds may select native vegetation due to a preference for native plant seeds, the period grassland birds are selecting breeding territories does not coincide with the period native vegetation goes to seed (USDA 2010). Some grassland birds, such as dickcissels (*Spiza americana*), may forage beyond the limits of their breeding territories (Zimmerman 1982); therefore, food abundance may not influence the selection of nesting sites. Vegetation structure may be more important than the food availability as an indicator of suitable habitat for breeding grassland birds.

Manitoba Conservation requires pastures to have a minimum of 30% native vegetation composition to be eligible for a twice-over rotational agreement (Greenall 1996). For comparative purposes, the season-long pastures surveyed in this study also had a certain proportion of native vegetation present. In some cases, the amount of native vegetation present on the season-long pastures was comparable to those found on twice-over rotation pastures (K. Murray, Manitoba Conservation, personal communication). Since grazing native prairie may provide habitat for grassland birds (Peterjohn 2003), grazed native prairie may be suitable for grassland birds regardless of grazing management. Therefore, grassland bird abundances may not be influenced by native or non-native plant species, but perhaps only on vegetation structure. For instance, Baird's sparrow, Savannah sparrow, vesper sparrow, horned lark, and western meadowlark were observed in equal abundances on both native and non-native pastures (Davis and Duncan 1999).

5.4 Influence of local vegetation structure on grassland birds

Vegetation structure affected obligate and facultative grassland birds differently, which may reflect a difference in the habitat requirements between the groups of grassland birds. For example, the species richness and diversity of obligate grassland birds were negatively influenced by the percent cover of shrubs, whereas species richness and diversity of facultative grassland birds were consistently positively influenced by percent cover of shrubs. Some species of facultative grassland birds prefer shrubby habitats, such as American goldfinch (*Carduelis tristis*), clay-colored sparrow, and common yellowthroat (Johnson and Temple 1986, Zimmerman 1992).

In contrast, the abundances of obligate grassland birds were positively associated with proportion cover of grass in southwestern Manitoba, which suggests grass cover is an important habitat characteristic for these grassland birds, whereas facultative grassland birds showed no preference for percent cover of grass. The higher proportion of grass on season-long than twice-over sites may have influenced the greater abundance, species richness and diversity of obligate grassland birds on season-long than twice-over sites.

The higher amount of exposed bare ground on season-long than twice-over sites in 2008 may have produced grassland habitat preferred by some birds and increased the species richness of grassland birds on the season-long pastures (Prescott and Murphy 1996). I found abundances of Savannah sparrows were positively influenced by the proportion of exposed bare ground in southwestern Manitoba, which is consistent with other studies (Davis 2004).

Vegetation height and density positively influenced the abundances of four obligate grassland birds and two facultative grassland birds. Management regimes that increase the percent cover of grass may positively influence obligate grassland birds. Although effects of many local vegetation characteristics on obligate and facultative grassland birds differed, both were positively influenced by percent cover of litter.

Bobolinks tended to use sites with taller and denser vegetation, which is consistent with other studies (Tester and Marshall 1961, Bollinger 1995, Madden et al. 2000), and bobolinks also tended to select sites with a higher proportion of forbs. Bobolinks were negatively associated with percent cover of litter in 2009, and with the percent cover of shrubs, which is consistent with other studies (Sample 1989, Bollinger and Gavin 1992). Although studies have shown bobolinks select sites with a high percent

cover of grass and moderate cover of forbs (Wiens 1969, Renken 1983, Herkert 1994, Madden 1996), they were not influenced by either percent cover of grass or forbs in southwestern Manitoba.

Clay-colored sparrow, eastern kingbird, western meadowlark, and red-winged blackbird densities were all positively associated with percent cover of litter in southwestern Manitoba, which is consistent with other studies (Rotenberry and Wiens 1981, Dechant et al. 1998c, Zimmerman and Euliss 1999, Bleho 2009).

Some grassland birds may select sites with lower litter coverage, such as chestnut-collared longspurs and grasshopper sparrows (Renken 1983, Berkey et al. 1993, Anstey et al. 1995, Swengel and Swengel 2001). Bobolinks were the only grassland bird to be negatively associated with the percent cover of litter in southwestern Manitoba. Although bobolinks may select sites with relatively low litter cover (Johnson 1997), this is in contrast to other studies that have found bobolinks to be positively correlated with litter cover (Delisle and Savidge 1997, Patterson and Best 1996). However, both studies were conducted on tame pastures, therefore the vegetation composition and structure of these studies may be quite different from the pastures surveyed in southwestern Manitoba.

Le Conte's sparrow abundances were positively associated with vegetation density, which is consistent with other studies that show Le Conte's sparrow tend to select nesting sites with dense, tall vegetation and a deep litter layer (Madden 1996, Dechant et al. 1998f).

Although research has found that Sprague's pipit abundances are influenced by vegetation height (Kantrud 1981, Davis 2004), I observed no correlation between

Sprague's pipit abundances and vegetation height or density in either year. Koper and Schmiegelow (2006a) also found Sprague's pipit abundances unaffected by vegetation height, density, litter depth, or percent cover of bare ground. Percent cover of grass, however, had a positive influence on Sprague's pipit abundances in southwestern Manitoba in both years, which is consistent with other studies (Prescott and Murphy 1996, Schneider 1998). Sprague's pipit abundances however, may be negatively influenced by proportion cover of non-native grasses such as Kentucky bluegrass (Schneider 1998).

Western meadowlark abundances may be positively correlated with litter depth, percent cover of grass, forbs, and a low to moderate litter cover, and negatively with vegetation height (Sutter and Brigham 1998, Madden et al. 2000). Similarly, in southwestern Manitoba, western meadowlark abundances were positively correlated with vegetation density, percent cover of grass, and litter. Influences of shrubs on western meadowlark abundances may vary (Kimmel et al. 1992, Anstey et al. 1995, Madden 1996); percent cover of shrubs had no influence on western meadowlark abundances in southwestern Manitoba.

Although Savannah sparrows tend to select habitat with short to intermediate vegetation height and density (Swanson 1998), I found Savannah sparrow abundances to be positively correlated with vegetation height. Another study conducted in the mixed-grass prairies also found Savannah sparrow abundance to be positively associated with vegetation height/density (Schneider 1998). They also show a preference for sites with a deep litter layer (Rising 1996); in contrast, in southwestern Manitoba they were negatively associated with litter depth. Influence of grass cover on Savannah sparrow

abundances are varied, either responding positively or negatively to percent cover of grass (Renken and Dinsmore 1987, Sutter 1996). Abundances of Savannah sparrows are generally negatively correlated with amount of exposed bare ground (Martin and Forsyth 2003), and positively correlated with percent cover of forbs (Rotenberry and Wiens 1980). I observed the opposite pattern in southwestern Manitoba where Savannah sparrow abundances were negatively correlated with percent cover of forbs and positively correlated to amount of exposed bare ground. However, other studies have also found preferred nesting sites of Savannah sparrows are dominated by short, dense grasses and few forbs (Wiens 1969, Vickery et al. 1992*b*). Vegetation structure at the local scale may have a strong influence on the habitat selection of grassland birds (Wiens 1989, Johnson and Igl 2001, Koper and Schmiegelow 2006*a*, Bleho 2009).

Percent cover of shrubs strongly influenced bird abundances in both years. Most obligate grassland birds, such as Le Conte's sparrow, Savannah sparrow, Sprague's pipit, and bobolinks, avoided shrubby sites, whereas only one facultative grassland bird, red-winged black bird, avoided sites with a high percent cover of shrubs. By contrast, clay-colored sparrow used idle sites in 2009 and was positively associated with shrubs in both years, which is consistent with other studies (Knapton 1994).

5.5 Influence of landscape characteristics on grassland birds

Landscape features can have strong influences on bird densities (Howell et al. 2000), especially on breeding grounds (Flather and Sauer 1996). Unlike many drier grassland ecosystems, for which successional climax species are grasses (Wallwork 1976), the mixed-grass prairie region of Manitoba receives enough precipitation to

support the growth of woody vegetation, and may succeed from grassland to forest in 10-20 years in the absence of ecological disturbance (N. Koper, personal communication, 2010). Woody vegetation can invade the area and easily become established without management. Six of the idle sites (75%) surveyed in this study were WMAs, which for the most part have been left unmanaged. With fire suppressed and grazers removed, the idle fields surveyed in this study are heavily invaded by woody vegetation.

The encroachment of woody vegetation has a large effect on the suitability of habitat for grassland birds (Samson and Knopf 1994, Winter et al. 2000, Nernberg and Ingstrup 2005). The larger proportion of woody vegetation on the ungrazed compared to the grazed sites likely contributed to the greater abundance, species richness and diversity of non-grassland birds on these sites. Woody vegetation can degrade grassland habitat and may contribute to the population declines of many grassland birds (Johnson and Igl 2001) at the landscape-scale (Coppedge et al. 2001), and at the patch-scale by negatively influencing nesting success (Johnson and Temple 1990, Winter et al. 2000, Patten et al. 2006). Spatial scale, such as the amount of suitable grassland patches on the landscape, may also influence site selection of grassland birds (Bakker et al. 2002).

Similar to tallgrass prairie regions, the matrix habitat surrounding mixed-grass prairies in southwestern Manitoba may be uninhabitable for many grassland birds (Winter et al. 2000), whereas other regions of mixed-grass prairie, such as southern Saskatchewan, may be surrounded by habitat similar in vegetation structure (Davis et al. 2006). Grassland fragments surrounded by inhospitable matrix habitat, for instance forested areas, will likely reduce occurrences of many habitat specialists, such as obligate grassland birds (Debinski and Holt 2000). Consequently, landscape characteristics, such

as roads, cropland, woodland, or grazed pastures, may also influence grassland bird responses to edge effects (Davis et al. 2006, Koper and Schmiegelow 2006a). For instance, although clay-colored sparrows and sedge wrens occupy both small and large patches, densities of these grassland birds may be lower in large patches within landscapes with little grassland habitat (Bakker et al. 2002).

Alternatively, the matrix habitat may be suitable for many grassland birds, depending on the management and composition of the surrounding fields. Even though some grassland birds use farmland and pastures during the breeding season and as wintering grounds, the quality of the surrounding matrix may affect the overall suitability of these sites. As agriculture around these sites continues to develop, suitability of grassland bird habitat may be negatively impacted (Askins et al. 2007).

Amount of treed area may indirectly influence grassland bird abundances by the increased amount of tree edge, which will reduce the amount of available core habitat (Davis et al. 2006). Grassland birds nesting near forest edges may experience higher rates of predation or brood parasitism (Winter et al. 2000). For instance, brown-headed cowbird densities may be greater along forest edges because of the increased number of perches that allow females to nest search (Brittingham and Temple 1983, Robinson et al. 1995). Grant et al. (2006) found clay-colored sparrows and vesper sparrows nesting in close proximity to forest edges experienced lower nesting success due to predation by thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*). Alternatively, some grassland birds, such as Savannah sparrows and bobolinks, may establish territories within the core areas of patches with a high degree of wooded areas (approximately 47% of the total patch area; Renfrew and Ribic 2008).

I found the abundances of two obligate grassland birds, western meadowlarks and Savannah sparrows, negatively correlated with proportion of woodland area on the site, which is consistent with other studies that have found an increase in amount of forest edge negatively influences densities of these grassland birds (Bakker et al. 2002).

Obligate grassland birds preferred sites with large open grassland areas and little to no woodland areas. In contrast, some facultative grassland birds selected sites with a high degree of woodland area. For instance, clay-colored sparrows, a facultative grassland bird, selected sites with a high proportion of trees and low amount of open grassland area in southwestern Manitoba, which may reflect this species ability to use both the grassland and the shrubby areas (Knapton 1994, Debinski and Holt 2000). Duran (2009) also found facultative grassland birds unaffected by ungrazed areas in southwestern Manitoba. Facultative grassland birds may be habitat generalists and therefore more resilient to changes in the landscape (Howell et al. 2000) or to changes in habitat structure.

The season-long sites had a larger proportion of grassland habitat available for songbirds than the twice-over rotation sites. The greater amount of grassland may have explained the greater abundance, species richness, and diversity of obligate and facultative grassland birds observed on the season-long than on the twice-over sites (Vickery et al. 2004, Johnson and Igl 2001, Davis 2004). A larger area will likely have more microhabitats that may enable the larger sites in this study to support more species (MacArthur and Wilson 1967) and may increase bird nesting success (Clark and Diamond 1993 reviewed in Ignatiuk and Duncan 2001). The proportion of suitable

habitat (i.e. grassland) within an area may be a better indicator of nesting success than total patch size (Reynolds et al. 1994).

Increased amount of edge may also negatively influence the quality of the grassland habitat, increase the amount of brood parasitism, and density of predators (Brittingham and Temple 1983, Johnson and Temple 1990, Robinson et al. 1995, Winter et al. 2000); however, this may depend on the habitat of the surrounding matrix (Koper and Schmiegelow 2006a, Koper et al. 2009). In addition, the size and shape of a grassland patch may influence grassland bird densities and breeding success (Herkert 1994, Vickery et al. 1994, Winter and Faaborg 1999, Davis et al. 2006).

My results were consistent with other studies that have found grassland birds select larger patches of grassland (Johnson and Igl 2001, Davis 2004, Mozel 2010). Grassland birds may select larger grassland patches because of the habitat quality or vegetation structure of the core area (Davis et al. 2006), or because of the greater distance to edge habitats (Johnson and Igl 2001). In addition, species diversity and density of grassland birds may be greater in larger prairie fragments than smaller ones (Herkert 1994). Conversely, smaller patches may not be large enough to include all of a species' territorial characteristics (Davis 2004). Savannah sparrow densities were positively correlated with size of grassland patches in southwestern Manitoba, which is consistent with other studies (Bakker et al. 2002). Some grassland birds, such as grasshopper sparrows, may be influenced by local vegetation characteristics within the patch rather than patch size (Winter and Faaborg 1999, Koper and Schmiegelow 2006a, Davis 2004).

Species sensitive to area fragmentation may avoid idle fields because of their small size and the high proportion of woody and shrubby vegetation within them. Species

that are area sensitive may also be influenced by close proximity to edge, predator community, and vegetative and landscape characteristics of small patches (Winter and Faaborg 1999). However, small prairie fragments with a high degree of interior habitat and low amount of edge may provide suitable habitat for area-sensitive species (Debinski and Holt 2000, Davis 2004).

As species may occur in high densities on a grassland patch, but still experience low reproductive success, Winter and Faaborg (1999) argue that census data based on species presence or absence are more valuable indicators of species area-sensitivity than bird species abundances. Although grassland birds may use both large and small prairie fragments within the landscape, some grassland birds, such as dickcissels, may occur in lower densities or experience a lower nesting success in smaller patches (Winter and Faaborg 1999).

Idle sites ranged from 0.15 km² – 1.85 km², whereas season-long sites were 0.15 km² – 3.4 km² and twice-over sites ranged from 0.32 km² – 2.6 km². A minimum patch size of 0.18 km² is suggested to support a variety of grassland bird species in the mixed-grass prairie, though many grassland birds, such as Sprague's pipits, may require larger contiguous segments (Davis et al. 2006). Although bobolinks used smaller sites in southwestern Manitoba, they showed a preference for larger areas of open grassland, which is consistent with other studies (Johnson and Igl 2001). Brown-headed cowbirds and western meadowlarks have shown no sensitivity to site area in other studies (Davis 2004); however, both were positively associated with site area in southwestern Manitoba. Sprague's pipit abundances were positively correlated with site area and clay-colored sparrows unaffected by site area in southwestern Manitoba, which is consistent with other

studies (Bakker et al. 2002, Davis 2004, Davis et al. 2006). The amount of grassland tended to influence grassland bird densities in southwestern Manitoba; therefore, management practices that involve tree removal and control the growth of woody vegetation may increase the amount of grassland habitat available for obligate grassland birds.

5.6 Contribution of grazing management to species at risk

The species at risk observed in this study used grazed pastures and avoided idle fields, but did not prefer one grazing regime over another. Therefore, the implementation of grazing systems may be an acceptable management approach for attracting these grassland birds, which supports the continuation of grazing management strategies in southwestern Manitoba.

Previous research has found that chestnut-collared longspur tend to select sites with dense vegetation, high vegetation diversity, and moderate litter depths (Renken 1983, Johnson and Igl 1995). They also tend to prefer grazed or mowed sites with few shrubs (Kantrud and Kologiski 1983, Davis and Duncan 1999, Davis et al. 1999). Although chestnut-collared longspurs tend to prefer native vegetation, non-native pastures, hay and croplands will be selected if the vegetation structure, including height and density, is suitable (Davis et al. 1999, Dechant et al. 1998*b*). Chestnut-collared longspurs feed and nest within their territories (Hill and Gould 1997), which may make chestnut-collared longspurs more discriminatory about site selection than birds that forage outside their nesting territory. In contrast to my observations, short-term studies conducted in the mixed-grass prairie region of North Dakota found chestnut-collared

longspur densities to be greater on twice-over rotation systems than other grazing regimes (Messmer 1990). The contrast between my study and Messmer's (1990) may be that I detected no significant difference in litter depth, vegetation height, or density between the two grazing treatments. Although percent cover of litter was significantly greater on twice-over rotation sites than season-long in 2009, this did not seem to be a determining factor for site selection by chestnut-collared longspurs. However, the mixed-grass prairie region of southwestern Manitoba is at the edge of their breeding range (Green et al. 2002), which may account for their low abundances in sites of all treatments.

Studies have found that Baird's sparrow use a variety of habitat types such as hayland, cropland, and non-native prairie (Dechant et al. 1998a, Davis and Duncan 1999), instead of only native prairies as previously thought (Davis and Sealy 1998). However, studies conducted in southwestern Manitoba found higher densities of Baird's sparrows on idle fields than hayed land (DeSmet and Conrad 1991, Duran 2009). Baird's sparrows tend to select sites with tall, dense vegetation, with a moderate amount of litter accumulation, and few shrubs (Kantrud and Kologiski 1983, Madden et al. 2000, Davis 2004). These four vegetation characteristics, however, did not differ significantly between grazing regimes in either year, which perhaps explains why pastures with either grazing regime are suitable for Baird's sparrow in southwestern Manitoba. A study conducted in North Dakota found Baird's sparrows preferred grazed over ungrazed sites but did not distinguish among grazing regimes (Messmer 1990). Baird's sparrows also prefer sites with little exposed bare ground for nesting (Green et al. 2002), which was greater on season-long sites in 2008, but did not differ between grazing regimes in 2009. Baird's sparrows require approximately 0.80-2.25-ha for their territories (Green et al.

2002), which fit into the ranges of site sizes from both grazing regimes. Baird's sparrows were one of the least common species at risk observed during surveys in southwestern Manitoba, with a total abundance of 3.5 individuals in 2008 and 2009 combined. Duran (2009) also found low abundances of Baird's sparrows in the mixed-grass prairie region of southwestern Manitoba, with a total abundance of 2.0 individuals during the same time period.

Trends from BBS data indicate Baird's sparrows have experienced a mean annual population decline of 8.2% nation-wide from 1988-2008. During the same time period, Baird's sparrows have experienced mean annual population declines of 6.9% in the Canadian prairie pothole region, with 3.7% in Alberta and 9.2% in Saskatchewan (BBS 2010). Baird's sparrows were once among the most common grassland birds in Manitoba, but are now restricted to the southwestern corner of the province where grassland habitats are severely fragmented (Davis and Sealy 1998). The high degree of habitat fragmentation increases nest predation and brood parasitism by brown-headed cowbirds which reduces habitat suitability and reproductive success for this grassland bird (Davis and Sealy 1998). Although Baird's sparrow was listed as "threatened" in 1989 by COSEWIC, it was delisted in April 1996 (Davis and Sealy 1998, COSEWIC 2010) and is currently not on Schedule 1 of the Species at Risk Act (SARA 2010). However, since in the past decade, the Baird's sparrow has experienced a mean annual population decline of 0.1 % nation-wide, its current status may need to be reevaluated.

Sprague's pipits showed no preference between sites grazed season-long or twice-over rotationally. They tend to prefer sites with vegetation of medium height and density, few shrubs, and moderate litter depth (Davis and Duncan 1999, Madden et al.

2000). Again, since these vegetation characteristics did not differ significantly between grazing regimes, this may explain why Sprague's pipits occurred as frequently on pastures of each grazing treatment. Studies in Saskatchewan found Sprague's pipit densities were higher on ungrazed than grazed pastures (Maher 1973, Owens and Myres 1973, Dale 1984). However, due to the relatively high degree of moisture in Manitoba's mixed-grass prairies, the idle sites in Manitoba likely had more woody vegetation than those found in Saskatchewan. Sprague's pipits tended to avoid idle fields in southwestern Manitoba, likely due to the higher amount of treed areas and forest edges (Davis 2004, Koper and Schmiegelow 2006a). Sprague's pipit densities may also be lower on lightly grazed areas than moderate or heavily grazed pastures (Kantrud 1981), but since stocking rates did not differ between season-long and twice-over rotation sites in southwestern Manitoba, there may be little reason for Sprague's pipit to prefer one grazing regime over the other.

The loggerhead shrike is a facultative grassland bird (Vickery et al. 1999) and prefers grassland-dominant areas with willows (*Salix* spp.) spread throughout, or shrubs and trees along the edges of fields (Godfrey 1986, Ehrlich et al. 1988, Dechant et al. 1998e). Although there are likely many factors that determine site selection by loggerhead shrike, the proportion of trees to open area may be an important site characteristic. The only observation of a loggerhead shrike was on an idle site (Bernice WMA) with a relatively low proportion of treed area compared to other idle fields surveyed in southwestern Manitoba. The Bernice WMA had the lowest proportion of treed area (0.11%) and the highest amount of open and shrubby area (99.89%) than other

idle sites surveyed. Therefore, it is possible that many idle sites in southwestern Manitoba may be too heavily forested for loggerhead shrikes (Appendix VIII).

Determining the threats to grassland birds on a provincial scale will contribute to the protection of threatened wildlife on a national scale. As migratory birds do not obey the limits of provincial or national borders, “compartmental” management plans may not be completely effective. Canada’s Migratory Birds Convention Act aims for international co-ordination with the US and Mexico with the primary goal to protect migratory birds, their eggs and nests (Migratory Birds Convention Act 1994). Legislation, policies, and management programs that include multiple jurisdictions and encompass the full habitat or migratory range of the species of concern are likely more effective than those focused specifically on a region.

6.0 CONCLUDING REMARKS

6.1 Management implications

6.1.1 Rotational grazing

Twice-over rotation grazing system in southwestern Manitoba may not be improving grassland habitat for grassland birds, rather, twice-over rotation sites supported more non-grassland birds than traditional grazing regimes. Managers should re-evaluate the vegetation, landscape, and grazing management characteristics in the mixed-grass prairie region of southwestern Manitoba to better accommodate grassland birds.

Management practices that maintain a heterogeneous landscape and include a range of habitat structures may better accommodate a wide variety of grassland birds adapted to the mixed-grass prairie habitat (Ricketts et al. 1999, Askins et al. 2007). Continuous grazing systems may increase landscape heterogeneity and if combined with patch-burning, produce a variety of habitats for wildlife (Fuhlendorf and Engle 2001).

Other studies have suggested that heterogeneous landscapes may be enhanced by rotational grazing systems (Renken and Dinsmore 1987, Madden 1996, Prescott and Murphy 1996, Dale et al. 1997, Johnson 1997), such as the twice-over rotational program; however, this may only be at the patch-scale, and may not translate to effects of management at the scale of commercial pastures. Alternatively, since I observed that many grassland birds tend to select pastures grazed season-long, it may be more beneficial to implement a number of grazing regimes throughout southwestern Manitoba rather than only relying on rotational grazing. A number of grazing regimes may produce

a heterogeneous landscape that supports a larger variety of grassland birds. Although season-long grazing may not produce habitat preferred by grassland birds in other geographical areas, it was preferred by many birds in southwestern Manitoba. Bock et al. (1993) recommends a grazing system that produces a continuum of heavily grazed areas to ungrazed areas. Grazing systems that promote tall, dense vegetation to provide nesting cover for some bird species, for instance many duck species, do not produce the short, sparse vegetation structure required for many obligate grassland birds such as Sprague's pipits and Baird's sparrows (Madden et al. 2000). Although the rangeland management community seems to value rotational grazing systems as improved management regimes, relatively few empirical studies actually support this (Hart et al. 1993, Manley et al. 1997, Briske et al. 2008). Briske et al. (2008:11) even suggest that the popularity of rotational grazing systems is "founded on perception and anecdotal interpretations" rather than based on the available research.

Funds allocated to the implementation of twice-over rotation grazing in southwestern Manitoba are providing little benefit to grassland birds. I could not determine within the parameters of my study whether twice-over grazing benefits native prairie plants, the primary focus of the twice-over rotation grazing regime. The increased fencing required for rotational grazing systems may be hazardous for some birds (Allen and Ramirez 1990): young-of-the-year (Knight et al. 1980), dabbling ducks (Stout and Cornwell 1976), burrowing owl young (Lohofener and Ely 1978 reviewed in Allen and Ramirez 1990). Although collisions with barbed-wire fences are uncommon (Allen and Ramirez 1990), an increased number of roads, fences, and other man-made obstacles may have impacts on wildlife. Paddock fences built across water and in close proximity to tall,

dense vegetation may be hidden and difficult to detect, creating hazards for many bird species (Allen and Ramirez 1990, Summers 1998).

Rotational grazing aims to control grazing pressure spatially and temporally, often through increased fencing (Savory 1988, Dormaar et al. 1997, Holechek et al. 1998). However, other methods may be more economical and may still improve livestock distribution on pastures such as rotating supplemental feeding stations, and water and mineral sources around the field (Hart et al. 1993, Holechek et al. 1998, Provenza 2009). Hart et al. (1993) found controlled stocking rates, smaller pasture sizes, and reduced distance to water sources were more beneficial for cattle gains, soil conditions, and forage production than grazing system.

6.1.2 Management of idle fields in southwestern Manitoba

The idle fields surveyed in this study need to be actively managed to improve the suitability of prairie habitat for grassland birds. Shrub and tree removal will likely produce more grassland habitat on these sites, and management practices that control the invasion and encroachment of woody vegetation should be implemented to help conserve grassland songbirds. Management practices that protect prairie habitat, such as mowing, burning, and grazing, should be implemented on idle fields rather than methods that remove prairie such as cultivation (Owens and Myre 1973, Stewart 1975). Grazing alone is successful as a management regime if the fields are not in an advanced successional phase (Holechek et al. 1998), such as many of the idle fields in southwestern Manitoba. Grazing and burning are suitable management practices for idle fields in the mixed-grass prairies since they are two of the natural drivers of the ecosystem. However, Briggs et al. (2005) also cautions that fire and grazing alone will likely not be sufficient in restoring

grasslands without the physical removal of woody vegetation. Therefore, tree removal programs may also be necessary for some heavily wooded idle fields in southwestern Manitoba.

Grazing systems aimed at both grassland conservation and livestock production may be conducive to preserving grassland habitat for songbirds (Herkert et al. 1996, Murphy 2003, Askins et al. 2007). If grazing systems accommodate the soil conditions, climate, and precipitation along with other contributing factors specific to the region, it may help reverse the severe decline observed in grassland bird populations (Dale et al. 2005).

Controlling the encroachment of woody vegetation on grazed sites is critical for preserving grassland habitat (Faanes 1983, Berkey et al. 1993, Anstey et al. 1995, Madden 1996). Shrubby habitats may have negative impacts on the breeding success of grassland songbirds by providing perches for female brown-headed cowbirds to search for nests (Davis and Sealy 1998). Although loggerhead shrikes, a facultative grassland bird, require the presence of thorny trees and low thick shrubs, such as willows and hawthorn (*Crataegus* spp.), they also require a dominant cover of non-woody vegetation for foraging (Hands et al. 1989 reviewed in Dechant et al. 1998e). Maintaining a minimal amount of shrubby habitat will also benefit other grassland birds that use woody vegetation such as vesper sparrows and clay-colored sparrows (Madden 1996, Dechant et al. 1998c, Grant et al. 2006). Clay-colored sparrows also prefer shrubby vegetation, however they occur in high densities with minimal amount of shrub cover; occurrence was 69% with 3% shrub cover and rose to 95% at 20% shrub cover (Madden et al. 2000).

Therefore, the growth of woody vegetation should be controlled to provide more suitable grassland habitat, but not eliminated completely.

Shrubs and stands of woody vegetation were found on privately owned pastures as well as on Wildlife Management Areas throughout southwestern Manitoba. Therefore landowner participation will be important for the implementation of any shrub or tree removal program. Although tree removal and shrub control may benefit grassland habitat, some producers may not support tree removal programs. Not only is tree removal expensive, but landowners generally prefer sites with a certain amount of trees to provide shade and shelter to their livestock (K. Murray, Manitoba Conservation and landowners, R.M.s Pipestone and Sifton, personal communication). Burning may be the most efficient management tool to remove treed areas (Kantrud 1981) and preserving grassland in southwestern Manitoba. However, burning and other practices such as mowing, grazing, and tilling, all of which disturb nesting habitat, should be delayed until after the breeding season (Patterson and Best 1996, Dale et al. 1997). If woody vegetation continues to invade the area, it may have negative impacts on the habitat suitability for grassland birds.

6.2 Future research

Grassland conservation also involves preserving native grassland vegetation and restoring grassland habitats of value to grassland birds (Johnson et al. 1993). A goal of the twice-over rotation grazing system is the restoration and preservation of native prairie through enhanced tillering of native grasses, and claims to improve their competitive ability against non-native species (MHHC 2002, Manske 2004). Species with a tillering

response to defoliation primarily occurs in grasslands that have a long evolutionary history of grazing (see Caldwell et al. 1981, Hodgkinson et al. 1985 in Milchunas et al. 1988). Vegetation species that have not evolved under the stress of grazers may be intolerant to grazing and poor competitors (Milchunas et al. 1988). However, because the prairie ecosystem may take some time to respond to a management regime, long-term monitoring on the effects of twice-over rotation grazing on grassland birds and their habitat should continue in southwestern Manitoba.

Previous research has found the grassland environment takes time to respond to twice-over rotational grazing systems (Salo 2003). The length of time the rotational pastures surveyed in this study have been in the twice-over system may be too brief a period to have much effect on native prairie habitat. Although rangeland improvements can be observed after as little as 5-7 years of implementing a specialized grazing system (Klippel and Bement 1961), it may take longer to see improvements in habitat structure for grassland birds. Salo (2003) also suggested pastures may need to be grazed rotationally longer to observe any effects of grazing systems on non-game birds. However, Heady (1961) observed that many researchers proposed explanations for why their results did not support rotational grazing, rather than acknowledging and relying on their findings. My results suggest that sites grazed season-long were preferred over twice-over by many grassland birds and it is difficult to predict if more time spent grazing twice-over rotationally will improve habitat for grassland birds.

Many landowners in southwestern Manitoba practice other forms of rotational grazing than twice-over and it would be valuable to compare the effects of twice-over rotation grazing to other rotational grazing systems on grassland bird habitats in this area.

Since the occurrence and abundance of grassland birds are not direct indications of breeding success or productivity, nor is it necessarily an indication of habitat quality (Van Horne 1983, Vickery et al. 1992a, Winter 1999, Howell et al. 2000), future research should evaluate the effects of twice-over rotation grazing on the breeding success of grassland birds in southwestern Manitoba. Studies evaluating the effect of rotational grazing systems on reproductive success have conflicting results. For instance, research conducted in North Dakota found that although twice-over rotational grazing improved potential habitat for many grassland birds, the total breeding bird density was lower on these sites compared to other rotational grazing systems (Messmer 1990). Conversely, a study conducted by Kirby and Grosz (1995) found sharp-tailed grouse had greater nesting success on rotationally grazed pastures than ungrazed fields, even though the nest density was higher on ungrazed fields. Although two rotational grazing systems were evaluated by Kirby and Grosz (1995), short-duration grazing and twice-over rotation, no comparison could be made between the two grazing regimes due to the low number of located nests. In addition, Schneider (1998) found grassland birds breeding success did not differ significantly between sites grazed season-long or rotationally in North Dakota. However, rotational grazing does not seem to improve nesting habitat for many grassland birds when compared to more traditional grazing systems. For instance, a study conducted by Temple et al. (1999) found that rotationally grazed pastures had lower nesting success than pastures grazed season-long, especially for Savannah sparrows and red-winged blackbirds, while the highest nesting success was found on ungrazed fields. The lowered nesting success on rotationally grazed fields in the Temple et al. (1999) study may have been caused by the higher density of cattle confined to one paddock,

which may have increased nest trampling (Paine et al. 1996) or the removal of vegetation concealing the nests. Alternatively, studies have found no difference between rotationally grazed pastures and pastures grazed season-long on duck-nesting success (Barker et al. 1990, Ignatiuk and Duncan 2001).

Although rotational grazing systems may produce suitable habitat for grassland birds, certain aspects, such as the timing of the rotations, may not be conducive to grassland bird breeding success. Some grassland birds, such as Sprague's pipits, may produce two broods in a season and the timing of the rotations may impact their second breeding attempt. However, rotational grazing systems with an extra paddock left cattle-free for the breeding season may minimize the disturbance to nesting grassland birds (Bowen and Kruse 1993). Temple et al. (1999) proposes a rotational grazing system that includes cattle-free paddocks that are left ungrazed during the peak of the nesting season, which for most grassland birds is between 15 May and 1 July. Similarly, in a 3 paddock twice-over rotation grazing system, two of the paddocks will have been grazed once by 1 July (Manske 2004), leaving the third paddock as a potential retreat from cattle for nesting birds. However, at moderate stocking rates, season-long grazing may have less of an impact on nesting birds because the cattle are free to move around the entire area of the pastures. In the twice-over system, when the herd is confined to one paddock it may cause more disturbance for nesting birds due to the increased density of cattle in a smaller area. For instance, disturbances to ground-nesting birds may increase at stocking densities above 2.5 AU/ha (Bareiss et al. 1986, Jensen et al. 1990). Alternatively, stocking densities may have little or no effect on nesting birds (Koerth et al. 1983 at 1.2 head/ha, Paine et al. 1996). Therefore future studies looking at the effects of twice-over rotation

grazing on the breeding success of obligate and facultative grassland birds are needed in southwestern Manitoba.

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APPENDICES

Appendix I - Average species richness and abundance of grassland birds observed in southwestern Manitoba in 2008, separated by treatment. Average relative abundances and standard deviations are shown for the ten grassland birds used for analysis.

	Treatment		
	Twice-over	Season-long	Idle
2008			
<i>Obligate grassland birds</i>			
Species Richness	2.20 ± 1.05	2.40 ± 1.18	0.50 ± 0.61
Relative Abundance	4.26 ± 2.40	4.60 ± 2.75	0.98 ± 1.41
Bobolink	0.14 ± 0.42	0.40 ± 0.93	0.38 ± 0.79
Le Conte's sparrow	0.21 ± 0.47	0.11 ± 0.27	0.05 ± 0.15
Savannah sparrow	1.56 ± 1.24	1.61 ± 1.23	0.19 ± 0.37
Sprague's pipit	0.27 ± 0.49	0.24 ± 0.46	0.00 ± 0.00
Vesper sparrow	0.21 ± 0.52	0.20 ± 0.47	0.12 ± 0.35
Western meadowlark	1.51 ± 1.02	1.41 ± 1.09	0.21 ± 0.44
<i>Facultative grassland birds</i>			
Species Richness	2.29 ± 1.03	2.25 ± 0.91	1.90 ± 0.86
Relative Abundance	4.93 ± 2.87	5.08 ± 2.64	4.86 ± 3.04
Brown-headed cowbird	0.98 ± 1.40	0.95 ± 1.13	0.71 ± 0.86
Clay-colored sparrow	1.70 ± 1.31	1.53 ± 1.29	1.60 ± 1.06
Eastern kingbird	0.37 ± 0.64	0.48 ± 0.80	0.45 ± 0.72
Red-winged blackbird	1.12 ± 1.39	1.50 ± 1.98	1.55 ± 2.07
<i>Non-grassland birds</i>			
Species Richness	0.94 ± 0.93	0.72 ± 0.68	1.26 ± 1.37
Relative Abundance	2.56 ± 15.30	1.05 ± 1.21	2.19 ± 2.68

Appendix II - Average species richness and abundance of grassland birds observed in southwestern Manitoba in 2009, separated by treatment. Average relative abundances and standard deviations are shown for the ten grassland birds used for analysis.

	Treatment		
	Twice-over	Season-long	Idle
2009			
<i>Obligate grassland birds</i>			
Species Richness	2.50 ± 1.14	2.84 ± 1.15	1.09 ± 1.03
Relative Abundance	4.89 ± 2.85	5.61 ± 2.88	1.65 ± 1.65
Bobolink	0.11 ± 0.35	0.41 ± 1.18	0.20 ± 0.40
Le Conte's sparrow	0.09 ± 0.28	0.09 ± 0.31	0.04 ± 0.19
Savannah sparrow	1.44 ± 1.18	1.07 ± 0.91	0.28 ± 0.56
Sprague's pipit	0.39 ± 0.57	0.41 ± 0.58	0.02 ± 0.10
Vesper sparrow	0.19 ± 0.36	0.32 ± 0.56	0.15 ± 0.30
Western meadowlark	1.78 ± 1.28	1.99 ± 1.33	0.57 ± 0.69
<i>Facultative grassland birds</i>			
Species Richness	2.73 ± 1.12	2.98 ± 1.11	2.91 ± 1.14
Relative Abundance	6.10 ± 3.16	6.41 ± 2.79	6.65 ± 3.16
Brown-headed cowbird	0.57 ± 1.15	0.40 ± 0.83	1.04 ± 1.06
Clay-colored sparrow	1.78 ± 1.46	1.42 ± 1.22	2.52 ± 1.24
Eastern kingbird	0.36 ± 0.58	0.37 ± 0.59	0.50 ± 0.64
Red-winged blackbird	0.93 ± 1.53	1.06 ± 1.63	0.96 ± 1.68
<i>Non-grassland birds</i>			
Species Richness	1.16 ± 1.09	0.87 ± 0.81	1.87 ± 1.02
Relative Abundance	1.85 ± 2.02	1.20 ± 1.14	3.07 ± 2.02

Appendix III - Obligate grassland birds observed during surveys in southwestern Manitoba, where at least one individual was recorded in 2008 (08), in 2009 (09), or each year (08 & 09), separated by treatment (Vickery et al. 1999).

Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<i>Obligate grassland birds</i>					
<u>Partridge, Grouse, Old World Quail</u>	<u>Phasianidae</u>				
Sharp-tailed grouse	<i>Tympanuchus phasianellus</i>		08 & 09	08 & 09	08 & 09
<u>Hawks</u>	<u>Accipitridae</u>				
Northern harrier	<i>Circus cyaneus</i>		09	08 & 09	
Swainson's hawk	<i>Buteo swainsoni</i>		09		
<u>Shorebirds</u>	<u>Scolopacidae</u>				
Upland sandpiper	<i>Bartramia longicauda</i>		08 & 09	08 & 09	09
Marbled godwit	<i>Limosa fedoa</i>		08 & 09	08 & 09	
<u>Larks</u>	<u>Alaudidae</u>				
Horned lark	<i>Eremophila alpestris</i>		08 & 09	08 & 09	
<u>Wrens</u>	<u>Troglodytidae</u>				
Sedge wren	<i>Cistothorus platensis</i>		09	09	09
<u>Pipits</u>	<u>Motacillidae</u>				
Sprague's pipit	<i>Anthus spragueii</i>		08 & 09	08 & 09	09
<u>Emberizids</u>	<u>Emberizidae</u>				
Vesper sparrow	<i>Pooecetes gramineus</i>		08 & 09	08 & 09	08 & 09
Lark bunting	<i>Calamospiza melanocorus</i>		08 & 09	08	
Savannah sparrow	<i>Passerculus sandwichensis</i>		08 & 09	08 & 09	08 & 09
Grasshopper sparrow	<i>Ammodramus sacannarum</i>		08 & 09	08 & 09	09
Baird's sparrow	<i>Ammodramus bairdii</i>		09	08 & 09	
Le Conte's sparrow	<i>Ammodramus leconteii</i>		08 & 09	08 & 09	08 & 09
Chesnut-collared longspur	<i>Calcarius ornatus</i>		08 & 09	08 & 09	
<u>Cardinals and Allies</u>	<u>Cadinalidae</u>				
Dickcissel	<i>Spiza americana</i>		09		
<u>Meadowlarks, Blackbirds, and Allies</u>	<u>Icteridae</u>				
Bobolink	<i>Dolichonyx oryzivorus</i>		08 & 09	08 & 09	08 & 09
Western meadowlark	<i>Sturnella neglecta</i>		08 & 09	08 & 09	08 & 09

Appendix IV - Facultative grassland birds observed during surveys in southwestern Manitoba, where at least one individual was recorded in 2008 (08), in 2009 (09), or each year (08 & 09), separated by treatment (Vickery et al. 1999).

Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<i>Facultative grassland birds</i>					
<u>Waterfowl</u>					
	<u>Anatidae</u>				
Snow goose		<i>Chen caerulescens</i>	08		
Canada goose		<i>Branta canadensis</i>	08 & 09	08 & 09	09
Gadwall		<i>Anas strepera</i>		09	
American wigeon		<i>Anas americana</i>	08 & 09	09	
Mallard		<i>Anas platyrhynchos</i>	08 & 09	08 & 09	08 & 09
Blue-winged teal		<i>Anas discors</i>	08 & 09	08 & 09	09
Northern shoveler		<i>Anas clypeata</i>	09	08 & 09	09
Northern pintail		<i>Anas acuta</i>	09	08 & 09	
Green-winged teal		<i>Anas crecca</i>		09	
<u>Partridge, Grouse, Old World Quail</u>					
Ring-necked pheasant	<u>Phasianidae</u>	<i>Phasianus colchicus</i>	08	08	08 & 09
<u>Hérons</u>					
American bittern	<u>Ardeidae</u>	<i>Botaurus lentiginosus</i>	08 & 09	08 & 09	09
<u>Cranes</u>					
Sandhill crane	<u>Gruidae</u>	<i>Grus canadensis</i>	09	09	
<u>Old World Plovers, Lapwings</u>					
Killdeer	<u>Charadriidae</u>	<i>Charadrius vociferus</i>	08 & 09	08 & 09	08
<u>Shorebirds</u>					
Willet	<u>Scolopacidae</u>	<i>Catoptrophorus semipalmatus</i>	08 & 09	08 & 09	09
Common snipe		<i>Gallinago gallinago</i>	09	09	09
Wilson's phalarope		<i>Phalaropus tricolor</i>	09	09	

Appendix IV Continued 1

Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<u>Gulls, Terns</u>	<u>Laridae</u>				
Franklin's gull		<i>Larus pipixcan</i>	08	08	
<u>Doves</u>	<u>Columbidae</u>				
Mourning dove		<i>Zenaida macroura</i>	08 & 09	08 & 09	08 & 09
<u>Goatsuckers</u>	<u>Caprimulgidae</u>				
Common nighthawk		<i>Chordeiles minor</i>		08	
<u>Tyrant flycatchers</u>	<u>Tyrannidae</u>				
Western kingbird		<i>Tyrannus verticalis</i>	09	08 & 09	
Eastern kingbird		<i>Tyrannus tyrannus</i>	08 & 09	08 & 09	08 & 09
<u>Shrikes</u>	<u>Laniidae</u>				
Loggerhead shrike		<i>Lanius ludovicianus</i>			08
<u>New World Warblers</u>	<u>Parulidae</u>				
Common yellowthroat		<i>Geothlypis trichas</i>	08 & 09	08 & 09	09
<u>Emberizids</u>	<u>Emberizidae</u>				
Clay-colored sparrow		<i>Spizella pallida</i>	08 & 09	08 & 09	08 & 09
Lark sparrow		<i>Chondestes grammacus</i>	08 & 09	08 & 09	08 & 09
<u>Meadowlarks, Blackbirds, and Allies</u>	<u>Icteridae</u>				
Red-winged blackbird		<i>Agelaius phoeniceus</i>	08 & 09	08 & 09	08 & 09
Brewer's blackbird		<i>Euphagus cyanocephalus</i>	08 & 09	08 & 09	08 & 09
Brown-headed cowbird		<i>Molothrus ater</i>	08 & 09	08 & 09	08 & 09

Appendix V - Non-grassland birds observed during surveys in southwestern Manitoba, where at least one individual was recorded in 2008 (08), in 2009 (09), or each year (08 & 09), separated by treatment (Vickery et al. 1999).

Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<i>Non-grassland birds</i>					
<u>Waterfowl</u>					
	<u>Anatidae</u>				
Redhead		<i>Aythya americana</i>	08 & 09	09	
Ring-necked duck		<i>Aythya collaris</i>	08		
Ruddy duck		<i>Oxyura jamaicensis</i>	09		
<u>Partridge, Grouse, Old World Quail</u>					
	<u>Phasianidae</u>				
Ruffed grouse		<i>Bonasa umbellus</i>	08 & 09	08	08 & 09
Wild turkey		<i>Meleagris gallopavo</i>	08		09
<u>Grebes</u>					
	<u>Podicipedidae</u>				
Pied-billed grebe		<i>Podilymbus podiceps</i>	09	09	
<u>Pelicans</u>					
	<u>Pelecanidae</u>				
American white pelican		<i>Pelecanus erythrorhynchos</i>		09	
<u>Cormorants</u>					
	<u>Phalacrocoracidae</u>				
Double-crested cormorant		<i>Phalacrocorax auritus</i>		09	
<u>Hérons</u>					
	<u>Ardeidae</u>				
Black-crowned night heron		<i>Nycticorax nycticorax</i>		09	
<u>Hawks</u>					
	<u>Accipitridae</u>				
Red-tailed hawk		<i>Buteo jamaicensis</i>	08 & 09	08 & 09	08 & 09
<u>Rails</u>					
	<u>Rallidae</u>				
Virginia rail		<i>Rallus limicola</i>	09		
Sora		<i>Porzana carolina</i>	09	09	
American coot		<i>Fulica americana</i>	09	09	
<u>Avocets</u>					
	<u>Recurvirostridae</u>				
American avocet		<i>Recurvirostra americana</i>	09		

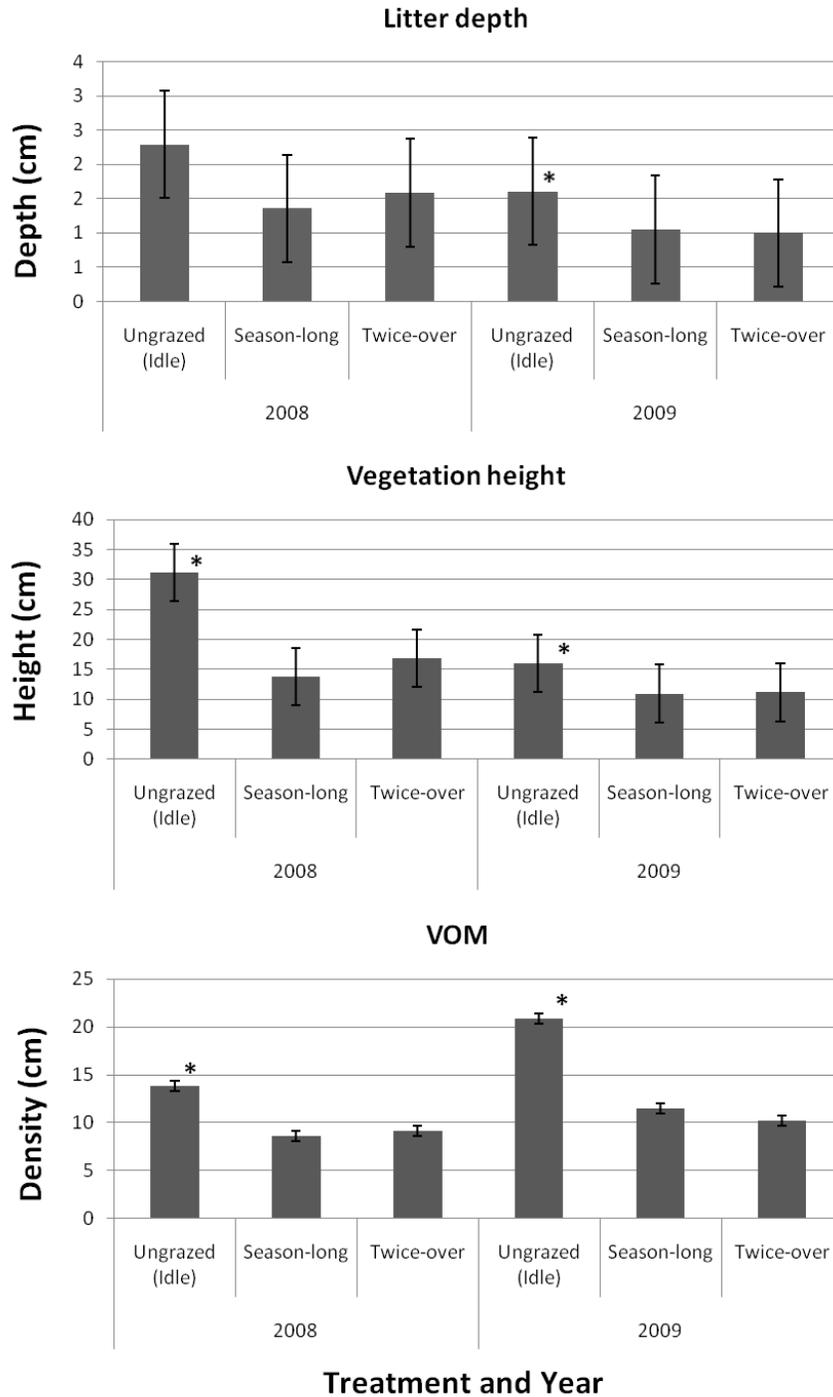
Appendix V Continued 1

Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<u>Shorebirds</u>	<u>Scolopacidae</u>				
Greater yellowlegs		<i>Tringa melanoleuca</i>		09	
<u>Gulls, Terns</u>	<u>Laridae</u>				
Black tern		<i>Chlidonias niger</i>	09	09	
<u>Owls</u>	<u>Strigidae</u>				
Great horned owl		<i>Bubo virginianus</i>		09	
<u>Hummingbirds</u>	<u>Trochilidae</u>				
Ruby-throated hummingbird		<i>Archilochus colubris</i>	09		
<u>Woodpeckers</u>	<u>Picidae</u>				
Yellow-bellied sapsucker		<i>Sphyrapicus varius</i>		08	
Downy woodpecker		<i>Picoides pubescens</i>	08 & 09		
Hairy woodpecker		<i>Picoides villosus</i>	08 & 09		
Northern flicker		<i>Colaptes auratus</i>	08 & 09	08 & 09	
<u>Tyrant flycatchers</u>	<u>Tyrannidae</u>				
Willow flycatcher		<i>Empidonax traillii</i>	08		08
Eastern phoebe		<i>Sayornis phoebe</i>		08	08 & 09
<u>Vireos</u>	<u>Vireonidae</u>				
Warbling vireo		<i>Vireo gilvus</i>	09	08	09
Red-eyed vireo		<i>Vireo olivaceus</i>	08 & 09		
<u>Crows, Jays</u>	<u>Corvidae</u>				
Blue jay		<i>Cyanocitta cristata</i>	09		
Black-billed magpie		<i>Pica hudsonia</i>	08 & 09	09	
American crow		<i>Corvus brachyrhynchos</i>	08 & 09	08 & 09	08 & 09
Common raven		<i>Corvus corax</i>	09	09	
<u>Swallows</u>	<u>Hirundinidae</u>				
Tree swallow		<i>Tachycienta bicolor</i>	08 & 09	08	08 & 09
Bank swallow		<i>Riparia riparia</i>			
Cliff swallow		<i>Petrochelidon pyrrhonota</i>	08 & 09	09	08
Barn swallow		<i>Hirundo rustica</i>	08 & 09	08 & 09	08
<u>Chickadees, Titmice</u>	<u>Paridae</u>				
Black-capped chickadee		<i>Poecile atricapillus</i>	08 & 09	08 &	08 & 09

Appendix V Continued 2

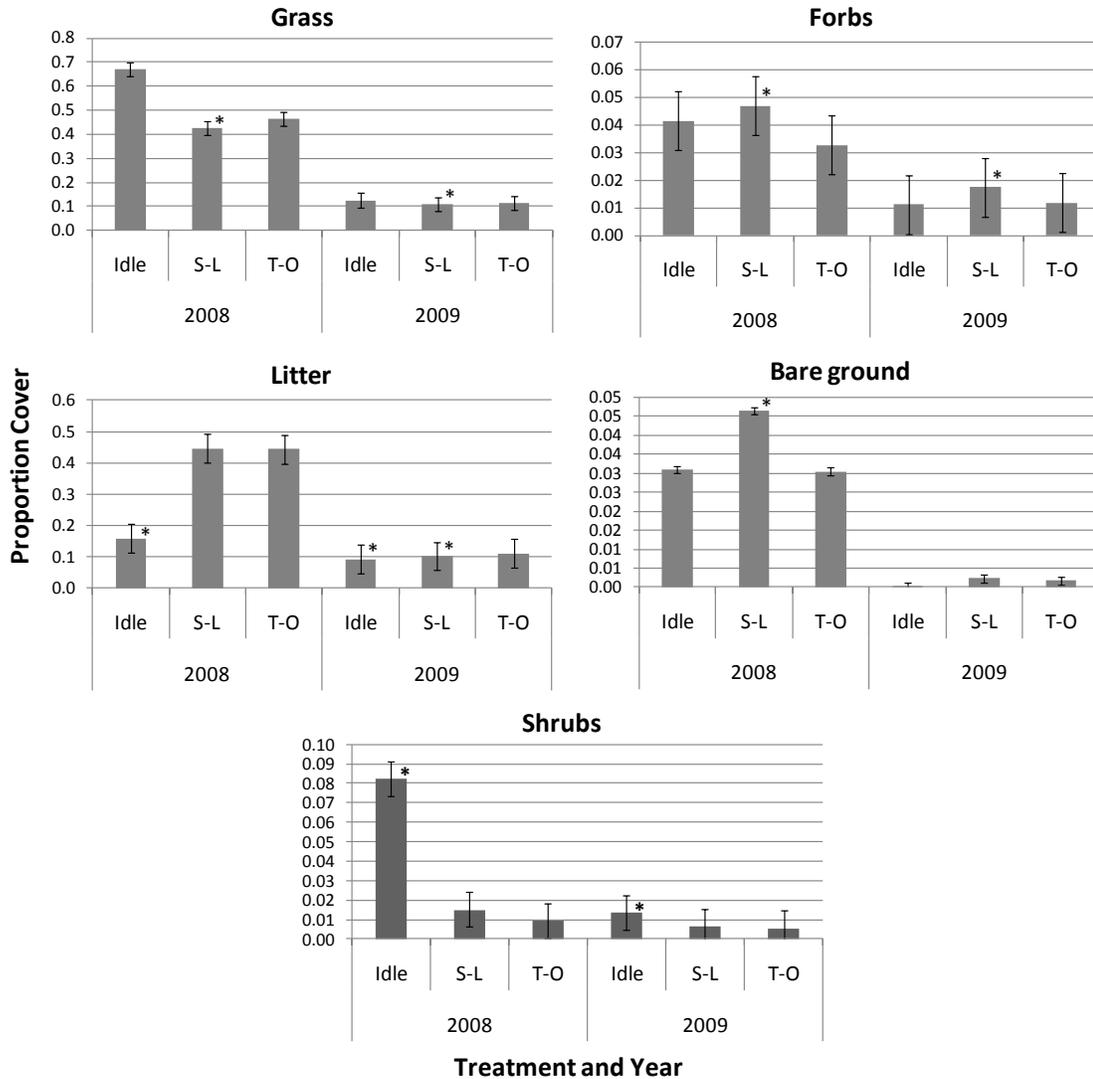
Common name	Family	Scientific name	Treatment		
			Twice-over	Season-long	Idle
<u>Wrens</u>	<u>Troglodytidae</u>				
House wren		<i>Troglodytes aedon</i>			09
<u>Kinglets</u>	<u>Regulidae</u>				
Ruby-crowned kinglet		<i>Regulus calendula</i>			09
<u>Thrushes and Allies</u>	<u>Turdidae</u>				
Veery		<i>Catharus fuscescens</i>	09	09	
American robin		<i>Turdus migratorius</i>	08 & 09	08 & 09	
<u>Mockingbirds, Thrashers, and Allies</u>	<u>Mimidae</u>				
Gray catbird		<i>Dumetella carolinensis</i>	08 & 09	08 & 09	08 & 09
Brown thrasher		<i>Toxostoma rufum</i>	08 & 09	08 & 09	08 & 09
<u>Waxwings</u>	<u>Bombycillidae</u>				
Cedar waxwing		<i>Bombycilla cedrorum</i>	08	08 & 09	08 & 09
<u>New World Warblers</u>	<u>Parulidae</u>				
Yellow warbler		<i>Dendroica petechia</i>	08 & 09	08 & 09	08 & 09
Yellow-rumped warbler		<i>Dendroica coronata</i>	09		09
<u>Emberizids</u>	<u>Emberizidae</u>				
Eastern towhee		<i>Pipilo erythrophthalmus</i>	08		
Chipping sparrow		<i>Spizella passerina</i>	08 & 09	08 & 09	08 & 09
Nelson's sparrow		<i>Ammodramus nelsoni</i>	08 & 09	08 & 09	
Song sparrow		<i>Melospiza melodia</i>	08 & 09	08 & 09	08 & 09
Dark-eyed junco		<i>Junco hyemalis</i>	08		
<u>Cardinals and Allies</u>	<u>Cardinalidae</u>				
Rose-breasted grosbeak		<i>Pheucticus ludovicianus</i>			
<u>Meadowlarks, Blackbirds, and Allies</u>	<u>Icteridae</u>				
Yellow-headed blackbird		<i>Xanthocephalus xanthocephalus</i>	08 & 09	08 & 09	08 & 09
Common grackle		<i>Quiscalus quiscula</i>	08 & 09	08	09
Baltimore oriole		<i>Icterus galbula</i>	08 & 09	09	
<u>Finches, Grosbeaks, and Allies</u>	<u>Fringillidae</u>				
American goldfinch		<i>Carduelis tristis</i>	08 & 09	08 & 09	08 & 09

Appendix VI – Plot scale vegetation measurements in southwestern Manitoba, averaged by treatment for 2008 and 2009. Significant differences among treatments are indicated. Visual obstruction measurement (VOM) is an evaluation of vegetation density. Error bars represent standard deviations.



* Significantly different from twice-over rotation sites, ($\alpha = 0.10$)

Appendix VII - Proportion cover of vegetation classes at the plot scale in southwestern Manitoba, averaged by treatment for 2008 and 2009. Significant differences among treatments are indicated. Error bars represent standard deviations.

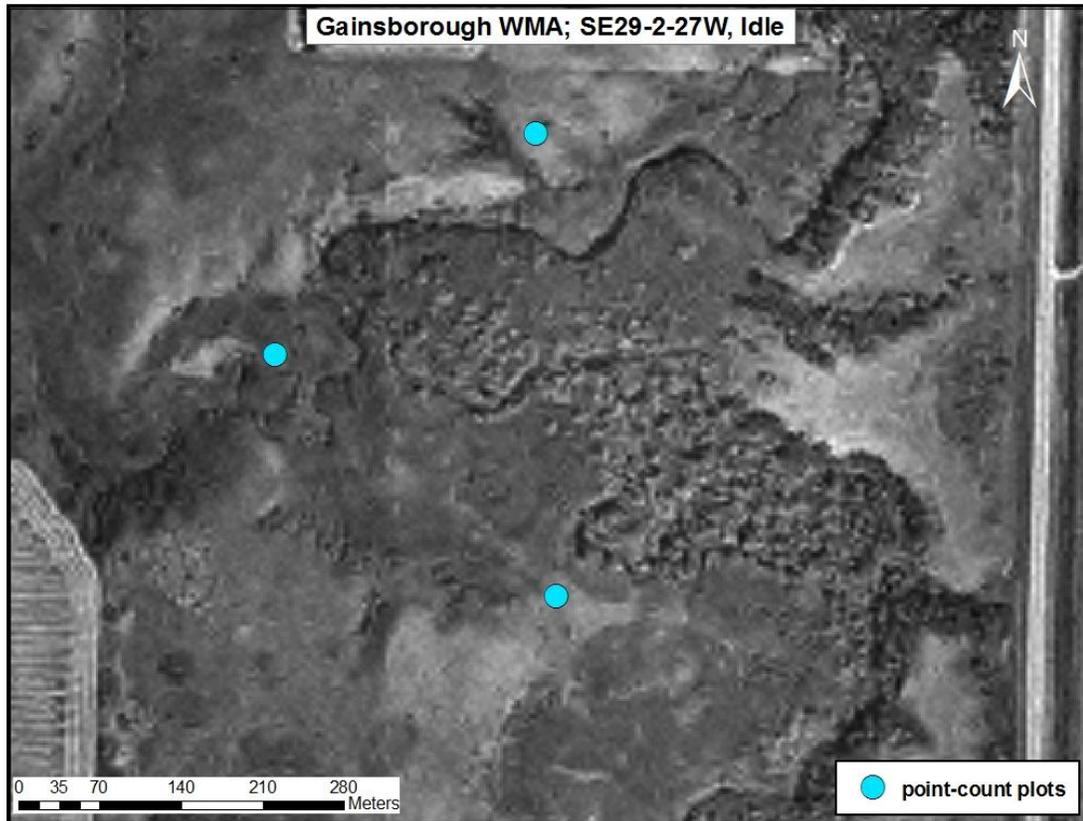


* Significantly different from twice-over rotation sites, ($\alpha = 0.10$)

S-L = Season-long grazing

T-O = Twice-over rotation grazing

Appendix VIII - Example of an idle site with a relatively high proportion of treed area in southwestern Manitoba. This site was not used by loggerhead shrikes in either survey year.



Appendix IX - Equations for Similarity Indices

Sørensen's binary index (Magurran 2004)

$$S = \frac{2C}{A + B}$$

where:

A = The total number of species in fauna A.

B = The total number of species in fauna B.

C = The total number of species in common between faunas A & B.

Sørensen's quantitative index (Magurran 2004, Lyman 2008)

$$Qs = \frac{2 \sum \min(A, B)}{\sum (A + B)}$$

where:

A = The total number of species in fauna A.

B = The total number of species in fauna B.

$\sum \min (A, B)$ = The sum of lower of the two abundances of species in common between faunas A & B.

Appendix X - Example of a generalized linear mixed-model run in SAS version 9.2

Sample code for species richness

```
proc glimmix data =SASUSER.CR_2009;
class TREAT SITE POINT;
model Richness = AvgLitterDepth AvgVegHeight AvgDensity propShrubs
              propForbs propGrass propLitter propBareGround
/solution dist =normal;
random _residual_/ subject=SITE;
title 'SpeciesRichness 2009';
output out = all pred = p PEARSON=PEARSRESID UCL = UPPER LCL=LOWER;
run;
```

Sample output

Solutions for Fixed Effects

Effect	Estimate	Standard DF	t Value	Pr > t
Intercept	8.0811	1.0012	45	8.07 <.0001
AvgLitterDepth	0.1731	0.1676	219	1.03 0.3029
AvgVegHeight	0.04993	0.03053	219	1.64 0.1034
AvgDensity	0.2055	0.2605	219	0.79 0.4309
propShrubs	1.8702	17.2967	219	0.11 0.914
propForbs	8.8251	11.9649	219	0.74 0.4616
propGrass	-1.4737	0.6031	45	-2.44 0.0185
propLitter	6.5625	6.1329	219	1.07 0.2858
propBareGround	130.97	173.08	219	0.76 0.45

Interpretation

The parameter estimates (β) values for significant responses ($\alpha = 0.10$) are interpreted as follows:

As the average vegetation height (AvgVegHeight) increased by 1.0 cm, species richness increased by 0.050 species per point-count plot (3.2 ha). As the proportion cover of grass (propGrass) increased by 1 m², species richness decreased by 1.47 species per 3.2 ha.