Effects of cattle stocking rate and years grazed on songbird nesting success
in the northern mixed-grass prairie

by

Emily Nicole Pipher

A Thesis Submitted to the Faculty of Graduate Studies of
The University of Manitoba
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ABSTRACT

Grassland bird species are declining more quickly than any other avian group within North America, possibly due in part to declines in nesting success. In 2009-2010, I monitored nests of five songbird species in southwestern Saskatchewan. Two 300-m² plots were located in each of 12 pastures, three of which were ungrazed controls. The remaining pastures had stocking rates ranging from 0.23 – 0.83 AUM/ha, which were grazed for 2-3 or >15 years. Stocking rate affected nest site selection by three species, suggesting that some pastures have a greater availability of nest sites than others. Logistic exposure nesting success models suggested a nonlinear effect of stocking rate on nesting success of Sprague's Pipit in 2009. The nesting success of two species was negatively correlated with grazing duration in 2009 and 2010, respectively. To encompass the different habitat needs of each species, I suggest maintaining rangeland landscapes with a range of grazing treatments.

i

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

Understanding environmental factors that influence avian breeding success is key to understanding trends in populations, and to developing successful management regimes for species at risk (Ricklefs 1969, Pasitschniak-Arts and Messier 1995). The rapid and alarming decline of grassland bird species has been called a "conservation crisis" by some (Brennan and Kuvlesky 2005). This decline is most likely due to the loss and degradation of vital breeding habitat (e.g., Knopf 1992, 1994; Herkert 1994). Species with populations that are decreasing more rapidly than others, such as the federally threatened Sprague's Pipit (*Anthus spragueii*), may act as indicators of ecosystem quality for other prairie bird species.

Grazing by domestic cattle (*Bos primigenius*) is the most common use of native prairies in North America. In the United States alone, 61% of the total land base is used as rangeland pasturage for cattle (Fuhlendorf and Engle 2001). North American prairies are arguably among the most endangered ecosystems on the continent. Mixed-grass prairies alone have been reduced by 70% of their historic extent (Samson et al. 2004).

Prairies were once grazed by large herds of bison (*Bison bison*), and both the faunal and floral communities consequently evolved to survive in a landscape constantly shaped by the variable disturbance associated with free-ranging herds (Knapp et al. 1999). Though bison are now gone from much of their historic range, cattle grazing may partially replace the disturbance-driven processes that once shaped this ecosystem.

The management of cattle has a strong effect on the vegetation structure of the area, in turn affecting abundance and habitat use by various bird species (Coppedge et al. 2008). Traditionally, the goal of rangeland management has been to increase cattle production through moderate stocking rates. Moderate stocking rates result in uniform grazing that decrease the variability of the landscape (Fuhlendorf and Engle 2001). However, bird communities are affected by the degree of heterogeneity on the landscape (Wiens 1974), benefiting most from an intermittent and patchy regime of fire and grazing at appropriate scales (Powell 2006). Birds tend to select nesting habitats with very specific vegetative characteristics (e.g., Cody 1985), so a heterogeneous habitat leads to more microhabitats that are suitable for different species. Reproductive success is also highly dependent on vegetation cover at the nest, as predation is the highest cause of nest failure for ground-nesting species (e.g., With 1994, Dion et al. 2000). Therefore, areas with high heterogeneity and, hence, a higher diversity of vegetation structures for different bird species to choose from, might result in the highest nesting success for the highest number of species. Though the conditions of rangelands have improved, the continuing decline of grassland bird species suggests that current methods of rangeland management do not sufficiently maintain avian diversity.

Very few studies have examined effects of management, such as livestock grazing, on the nesting success of grassland songbirds such as the Sprague's Pipit (e.g., Davis 2005, 2009). Yet research has suggested that productivity studies, such as those that measure nesting success, are vital for determining patterns of population change (DeSante and Rosenberg 1998) (see Section 2.2). Low nesting success may affect population size through low recruitment, which could ultimately cause the loss of certain

populations or species. Davis (2003) found Mayfield nesting success ranging from 13.9 – 24.0% for the six most common species in southern Saskatchewan, which he considered to be quite low. Without knowing how grazing affects the nesting success of grassland species, it is difficult to formulate a comprehensive management plan for successfully conserving these birds.

1.2 Problem Statement

Most of Canada's remaining mixed-grass prairies are grazed by cattle (Fuhlendorf and Engle 2001). Moderate stocking rates of cattle (approximately 50% utilization) are the most common grazing regime currently in use (Abouguendia 1990). The result is a homogenous landscape that is suitable for only a portion of prairie plant and animal species (Fuhlendorf and Engle 2001), leaving little habitat for species that prefer habitats resulting from light or heavy grazing.

Birds often require landscapes with very specific vegetative characteristics to use as nesting sites (e.g., Cody 1985). As the species composition of the plant community is affected by cattle grazing (e.g., Augustine and McNaughton 1998, Towne et al. 2005), grazing may influence the selection and success of nest sites. However, to the best of my knowledge, no studies have examined the effects of cattle stocking rates on the nesting success of mixed-grass prairie songbirds. Research is needed to determine which grazing intensities will result in the highest nesting success for the largest number of songbirds, including threatened species such as the Sprague's Pipit and Chestnut-collared Longspur (*Calcarius ornatus*). The Sprague's Pipit is endemic to the grasslands of the Central Plains (Robbins and Dale 1999). However, it is one of the least-studied birds in North

America (Davis 2009), making it inherently difficult to develop a successful management regime for conserving and recovering its populations on Canada's mixed-grass prairies.

A key research objective for the Sprague's Pipit Recovery Plan is to determine how reproductive success varies with landscape factors (which are influenced by grazing, see Section 2.3.2), and to identify beneficial land use practices (Environment Canada 2008). Only then can natural resource managers and ranchers begin to identify how best to manage the remaining grasslands to ensure the continuance of this species, and others that utilize the same habitat. To provide the nesting habitat required for the greatest number of species, a matrix of different habitat structures containing varying degrees of disturbance, such as grazing, may be needed.

1.3 Objectives and Hypotheses

The primary objectives of this study were:

1. To determine if any specific stocking rates or lengths of time grazed result in higher nesting success for mixed-grass prairie songbird species, both individually and collectively.

2. To determine whether selection of nest sites is affected by cattle stocking rate.

3. To suggest a management plan that will result in the highest nesting success for the largest number of species, particularly those of highest conservation concern.

Because cattle grazing alters vegetation structure (particularly height), different stocking rates should result in a gradient of different vegetation structures and heights. If songbirds choose nest sites with specific vegetation characteristics, characteristics at the nest may differ significantly from vegetation characteristics in the surrounding landscape. If vegetation characteristics at the nest affect incidence of predation, then different grazing intensities should result in differential nesting success for songbird species due to varying predation rates.

1.4 Research Rationale

Prairie birds are among the most quickly declining groups of birds. This is mostly due to changes in their breeding habitats, the majority of which have seen drastic reductions in both extent and quality (Knopf 1992, Fritcher et al. 2004). Though the condition of breeding habitat is vital for successful reproduction, few studies have examined the impacts of landscape changes on prairie songbirds (e.g., Danley et al. 2004, Davis 2004). Furthermore, little detailed research has examined the effects of cattle stocking rates on nesting success of songbirds in mixed-grass prairie habitats. This is a large oversight given the widespread degree of cattle grazing in the remaining native prairies (Fuhlendorf and Engle 2001). Indeed, nesting success is a key factor in the stability of bird populations (DeSante and Rosenberg 1998). However, there is a lack of such studies (Marzluff and Sallabanks 1998), particularly in this threatened ecosystem and with this group of birds.

Prairie songbirds are also important to study because they are primarily ground nesters. Ground-nesting songbirds are some of the least studied guilds of birds, yet they

are thought to be good indicators of habitat disturbance (Martin 1993). As cattle grazing can result in a landscape mosaic of varying vegetation compositions, ground-nesting songbirds may serve as good biological indicators of grazing effects at a local scale.

Cattle grazing is an important and widespread use of grasslands (Fuhlendorf and Engle 2001). Determining which grazing regimes result in higher nesting success for declining bird species would benefit both wildlife managers and local ranchers. Many ranchers may welcome the opportunity to maintain the biological integrity of the landscape while still utilizing it for their livelihoods. Up until now, this possibility may not have existed due to the lack of adequate research or proper communication between wildlife managers and ranchers.

Though many studies have examined the effects of grazing on rangeland ecological communities (e.g., Fuhlendorf and Engle 2001), most of these were conducted at a small scale, used machines rather than livestock, or used three or fewer grazing intensities (Koper et al. 2008). The large-scale, long-term grazing experiment being conducted in Grasslands National Park of Canada (GNPC) is thus an ideal location to be carrying out this study. It is the first of its kind to utilize a modified Beyond-After-Control-Impact ("beyond BACI") design, using both ungrazed and conventionally grazed controls together with a gradient of stocking rates ranging from 0.23 – 0.83 AUM (Animal Unit Months)/ha.

2.0 LITERATURE REVIEW

2.1 Causes of Declines of Prairie Songbird Species

Grassland bird populations have experienced a higher, more widespread decrease than any other group of North American avian species (Knopf 1992). Approximately half of all grassland-breeding birds are of conservation concern, some experiencing declines up to 68-91% (North American Bird Conservation Initiative 2009). Mixed-grass prairie is home to several species at risk, including Sprague's Pipit, which is declining at a rate of 3.7% annually across its range, and the Chestnut-collared Longspur, which is declining at a rate of 4.2% annually across its range (Sauer et al. 2008).

There is a range of possible causes for declines in prairie songbirds. Pesticide use reduces the abundance of insects as a food source (e.g., Martin et al. 2000). Encroachment by woody vegetation reduces the area of open grassland habitat (Peterjohn and Sauer 1999) and grassland birds avoid woody vegetation and grassland habitat edges (O'Leary and Nyberg 2000, Winter et al. 2000, Jensen and Finck 2004). In addition to problems in their summer breeding grounds, prairie songbirds are also facing habitat losses in their wintering grounds associated with overgrazing, conversion to agriculture, and encroachment of woody vegetation (e.g., Robbins and Dale 1999).

However, declines in prairie songbirds are predominately due to the loss and reduction in quality of the grassland habitat their life cycle requires (Herkert 1994, Knopf 1994). Due to agricultural intensification, the remainder of the prairie has undergone extensive fragmentation (Samson and Knopf 1994), as well as a loss of heterogeneity (Fuhlendorf and Engle 2001).

7

Fragmentation

Remaining mixed-grass grasslands are, as a rule, a fragment of a previously extensive area. This is mostly because of a widespread conversion of native grasslands to agriculture (Samson and Knopf 1994). Fragmentation is caused by a net loss of crucial habitat, which is probably a leading factor behind grassland bird declines. Unfortunately, few studies have examined reproductive response of birds to grassland fragmentation, so the full effects on nesting success are unknown.

Fragmentation often allows the introduction of new predators into a given area due to the predators' use of the intervening matrix habitats as a travel corridor (see citations in Johnson and Temple 1990). For example, grassland songbirds tend to suffer heavier nest predation near wooded landscapes (e.g., Gates and Gysel 1978), likely due to some predators' preferences for habitat with more cover than that found in open grasslands (Johnson and Temple 1990). When agricultural shelterbelts are introduced into a prairie system, certain predators use them as travel corridors (e.g., Fritzell 1978). The ratio of edge to core habitat becomes greatly increased with smaller patch sizes, possibly resulting in higher predation, both on individuals and nests. It should be noted, however, that other studies have found no effect of fragmentation on nesting success (e.g., Howard et al. 2001).

Many prairie songbird species require a territory of a certain size in which to forage and breed. A pair of Chestnut-collared Longspurs typically defends an area between 0.4 and 0.8 ha (Hill and Gould 1997). As the amount of suitable habitat decreases, bird populations become increasingly dense, resulting in smaller territories and increased conflicts between individuals. Birds also avoid suitable habitat patches if those

patches are smaller than their minimum territory area requirements (Herkert 1994). It follows that as areas available for nesting decrease, the fewer birds might be able to successfully breed, thus depressing reproductive success and consequently population size.

Loss of Heterogeneity

Many of today's remaining mixed-grass prairies are managed through the use of intensive, uniform cattle grazing (Coppedge et al. 2008). This type of management reduces the heterogeneity of the landscape. A reduction in heterogeneity consequently reduces the availability of some types of vegetation structures preferred by certain species of birds. For example, species requiring relatively tall, dense vegetation in which to nest may be unable to find a suitable area in uniformly grazed pastures. Grassland birds evolved in an ecosystem dominated by a mosaic of disturbances that often included both recently burned and/or grazed areas, and areas that had remained unburned or ungrazed for years (Fuhlendorf and Engle 2001). The conversion of these areas into a spatially and temporally uniform grazing regime results in a loss of heterogeneity, and thus a loss in habitat for those species that depend upon the more extreme habitat conditions.

2.2 Nesting Success as an Indicator of Population Viability and Habitat Quality

Bird species may show sensitivity to changes in habitat and landscape through changes in abundance and density. However, estimates of abundance alone cannot identify mechanisms of change or reasons behind population declines (DeSante and

9

Rosenberg 1998). Nesting success is a contributing factor to abundance, and may reveal further insights into population changes.

Studies have shown that abundance and density are often poor indicators of habitat quality (Van Horne 1983, Maurer 1986). This is especially true for seasonally variable habitats, such as prairies. Habitat characteristics associated with a species' abundance are often different from characteristics associated with nesting success (Hughes et al. 1999). Consequently, there is often no correlation between density and breeding habitat suitability (Fretwell 1969). In fact, densities of breeding Field Sparrows (*Spizella pusilla*) have been shown to be higher in areas of lower breeding success (Fretwell 1969). Therefore, management regimes based upon abundance or density alone may be insufficient to protect breeding habitats of species at risk, as they may result in a habitat sink or ecological trap. Factors such as nesting success and fledgling growth may provide better evidence of habitat quality (Maurer 1986).

2.3 Ungulate Grazing in Prairies

2.3.1 History

The appearance of bison on the North American Great Plains during the Pleistocene era, along with a change in climate, brought about a lasting change on the landscape by altering the dominant plant community (Stebbins 1981). Before the arrival of bison, horses and pronghorns were the major grazing herbivores on the grasslands. They graze more closely to the ground, excluding certain grass species from the

landscape that cannot tolerate this type of grazing pressure. But with the arrival of bison, species such as bunch grasses (*Stipa* spp.) were able to take over.

Estimates of the bison population reported by early explorers ranged between 30 and 60 million across the Great Plains (see citations in Knapp et al. 1999). However, widespread slaughter between 1830 and 1880 resulted in a population decline to just a few thousand animals. Because of this, many ecological effects of bison grazing are poorly understood. Though bison populations remained stable on mixed-grass prairies in the early to mid-19th century due to their distance from centers of human civilizations, the species disappeared from tall-grass prairie by 1833 (Shaw and Lee 1997).

Bison and cattle grazing differ in several ways. Although both ungulates are considered generalist foragers, cattle are more selective in the plants they consume (Peden et al. 1974). Both herbivores exhibit seasonal differences in the type and quantities of plant species on which they feed (Plumb and Dodd 1993). This is especially true for bison, when social time investments required during their seasonal rut ultimately limit their feeding time (e.g., Fuller 1960). However, bison compensate for this nutrient and time imbalance by consuming almost exclusively graminoids during the rut (Plumb and Dodd 1993).

As grasslands evolved in the presence of large grazing ungulates, the flora and fauna inhabiting these prairies have evolved to tolerate or benefit from these species. Plumb and Dodd (1993) suggest that bison may not be the primary candidate for grassland management, despite their historic role in this capacity. This is especially true in areas with small tracts of rangeland, or where management regimes are complex (Plumb and Dodd 1993). The widespread use of grasslands as pasturage for cattle may

have similar effects on the surrounding landscape, as both cattle and bison create disturbances that alter vegetation structure.

2.3.2 Impacts of Grazing on Vegetation

Grazing by large ungulates can increase the spatial variability of prairie landscapes (Hobbs 1996, Knapp et al. 1999). Within any pasture undergoing continuous moderate grazing, there are small interspersed patches of both lightly and heavily grazed vegetation. This is because cattle exhibit uneven patterns of grazing, and tend to selectively graze areas that lack biomass accumulations (Bailey et al. 1998). This results in a pattern of heterogeneity at the small scale. Grazing pressure is also higher near sources of water, as cattle tend to concentrate in those areas, resulting in heterogeneity at a larger scale. Therefore, at both the local and landscape scales, cattle grazing leads to an increased availability of niches and a higher biodiversity of plant and animal species (Augustine and McNaughton 1998). Fuhlendorf and Engle (2001) suggest that rangelands may serve as repositories for biodiversity due to their ability to sustain large communities of native plants.

In GNPC, both short-term and long-term grazing caused a decrease in vegetation height and density, litter cover, and litter depth (Bleho 2009, Sliwinski 2011), and an increase in exposed moss and lichens, and percent bare ground (Bleho 2009). However, some plant communities are more sensitive to grazing than others. At a local scale, grazing increases the canopy cover of annual forbs, perennial forbs, and cool-season grasses (Towne et al. 2005). Conversely, the history of grazing on a site may affect the impacts of grazing on a landscape scale. Milchunas and Lauenroth (1993) found that on

sites with longer evolutionary histories of grazing, the re-introduction of grazing caused greater changes in plant species composition than on sites with less extensive histories of grazing.

The amount and quality of litter (i.e., a layer of dead plant matter) has a large effect on grassland plants. By providing protection from direct sun exposure, litter retains soil moisture and helps regulate soil temperature (Deutsch et al. 2010). This in turn influences the growth of different plant species. Litter also acts as a fuel for combustion, meaning that the quantity and distribution of litter has a large effect on the fire regime of an area.

By removing litter through grazing, cattle can alter the prairie landscape. At a local scale, areas where litter has been removed through grazing are often more productive than others (see citations in Harrison and Bardgett 2008). They also often experience fewer, less intense fires due to the reduction of a fuel source (Hobbs 1996). In addition, cattle return nutrients such as nitrogen to the soil through their waste (e.g., Hobbs 1996). The presence of livestock thereby affects the nitrogen cycle of the entire system by both removing and returning nitrogen to the soil more quickly than it would without the presence of grazing ungulates. Ranching, while extractive on the landscape, is still less modifying of prairie habitat than agriculture.

Effect of Stocking Rate on Vegetation

The effects of cattle grazing on grassland vegetation vary with intensity. Stocking rate influences the species composition of grassland vegetation by altering the proportion of forage produced on the landscape (Ellison 1960). In GNPC, stocking rate had a

nonlinear effect on vegetation height, litter depth, and litter cover during both years of my study, with habitat structure changing dramatically at 0.4 AUM/ha (Sliwinski 2011).

A study done in southwestern Alberta showed that a stocking rate of 1.2 AUM/ha (a low stocking rate for that region) did not affect the vegetation of rough fescue grassland, while increases in stocking rate beyond that caused a decrease in the basal area of rough fescue (Willms et al. 1985). Among dominant mixed-grass prairie species, an increase in grazing intensity leads to an increase in blue grama (*Bouteloua gracilis*) and prairie sage (*Artemisia frigida*), and a decrease in western wheatgrass (*Pascopyrum smithii*) and needle-and-thread grass (*Stipa comata*) (Smoliak et al. 1972, Milchunas et al. 1989, Willms et al. 2002). In addition to changes in species composition, increases in stocking rate also decrease the overall range condition of the grassland (Willms et al. 1985). Range condition is commonly defined as the similarity between the present vegetation and the potential or climax vegetation of a site (Smith 1979). Areas of low range condition produce less forage for grazers than those of high range condition (Frost and Smith 1991).Grazing may alter landscape heterogeneity to different extents, depending on stocking rate. Sliwinksi (2011) observed a negative correlation between stocking rate and heterogeneity of vegetation height in GNPC in 2009, but a positive correlation in 2010. Heterogeneity of litter depth increased at moderate stocking rates but decreased at high stocking rates, while heterogeneity of vegetation density increased at moderate stocking rates (Sliwinksi 2011). A wide range of available microhabitats on the landscape may increase the quantity of suitable nest sites for the variety of songbirds found in GNPC.

Invasive plant species such as cheatgrass (*Bromus tectorum*) and leafy spurge (*Euphorbia esula*) have begun to dominate many prairie ecosystems, replacing native species such as blue grama. Overstocking can create ecosystem niches for plant invaders where they would not have occurred at lower stocking rates (Finnoff et al. 2008). What constitutes an optimal stocking rate for a particular area may therefore be influenced by the proportion of plant invaders present in the plant community. In GNPC, exotic invasive species of concern include crested wheatgrass (*Agropyron cristatum*), yellow sweet clover (*Melilotus officinale*), and leafy spurge (*Euphorbia esula*), among others (Michalsky et al. 2005). Management goals for GNPC should take into account how invasive vegetation will be affected.

2.3.3 Impacts of Grazing on Birds

Determining any direct influences of grazing on bird populations has been difficult due to insufficient data, poor study design, and the challenge of separating the effects of grazing from those of other disturbances (Martin et al. 2005). Coppedge et al. (2008) found that bird diversity and richness in grassland systems was highest in areas with different intensities of disturbance. This is similar to the grazing experiment being conducted in Grasslands National Park of Canada, where pastures are being subjected to a range of grazing intensities. In this case, pastures with different ranges of vegetation structure at the same site can be compared to determine which (if any) impact nesting success of grassland songbirds.

Effects of Grazing on Nesting Success

Nest site selection and preferences are the result of evolutionary traits that favored individuals choosing nest sites with a lower incidence of predation. Often, species will prefer to nest in or near a particular plant species or patch type (Martin 1993). As grassland birds evolved in an environment maintained by large herds of grazing ungulates, some species may have evolved a preference for nest sites containing vegetation species and structures that occur in the presence of those ungulates. Though grassland songbirds evolved alongside bison and not cattle, cattle may still benefit songbird nesting success as the heterogeneous grazing habits of cattle result in a similar mosaic of landscape patches at different stages of succession as bison (Plumb and Dodd 1993).A study in southern Alberta found that neither grazing nor vegetation structure affected the nesting success of most songbirds (Koper and Schmiegelow 2007). Management during this research involved deferred grazing, which is a practice that can be used to increase nesting success of waterfowl species. Although duck nesting success was influenced by this type of grazing regime, Koper and Schmiegelow (2007) concluded that management for ducks cannot be assumed to benefit songbirds, as songbirds respond to grazing differently than do waterfowl (Koper and Schmiegelow 2006b).

A study by Lusk (2009) in GNPC found no correlation between long-term grazing and nesting success of grassland songbirds, including Sprague's Pipit, Chestnut-collared Longspur, and Vesper Sparrow. Hovick et al. (2011) found no effect of grazing on post-fledging survival of Grasshopper Sparrows (*Ammodramus savannarum*), suggesting that factors such as depredation and exposure had a greater impact on mortality of fledglings. Some studies have observed differential responses of nesting success to grazing, where

some species are negatively affected while others show no affect (e.g., Rahmig et al. 2008, Kerns et al. 2010). In British Columbia, grazing was found to reduce the availability of suitable nesting habitat, as well as depress nesting success of Vesper Sparrows (Harrison et al. 2011). Similarly, Walsberg (2005) found that livestock grazing dramatically reduced the nesting success of Dark-eyed Juncos (*Junco hyemalis*), another ground-nesting sparrow.

Cattle can influence nesting success of songbirds directly through trampling of nests (e.g., Fondell and Ball 2006, Perlut and Strong 2011) (see section 2.5.6). Much more importantly, however, cattle grazing influences nesting success through the alteration of plant communities. Differences in vegetation affect nesting success through the exposure of the nest to different types of predators (e.g., With 1994, Dion et al. 2000). Because grazing influences vegetation, which can in turn influence nest predators, then grazing at different stocking rates may have different effects on nesting success.

Effect of Stocking Rate on Birds

Few studies have examined the effects of cattle stocking rate on grassland bird communities. However, birds have shown a shift in species composition in response to grazing intensity, and may be more sensitive to grazing treatments than other groups of prairie animals (Milchunas et al. 1998). Chestnut-collared Longspurs, for example, may utilize moderately grazed (Milchunas et al. 1998) or heavily grazed (Bleho 2009, Sliwinksi 2011) pastures. Sprague's Pipits may be sensitive to grazing, as they are found more frequently in pastures with low to moderate stocking rates (Saab et al. 1995, Davis et al. 1999). A study in the United Kingdom revealed a negative correlation between

stocking rate of sheep and egg size of the Meadow Pipit (*Anthus pratensis*), though no effect on fledging success was observed (Evans et al. 2005). This study, conducted on a close relative of the Sprague's Pipit, suggests that stocking rates in GNPC may negatively influence the reproductive success of this bird.

There may be a threshold in which bird abundances begin to shift in response to grazing pressure. Research done concurrently in my study area of southwest Saskatchewan showed that at a stocking rate of 0.4 AUM/ha, Chestnut-collared Longspurs increased in abundance and Baird's Sparrows decreased in abundance (Sliwinksi 2011). However, Davis et al. (1999) found that Chestnut-collared Longspurs were often relatively insensitive to differences in grazing intensity. Although also conducted in southern Saskatchewan, their study encompassed a much larger area than the GNPC study site. Some grassland songbird populations may be more sensitive to grazing intensity than others, depending upon specific topographic characteristics. However, as songbird abundances are often affected by grazing intensity, it follows that songbird nesting success may be affected as well.

2.4 Effects of Vegetation on Nesting Success

Grassland songbirds utilize nest sites that have significantly different vegetation than what is available in the surrounding landscape (e.g., Sutter 1997, Dieni and Jones 2003, Lusk et al. 2003, Davis 2005, Fisher and Davis 2011). In particular, nest sites tend to have greater vegetation height and density, greater litter cover, and less bare cover than random sites (e.g., Sutter 1997, Dieni and Jones 2003, Lusk et al. 2003, Davis 2005, Kerns et al. 2010). Not only microhabitat nest characteristics, but habitat types may also

affect nesting success. Lloyd and Martin (2005) found that nest survival and nestling growth of Chestnut-collared Longspurs were lower in grasslands dominated by exotic plants than those dominated by native species.

The primary effect of vegetation on songbird nesting success is through the exposure of the nest to various predators (see Section 2.5.1). Different predators may be attracted to or unable to find nests located in vegetation of different heights, types, and structures. For example, greater shrub cover has been linked with a decrease in nesting success for grassland songbirds because of preferential use of shrubs by egg-eating snakes (Klug et al. 2010). Conversely, vegetation at the nest may assist in concealment from predators (e.g., DeLong et al. 1995). It may also inhibit the movements or foraging efficiency of predators (Sugden and Betersbergen 1986).

Aerial predators and large mammals can more easily detect nests in areas of sparse vegetation, as they rely more on eyesight to hunt (Dion et al. 2000). Conversely, small mammals are typically olfactory-driven in their foraging behavior, and thus can find and depredate nests hidden within dense vegetation (With 1994, Dion et al. 2000). Small mammals tend to hide in dense vegetation from predators as well, which allows them increased opportunity to find and depredate nests (With 1994, Dion et al. 2000). Further, nest predation from large mammals or other birds may decrease if an abundance of an alternate food source (e.g., small mammals) for those species is available (Ackerman 2002). Thus, an increase in the population of small mammals may increase nest predation by small mammals, but decrease nest predation by larger predators which opportunistically feed upon the small mammals (Ackerman 2002).

Davis (2005) found vegetation structure at the nest to be an important predictor of prairie songbird nesting success. Some studies have found that successful grassland songbird nests are more often built in areas of greater forb cover and less grass cover than those of unsuccessful nests (e.g., Dion et al. 2000). Others have found that successful nests were found in areas of greater grass cover and lower forb, shrub, and bare ground cover (e.g., Sutter 1997, Lusk et al. 2003). Predation tends to decrease with increasing vegetation height located at artificial nests (Howard et al. 2001). The location of a nest among vegetative strata also affects predation. For example, ground nests have higher success rates than above-ground nests (Pietz and Granfors 2000).

Measuring vegetation at nest sites is helpful for identifying habitat features that affect a species' nesting success. It may identify reasons why livestock grazing effects nesting success. This will help wildlife managers to better determine specific habitat requirements for species at risk, allowing them to make management decisions about which areas to protect. Comparing vegetation at nests to vegetation at non-nest sites will provide further insight into whether grazing affects the choice of nest sites and habitat use by grassland songbird species.

2.5 Reasons for Nest Failure

The aim of this research is to determine how grazing will effect nesting success of songbird species, both individually and collectively. To do this, it is important to examine the causes of nest failure, as each may be impacted by different grazing intensities and durations.

2.5.1 Predation

Although various reasons exist for nest failure in songbirds, predation is the most important cause (Ricklefs 1969, Martin 1995). Predation has been shown to cause almost 90% of nest failures in southern Saskatchewan prairie songbirds (Davis 2003). For altricial species, predation is typically higher for nests with chicks than nests with eggs (Best 1978, Pietz and Granfors 2000, Davis 2003). It is likely that nests with chicks are more easily detected by predators due to increased noise and scent levels, as well as increased visits from parents. Skutch (1949) found that the probability of nest predation increased with increased numbers of chicks.

Effects of vegetation and landscape on nest predation

Predation may be influenced by factors such as vegetation height, density, and structure (which may aid in or impair concealment), nest type, distribution, and distance to edge habitat. These factors may also influence the types of predators attracted to or unable to find a nest. For example, open nests built in sparse vegetation (e.g., Chestnut-collared and McCown's Longspurs) are more easily seen by aerial predators (Dion et al. 2000). Conversely, closed nests built in dense vegetation may be more easily found by ground predators such as mice, which hide in thick grass or litter cover from those same aerial predators (With 1994). However, some studies have shown that predation rates do not differ between open and closed nests, even though there is a difference in the predator communities that depredate each type of nest (e.g., Pietz and Granfors 2000).

The degree of landscape heterogeneity (i.e., different patch types) may have a greater effect on nesting success than nest cover (Bowman and Harris 1980). As

heterogeneity increases, the foraging efficiency (the number of clutches found per unit time) of predators decreases (Bowman and Harris 1980). Heterogeneity may decrease prey vulnerability as it results in a greater range of microhabitats for prey to hide in and utilize.

Fragmentation, and the increased area of edge habitat that results, often affect depredation. There is evidence that edges are used as travel corridors for mesopredators (e.g., Gates and Gysel 1978, Angelstam 1986). Birds nesting in fragmented prairie habitat may therefore experience a higher incidence of nest predation (Burger et al. 1994). However, Koper and Schmiegelow (2006a) found little evidence that landscape characteristics affected the nesting success of either prairie songbirds or waterfowl.

Researcher Effects on Nest Predation

Nest monitoring by researchers may increase predation. Sutherland et al. (2004) suggested that monitoring draws the attention of predators to a nest or prevents adults from protecting it. Some studies have shown that disturbance caused by researchers reduced nesting success by increasing predation opportunities (e.g., Westmoreland and Best 1985). However, Götmark and Åhlund (1984) found that clutch size and frequency of predation on Common Eiders (*Somateria mollissima*) did not increase after disturbance by human observers. Similarly, O'Grady et al. (1996) found that nest visitation did not increase nest predation of Chestnut-collared Longspurs, and that in fact predation decreased as visitation increased. A study of ground-nesting songbirds in the southern hemisphere also found that frequently visited nests did not suffer from increased mammalian predation (Lloyd et al. 2000). It is likely that researcher disturbance has

effects that vary among species and habitats. To avoid potential risks of visitors to monitored nests, I limited both the time spent at each nest (< 5 minutes), and the frequency of visits (minimum 3-day interval unless young were close to fledging).

Picozzi (1975) observed that certain predators, such as corvids, are attracted to human-made nest markers (such as flags) and learn to use them to locate nests. To avoid this problem, I placed markers 10 m away from nests, rather than directly adjacent to them (see Section 3.2).

Possible Predators

Possible nest predators in this habitat were many and varied, and included the thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*), long-tailed weasel (*Mustela frenata*), plains garter snake (*Thamnophis radix*), and Brown-headed Cowbird (*Molothrus ater*) (Pietz and Granfors 2005). Striped skunk (*Mephitis mephitis*), swift fox (*Vulpes velox*), American badger (*Taxidea taxus*) (With 1994), white-tailed deer (*Odocoileus virginianus*), red foxe (*Vulpes vulpes*), and coyote (*Canis latrans*) have also been observed as nest predators (Pietz and Granfors 2000). Other possible nest predators observed at the study site include Richardson's ground squirrel (*Urocitellus richardsonii*), western hognose snake (*Heterodon nasicus*), as well as mice and vole species.

Predation of eggs or chicks is not the only factor in nest failure. If one parent is depredated, the nest may be unsuccessful for species where both parents care for nestlings (Lynn and Wingfield 2003), or only the female incubates the eggs

23

2.5.2 Abandonment

Desertion of nests falls between 1.0 – 9.2% for songbird species in southern Saskatchewan (Davis 2003). Nest abandonment typically occurs before nest building has been completed (Maddox and Weatherhead 2006). Only rarely are nests abandoned after more than one egg had been laid. This could be because eggs represent a much higher reproductive investment than a nest alone, so the cost to the pair is much higher to abandon a nest with eggs than without.

Abandonment decreases as the breeding season progresses, suggesting that pairs often abandon a partially completed nest because the weather and/or resources have not reached an optimal point for highest nesting success (Maddox and Weatherhead 2006). This may also be due to switching of mates early in the breeding in the season, as the cost of starting a new nest with a more suitable mate is lower than finishing one with a sub-optimal mate (Maddox and Weatherhead 2006).

It is possible that finding and visiting nests may cause abandonment, thus causing a discrepancy between observed and actual nesting success. However, abandonment rates at monitored songbird nests are typically very low. Pietz and Granfors (2000) observed a 2% (7 of 363) abandonment rate when nests were checked once a week. If human disturbance played a large part in nest abandonment, then it would follow that as researcher activity increases throughout the breeding season, so too should nest abandonment. However, Maddox and Weatherhead (2006) found the opposite pattern, suggesting that abandonment due to nest monitoring may not be substantial. Disturbance to a nest tends to be greater when nests are first found, due to the increased length of stay required to locate and record the nest (Martin and Geupel 1993). Subsequent visits are

often brief, which reduces stress to the adult. If a nest is not abandoned after the first visit, it isunlikely to be abandoned due to human interference unless the disturbance is significant.

2.5.3 Parasitism

In many songbird species, brood parasitism by Brown-headed Cowbirds plays a large part in the nesting success and overall productivity of the host. Brown-headed Cowbirds generally lay their eggs in nests of other altricial insectivorous bird species, leaving the host bird to hatch and raise the young. Cowbirds tend to choose hosts whose eggs are similar in size (e.g., Klippenstine and Sealy 2008). This helps to reduce egg and nestling rejection by hosts, although frequency of cowbird egg rejection varies widely among species (Payne 1977, Klippenstine and Sealy 2008). Rothstein (1982) suggested that rather than evolving a recognition of parasitic eggs, common cowbird host species have evolved a recognition of their own eggs. Thus, a built-in tolerance is developed in that eggs that differ in only 1 of 3 main egg traits (i.e., size, color, and pattern) are not rejected (Rothstein 1982) in case they are merely atypical eggs of the host.

Frequencies of cowbird parasitism tend to vary by geographic location, especially for grassland species (see citations in Jensen and Cully 2005). Cowbirds likely evolved alongside herbivorous grazers on the Great Plains, utilizing the vegetation trampled by large ungulates as areas to forage for invertebrates (Friedmann 1929). Today, cowbirds are common in shortgrass habitats such as pastures, croplands, and feedlots (e.g., Friedmann 1929, Morris and Thompson 1998).

Parasitism by cowbirds may depress nesting success of the host in several ways. Cowbirds often reduce the clutch size of the host by removing one or more of the host's eggs from the nest (Sealy 1992). Cowbird chicks, which often grow faster and are larger than the host nestlings, often monopolize parent care by crowding out and subsequently starving the host young. Consequently, parasitized nests typically fledge fewer host young than non-parasitized nests (Payne 1977, Davis and Sealy 1998, Lorenzana and Sealy 1999)However, a very abundant species with low frequencies of parasitism, such as the Red-winged Blackbird (*Agelaius phoeniceus*), may be a more important host species than a less abundant, but more frequently parasitized species through sheer numbers (Weatherhead 1989, Lowther 1993). Parasite young may also exhaust the parent(s) to the extent that a second breeding attempt is delayed or not undertaken (Lorenzana and Sealy 1999).

Cowbirds lay their eggs from mid-May through mid-July, with peak laying taking place in the second week of June, overlapping with the main nesting interval of other prairie songbirds (see Section 2.4). They tend to parasitize 15 – 29% of nests of the most common mixed-grass prairie songbird species, though both higher and lower frequencies have been recorded (Davis 2003). Davis and Sealy (1998) found that 36% ($n = 74$) of Baird's Sparrow nests in southwestern Manitoba were parasitized. Davis (2003) observed that multiple parasitism was frequent, with cowbirds laying up to three eggs in each host nest. Of the six species I studied, Savannah Sparrows have been found to have the highest rate of parasitism in southern Saskatchewan (29%), though Baird's Sparrow nests collectively had the highest number of cowbird eggs per nest (60% of parasitized nests had more than one cowbird egg) (Davis 2003). Five out of six of my study species (minus

McCown's Longspurs) have been observed accepting nearly all cowbird eggs placed in their nests (Klippestine and Sealy 2008, but see Davis et al. 2002). These species demonstrate a susceptibility to egg mimicry by cowbirds, whose eggs may have evolved a general appearance which imitates that of multiple grassland host species (Klippenstine and Sealy 2010). Frequency of parasitism for each species differs among years depending on resources and populations of each species (Davis and Sealy 2003).

Cowbird parasitism on both Sprague's Pipits and Chestnut-collared Longspurs in southern Saskatchewan was low and infrequent (Davis 2003). In the longspurs, Davis et al. (2002) suggested that nest defense strategies are the reason for this. As these two prairie songbird species are among those of highest conservation concern in Canada, low observed rates of brood parasitism can be of importance to management. It suggests that cowbirds do not need to be managed as elsewhere to protect threatened species such as Kirtland's Warbler (DeCapita 2000). As my study plots in GNPC are far from wooded areas, I predict brood parasitism rates to be low (Best 1978, Gates and Gysel 1978).

2.5.4 Inviability

Occasionally, some eggs never hatch. This could be due to the egg not being properly fertilized, the embryo dying during incubation, or the egg not being sufficiently incubated. Egg inviability is an inevitable consequence of nesting, though it does not depress nesting success as greatly as predation or brood parasitism. Percentages of egg viability in grassland songbirds appear to vary widely. Pietz and Granfors (2000) observed a 4% ($n = $ 193) incidence of infertile eggs or dead embryos. By contrast, Davis

27

(2003) observed that, on average, 27% ($n = 590$) of common prairie songbird eggs remained unhatched despite being incubated to full term.

2.5.5 Weather

Extreme weather events have been shown to directly influence nesting success. Heavy storms may destroy nests or wash away eggs, while hail may crush eggs or kill chicks and/or adults. Eggs or chicks may quickly die if left exposed during poor weather events (personal observation).

Weather may also affect nesting success indirectly. In times of severe drought, population densities of prairie songbirds decline sharply due to increased mortality via dehydration or starvation, leaving fewer birds attempting to nest. Of those birds remaining to nest, many abandon during incubation, thus decreasing nesting success (George et al. 1992). In years of colder weather and later frosts, populations of prey species such as insects are reduced (Schmidt 1999). Therefore, as foraging time by parents is increased, and vigilance at the nest is decreased, higher predation rates by predators may result.

2.5.6 Cattle

For birds nesting in areas with cattle, there is a possibility of nests being trampled. The incidence of this appears to range from low (6-12%) (Fondell and Ball 2004) to high (32%) (Perlut and Strong 2011) Evidence suggests that cattle are attracted to human-made objects (Renfrew and Ribic 2003). I placed a stake and a brightly-colored flag 10 m from each nest, and observed cattle investigating the objects on multiple occasions.

Trampling rates may be higher in pastures with higher stocking rates of cattle (Fondell and Ball 2004).

Additionally, there have been records of cattle depredating ground nests of prairie songbirds. Nack and Ribic (2005) observed the predation of three Savannah Sparrow nests by cattle. There may be a higher impact on nests by cattle than traditionally thought if they have not previously been considered nest predators.

2.6 Breeding Biologies

Sprague's Pipit

Sprague's Pipits in Canada occur in Alberta, Manitoba, Saskatchewan, and small areas of British Columbia (Dunn and Alderfer 2006). They are endemic to North American short- and mixed-grass prairies (Robbins and Dale 1999), and are one of the least studied birds on the continent (Davis 2009). They avoid heavily-grazed areas (e.g., Dale 1983), and tend to prefer native grassland to those areas dominated by non-native vegetation (Sutter 1996, Fisher and Davis 2011).

Birds arrive on the breeding grounds from late April to early May (Davis 2003). Males are polygynous and may have several females within their territory (Dohms and Davis 2009). Nesting begins in mid-May and typically extends through early July, though rarely birds have been recorded nesting as late as mid-August (Davis 2003). Nests are built, presumably by the female, from dead grasses in a depression in the ground (Robbins and Dale 1999). Overarching grasses typically form a "tunnel", with the entrance facing one direction.

Clutch size is typically between four and five, with two to six eggs being recorded occasionally (Davis 2003, 2009). The largest clutch sizes tend to be laid halfway through the breeding season (Davis 2003). Incubation lasts from 13-15 days (Davis 2009), and is carried out by the female only (Robbins and Dale 1999). Males have been observed feeding nestlings (Dohms and Davis 2009). Chicks fledge from the nest within 11-14 days, with 12 days being average. Double brooding may be rare, though renesting is common (Davis 2009), with an average of 1.5 clutches being produced per year (Robbins and Dale 1999). New nests are typically built within 100 m of the initial nest (Sutter 1996). Nesting success for Sprague's Pipits in southern Saskatchewan is approximately 30% (Davis 2003), though this percentage may vary widely.

Chestnut-collared Longspur

Chestnut-collared Longspurs in Canada occur in Alberta, Saskatchewan, and Manitoba (Dunn and Alderfer 2006). They are a prairie specialist and endemic to North American's grasslands (Hill and Gould 1997). They are found in the highest densities in grazed areas (see citations in Fuhlendorf and Engle 2001).

Birds arrive on the breeding grounds in mid-April (Harris 1944, Davis 2003). Males proclaim and defend breeding territories through aerial displays of song (Hill and Gould 1997). Nesting begins in early to mid-May and continues through mid to late July (DuBois 1935, Harris 1944, Davis 2003). Females scratch a hollow, typically beside a cow patty or clump of grass, into which they build an open cup nest (Hill and Gould 1997). Nests are placed in areas of sparse vegetation (Hill and Gould 1997) and are

constructed from dry grasses, typically in areas with more bare ground and less litter than other species (Davis 2005).

Clutch size is typically three to five, with four being the most common (Hill and Gould 1997, Davis 2003). Occasionally, two- and six-egg clutches have been reported (Hill and Gould 1997, Davis 2003). Eggs are laid during the early morning, one per day (Harris 1944). Incubation, performed by females only, lasts 10-13 days (DuBois 1935, Harris 1944). Eggs hatch within a 48-hour period of each other (DuBois 1935). Chicks fledge within another 9-13 days, with young being cared for by both parents (Dubois 1935, Harris 1944). Double-brooding has been observed; however, though pair bonds remain intact throughout the season, extra-pair copulations are common (32%, $n = 25$) (Hill and Gould) Nesting success for Chestnut-collared Longspurs in southern Saskatchewan is approximately 30% (Davis 2003), though this value may vary widely.

McCown's Longspur

McCown's Longspurs (*Rhynchophanes mccownii*, previously *Calcarius mccownii*) in Canada occur in Alberta and Saskatchewan only (Dunn and Alderfer 2006). They are a prairie specialist and endemic to North American's grasslands (With 2010).

Males proclaim breeding territories by performing a flight song display (DuBois 1935, Mickey 1943). Nesting begins in early May and continues through the end of July (DuBois 1935). Clutch size is typically three to four, with five eggs encountered rarely (DuBois 1935, Mickey 1943). Nests, constructed by the female out of dead grasses and weeds, are set into shallow depressions, typically at the base of a tuft of grass (With 2010). Mickey (1943) observed many nests also being placed beneath rabbitbrush

(*Chrysothamnus* spp.). Nests placed near shrubs, however, are 2-3 times more likely to be depredated (With 1994). Vegetation around the nests often provides little concealment, with the cup rim usually being even with the ground (With 2010).

Eggs are most likely to be laid in the early morning, and are laid one per day (With 2010). Incubation, performed by the female only, takes about 12 days (Mickey 1943). Chicks within one nest will all hatch within 48 hours of each other. The chicks fledge within 10-12 days, with both parents tending the young. These birds will double brood (DuBois 1935, Mickey 1943), though it is unknown whether pairs remain monogamous throughout the season.

Vesper Sparrow

Vesper Sparrows (*Pooecetes gramineus*) are widespread, occurring during the breeding season in all the Canadian provinces except Newfoundland, Nunavut, and Northwest and Yukon Territories (Dunn and Alderfer 2006). They prefer open areas with sparse vegetation (Best and Rodenhouse 1984). The species has adapted to human disturbance and can often be found nesting in cropland.

Birds arrive on the breeding grounds in April (Best and Rodenhouse 1984). Males defend territories by singing from perches such as shrubs or fence posts. Nests are constructed by the female alone (Jones and Cornely 2002) of dead grass, and typically have partial domes or else are covered by overhanging vegetation (Wiens 1969). Often nests are built at the base of small sagebrush shrubs (Best 1972).

Clutch size is typically three to four, though instances of two to six have been recorded (Wray and Whitmore 1979). Eggs are incubated for 12 days by the female only,

with chicks fledging after another 8-10 days (Sutton 1960). Males assist in feeding the young (Wiens 1969).

Nest failure has been observed around 60% (Wray and Whitmore 1979), thus renesting attempts are common and double brooding is rare (Wiens 1969). Vesper Sparrows are typically monogamous throughout the breeding season (Wiens 1969)

Savannah Sparrow

Savannah Sparrows (*Passerculus sandwichensis*) are generalists, breeding in a number of open habitats (Welsh 1975). They occur in all the Canadian provinces during the breeding season (Dunn and Alderfer 2006). Birds begin arriving on the breeding grounds from late April to early May (Davis 2003). Males defend territories by singing both from raised perches and from the ground (Welsh 1975). Nesting begins in mid-May and continues through July (Dixon 1978, Davis 2003), though some young have been recorded leaving a nest as late as mid-August (Welsh 1975). Nests are built of dead grasses by the female alone (Welsh 1975, Bédard and Meunier 1983), and are typically well-concealed within bunches of vegetation (Welsh 1975). Savannah Sparrow nests are often roofed in such a way that one side is generally used as an entrance, though they may be open as well (Wiens 1969, Welsh 1975).

Clutch size averages three to five, though two to six eggs have been recorded (Wiens 1969, Dixon 1978, Bédard and Meunier 1983, Davis 2003), with eggs typically being laid one per day (Welsh 1975). As the breeding season progresses, clutch size tends to decrease (Davis 2003). Incubation is carried out mostly by the female, though males will occasionally contribute, and lasts from 11-13 days (Wiens 1969, Welsh 1975).

Chicks fledge within 7-11 days after hatching, though nine days is most typically (Welsh 1975, Dixon 1978). Nestlings are cared for by both parents (Bédard and Meunier 1983). Renesting attempts are common due to heavy nest failures (~60%), with pairs sometimes nesting three or more times to produce even a single successful chick (Dixon 1978). Double brooding occurs commonly; most pairs remain monogamous throughout the season, though some polygyny has been observed (Wiens 1969, Welsh 1975). Nesting success for Savannah Sparrows in southern Saskatchewan is approximately 28% (Davis 2003), though this value may vary widely.

Baird's Sparrow

Baird's Sparrows (*Ammodramus bairdii*) are endemic to the Great Plains grasslands (Knopf 1994), and in Canada occur in Alberta, Saskatchewan, and extreme southwestern Manitoba (Dunn and Alderfer 2006). Their highest densities are often, but not always, found in grazed areas (see citations in Fuhlendorf and Engle 2001).

Few studies have examined the breeding biology of Baird's Sparrows, most likely due to difficulty in finding nests (Davis and Sealy 1998). They arrive on the breeding grounds in early May, with clutch initiation peaking in late May – early June and ending by early August (Davis 2003, Davis and Sealy 1998). Nests are established in often self-made depressions, usually concealed by overhanging grass, and are not typically associated with shrub cover (Cartwright et al. 1937, Davis and Sealy 1998). It is unknown whether the female alone or both sexes build the nest.

Females lay one egg per day in the early morning hours. Clutch sizes are typically between three and six, with five eggs being the most common (Cartwright et al. 1937,

Davis 2003, Davis and Sealy 1998). Most five-egg clutches are initiated early in the breeding season, with smaller clutches possibly being the result of double brooding and re-nesting attempts later in the breeding season (Davis and Sealy 1998). It is unknown whether pairs remain monogamous throughout the season.

Incubation lasts from 11-12 days, with chicks fledging after 8-11 days (Lane 1968, Davis and Sealy 1998). Eggs are incubated by the female only, with chicks being fed by both parents (Green et al. 2002). Double-brooding has been recorded, though records are few (Cartwright et al. 1937, Davis and Sealy 1998). One study found nesting success for Baird's Sparrows in southern Saskatchewan to be approximately 26% (Davis 2003), though this will vary relative to factors such as landscape, biotic community, and weather.

2.7 Status of Species

2.7.1 Species at Risk Act

The Species at Risk Act (SARA) was developed as a means to prevent Canadian wildlife from becoming extinct by providing the necessary actions for their recovery and continuation. It was first proclaimed in 2003 and complements existing laws and regulations to ensure the legal protection of wildlife species, as well as conserving Canada's biological diversity. SARA applies to all Federal lands in Canada. At its inception, SARA began utilizing the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to provide the scientific knowledge necessary to accurately assess

the status of wildlife species. Individual species are reviewed through a process of monitoring, assessment, response, recovery, and evaluation (Environment Canada 2009).

As of 2008, SARA listed 97 species as "of special concern" (may become threatened or endangered because of a combination of biological characteristics and identified threats), 117 species as threatened (likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction), 190 species as endangered (facing imminent extirpation or extinction), 21 species as extirpated (no longer exists in the wild in Canada, but exists elsewhere), and 13 species as extinct (no longer exists) (Environment Canada 2009).

Committee on the Status of Endangered Wildlife in Canada (COSEWIC)

COSEWIC comprises a panel of scientific experts that regularly assesses which Canadian wildlife species are most at risk of extinction (COSEWIC 1996). It was first created in 1977 due to the need for a scientifically reliable, national classification of species at risk. Originally, it was only granted the approval to classify vertebrate species (mammals, birds, reptiles, amphibians, and fish). In 1994 this mandate expanded to include insects in the order Lepidoptera (butterflies, skippers, and moths), molluscs, lichens, and mosses. In 2003, COSEWIC was finally granted the right to assess all other arthropods, such as non-Lepidopteran insects, spiders, and crustaceans (e.g., lobsters, shrimp, crayfish).

COSEWIC currently lists 162 species as special concern, 150 species as threatened, 290 species as endangered, 23 species as extirpated, and 13 species as extinct. COSEWIC holds the power to grant emergency status to species that are in immediate

danger of serious decline. In 2003, SARA adopted COSEWIC as an advisory board and takes its designations into consideration when deliberating over the Federal status of a species. This ensures that the designation of wildlife as species at risk is the result of the best available scientific knowledge (Environment Canada 2009).

2.7.2 Status of Species

Sprague's Pipit

This species was last assessed by COSEWIC in 2000, in which it was classified as "threatened." It was officially listed as "threatened" under SARA in June 2003 (Environment Canada 2009). In 1996 it became ranked as "May be at Risk" in Alberta due to its rapidly declining population and lack of available research (Prescott 1997), and is also listed as "threatened" under the Manitoba Endangered Species Act (Manitoba Conservation 2009). Habitat loss and degradation are thought to be the main causes of population reductions throughout North America (Environment Canada 2009).

Chestnut-collared Longspur

This species was recently listed as "threatened" in November 2009 by COSEWIC, but currently is not protected under SARA (Environment Canada 2009).

McCown's Longspur

This species was listed as "special concern" during the last COSEWIC assessment in 2006, and is also listed as "special concern" under SARA. The Canadian population

has experienced a 98% population decrease since 1968, though the population has stabilized over the last 10 years. The largest threats are loss and degradation of this species' breeding habitat, as well as pesticide exposure due to more recent use of cultivated fields as nesting habitats (Environment Canada 2009).

Vesper Sparrow

This species is not listed under COSEWIC or SARA, possibly due to its large range and generalist habits. A subspecies found only in British Columbia is listed as "endangered" under both COSEWIC and SARA (Environment Canada 2009).

Savannah Sparrow

This species is not listed under either COSEWIC or SARA, most likely due to its wide range and large population size. The "Ipswich sparrow," a subspecies located only in Nova Scotia, is listed as "special concern" under both COSEWIC and SARA (Environment Canada 2009).

Baird's Sparrow

This species was listed as "threatened" in 1989 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The last COSEWIC assessment was in 1996, when the species was delisted due to a larger than expected population increase. Baird's Sparrows became listed as "endangered" in 1996 under the Manitoba Endangered Species Act (Manitoba Conservation 2009), though they are not protected under SARA (Environment Canada 2009).

2.8 Summary

Cattle grazing can affect landscapes through an alteration in the composition of plant communities (Hobbs 1996, Knapp et al. 1999, Towne et al. 2005). Specific vegetative characteristics influence the species of birds that choose to nest there (e.g., Cody 1985, Martin 1993). Vegetation at the nest also plays a large role in the type and frequency of nest predators (With 1994, Dion et al. 2000). Therefore, the type of grazing regimes implemented in mixed-grass prairie may affect the nesting success of grassland songbirds. Grazing at different stocking rates or durations of time may influence these factors to different degrees, resulting in a possible gradient of nesting successes. As grassland songbird populations are declining quickly (e.g,. Knopf 1992), and most native prairie is grazed to some extent each year (Fuhlendorf and Engle 2001), it is imperative to understand how grazing will affect the reproductive success of songbird species. Only then can we begin to properly manage our rangelands for the long-term continuation of songbird populations.

3.0 METHODS

3.1 Study Area

3.1.1 Study Site

North American mixed-grass prairies extend from southern Canada and eastern North Dakota south to Texas (Samson and Knopf 1994). GNPC in southwestern Saskatchewan is one of the few areas protecting the remainder of this ecosystem. It preserves 571 square kilometers of native mixed-grass prairie, and is the first national park in Canada to do so (Parks Canada 2010). Between homesteading in the early 1900's and its establishment by Parks Canada in 1981, GNPC remained unfragmented by either cultivation or heavy grazing (Henderson 2006).

My research was conducted in the East Block of GNPC and the adjoining Mankota community pastures, approximately 40 km southeast of the town of Mankota. The East Block is located entirely within the Missouri River drainage basin. My study plots were in an area of low elevation (750 to 850 m above sea level), with a mean annual precipitation of approximately 350 mm. The park is comprised of vegetation characteristic of mixed-grass prairie. Upland areas are dominated by blue grama, northern wheatgrass (*Agropyron dasystachyum*), western wheatgrass, needle-and-thread grass, and June grass (*Koeleria macrantha*). Clubmoss (*Selaginella densa*) is widespread, with common forbs including prairie sage, moss phlox (*Phlox hoodii),* and scarlet globemallow (*Sphaeralcea coccinea*).

Riparian (lowland) areas are dominated by sagebrush (*Artemesia cana*), western snowberry (*Symphoricarpos occidentalis*), and prairie rose (*Rosa acicularis*). Elevated salt flats are inhabited by cactus (*Opuntia* spp.) and shrubs such as greasewood (*Sarcobatus vermiculatus*), silver sagebrush (*Artemesia cana*), saltbush (*Atriplex* spp.), and rabbitbrush (*Chrysothamnus nauseosus)*. Dominant grasses in these areas include wheatgrasses, saltgrasses (*Distichlis stricta*, *Puccinella nuttallii*), and bluegrasses (*Poa sandbergii*, *P. compressa*).

3.1.2 Adaptive Management

In 2008, cattle were brought into the East Block, which had remained free of grazing since 1985 (Henderson 2006), following a Beyond BACI experimental design (Koper et al. 2008). Six experimental pastures (approx. 300 ha each) were built, each encompassing equal (relative to each other) proportions of the riparian, valley, and upland areas characteristic of the diverse prairie landscape (Henderson 2006). Each pasture was assigned a different stocking rate, which ranged from ranged from 0.23 AUM/ha (very low) to 0.83 AUM/ha (very high) (Fig. 1). An AUM (Animal Unit Month) is the amount of forage necessary to sustain one animal for one month, and is calculated as a proportion of the number of cow-calf pairs that one particular steer (as used in our study) is worth. Three additional control pastures were left ungrazed by cattle, though they were grazed by mule deer (*Odocoileus hemionus*) and pronghorn antelope (*Antilocapra americana*) to a small extent. Data were also collected from 4 pastures of the adjacent Mankota pastures, in which moderate grazing (approximately 20-40% utilization) typical of local grazing management had occurred for >15 years (Koper et al.,

unpublished data). Cattle were grazed in the Mankota pastures between June and

October, with no grazing occurring during the remaining months (Henderson 2006).

Grazed pastures were fenced, whereas ungrazed pastures were unfenced.
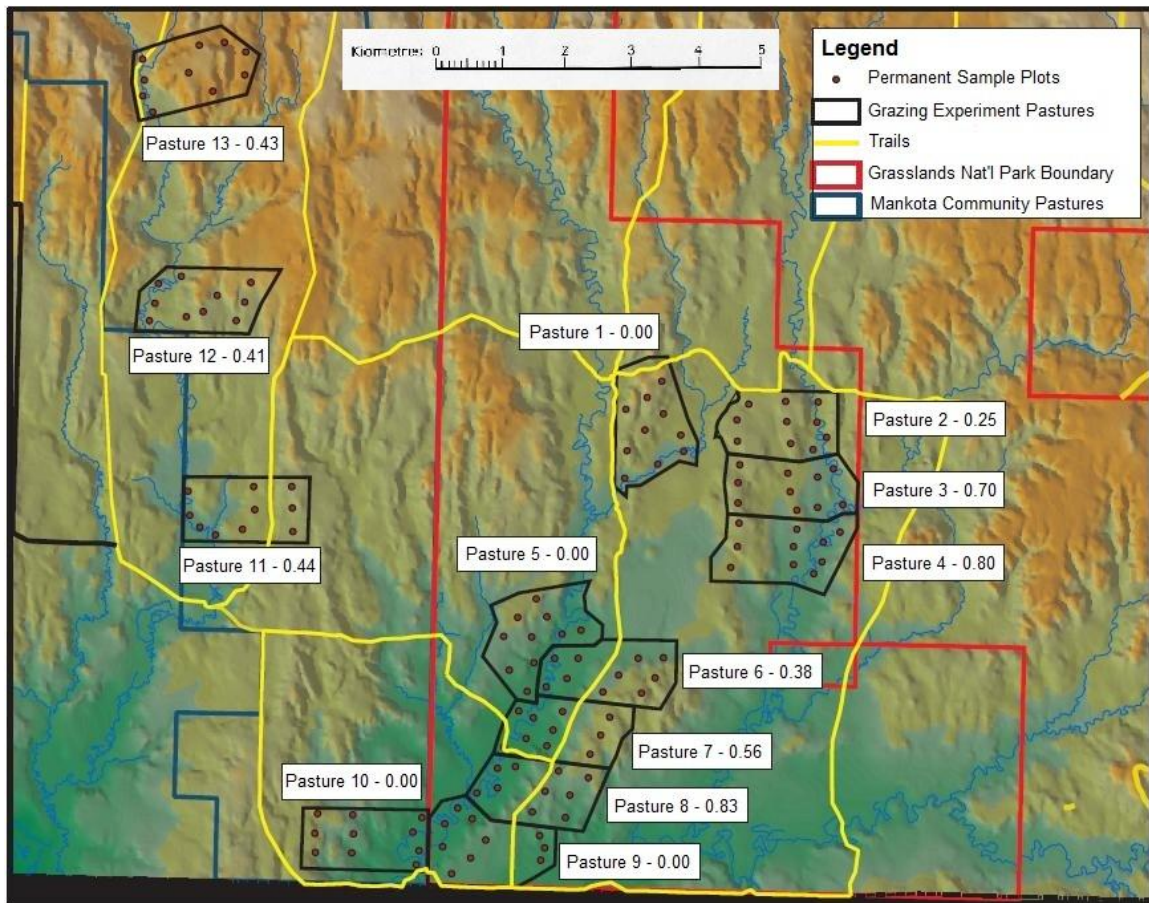
Figure 1. Grasslands National Park of Canada's East Block Grazing Experiment,
southwestern Saskatchewan, Canada (Koper et al. 2008).
Units are AUM/ha (averaged from 2009 and 2010).

Table 1. Average stocking rates for study sites in southwestern Saskatchewan, Canada, 2006 – 2007 and 2009 – 2010. Nests in pasture 10 were used to analyze nest site selection only.

Pasture	Hectares	Average AUM 2006-2007	Average AUM/ha 2006-2007	Average AUM 2009-2010	Average AUM/ha 2009-2010
1	301.6	0	0	0	0
2	281.6	0	0	69.5	0.25
3	288.4	0	0	202.4	0.7
4	313.6	0	0	249.9	0.8
5	295.2	0	0	0	0
6	296.1	0	0	112.9	0.38
7	280.4	0	0	158.1	0.56
8	289.6	0	0	241.3	0.83
9	320.9	0	0	0	0
10	2460	716.25	0.29	0	0
11	1942	917.57	0.47	846	0.44
12	1942	991.48	0.51	794.65	0.41
13	2072	1166.64	0.56	898.65	0.43

3.1.3 Nest Plots

I sampled 26 nest plots (each 300 m²), two in each of the 13 experimental pastures. These plots were unfenced subsamples within the larger pastures. One plot was located in an upland area of the pasture, the other in lowland. Eighteen plots were located within GNPC, 12 of which were grazed for 2 (in 2009) or 3 (in 2010) years and 6 of which were ungrazed; the remaining 8 plots were located in the Mankota pastures. Nest plots were established in 2006 by Lusk (2009), using randomly selected UTM lines on study area maps. Plot locations were chosen randomly but were adjusted to avoid water bodies and streams, and steep areas with vegetation transitioning from upland to lowland.

Each plot was searched twice between the months of May and July in both 2009 and 2010. I alternated between searching long-term grazed plots in the Mankota community pastures and short-term and ungrazed plots in GNPC to avoid seasonal bias among the treatments. Plots were also searched in a different order from one year to the next to help reduce temporal bias.

3.2 Nest Searching and Monitoring

I used the rope-drag method (e.g., Davis 2003) to sample nest plots. This involved dragging a 20-m long rope across the ground between two people to flush ground-nesting birds from their nests. The rope had rock-filled aluminum cans attached at 1-m intervals, which aided in flushing birds off nests before the rope passed over them. This was a safe and efficient way of searching a large area as there is no current evidence that this method has harmed nests, eggs, or chicks. Though this method helped me to search for nests across the study plots, it was inevitable that a percentage of nests were missed.

Nests in the egg-laying state are particularly difficult to find, as females often visit the nest only once a day to lay an egg (Martin and Geupel 1993). Nests found during other research activities were also monitored if they were in an experimental pasture. Most of my study species typically lay eggs in the early morning, before 0730 MST (e.g., Mickey 1943, Robbins and Dale 1999, Green et al. 2002). To reduce the risk of flushing a female during egg-laying, rope-dragging took place between approximately 0730 and 1400 MST.

Nests of six songbird species were monitored: Sprague's Pipit, Chestnut-collared Longspur, McCown's Longspur, Vesper Sparrow, Savannah Sparrow, and Baird's Sparrow. Songbird nests require much time and energy to find, thus sample sizes are generally low. I monitored these six species as they were either the most common songbirds in my study area, or those of the highest conservation concern. Nests found with cowbird eggs or chicks were monitored until nest termination. The locations of nests of non-target species were recorded, but nests were not monitored.

I returned to each nest every 3-4 days (or every 2 days as fledging date approached), which is the recommended interval suggested by Martin and Geupel (1993). The longer this interval is, the more difficult it is to accurately estimate nest outcome. However, nests were not checked more frequently than this due to both time constraints, and to decrease the chances of attracting predators to the nest or stimulating premature fledging. I did not monitor or rope-drag during rain, to avoid flushing females from the nest and exposing eggs and nestlings to inclement weather.

I recorded the number of eggs and young, approximate age of young, and begging behaviour. I did not attempt to age eggs. Ages of chicks were estimated using codes

45

based on the Ontario Nest Records Scheme, which is based on observations such as feather quality and coverage, and extent of begging behaviour (Bird Studies Canada 2001). I also recorded the presence and behaviour of adults (i.e., acting defensively) on or near the nest. Nests were marked with a flag set 10 m west of the nest, and a bamboo stake set 10 m south to aid in relocation. This distance conceivably reduced the risk of increased predation that can occur when using flags or similar markers (Picozzi 1975). Upon completion or termination of each nest, I determined outcome based on recorded visual evidence such as age of chicks upon last visit, presence (or lack thereof) of eggshells and/or feathers in the nest, obvious disturbance of the nest, and adult activity at or near the nest.

A nest was determined to be abandoned if several visits yielded no evidence of parental attentiveness, in combination with cold eggs and no signs of hatching despite nest age. A nest was considered successful if it fledged at least one chick. In a study with video cameras at nests, up to half of depredated nests showed no physical signs of depredation, including those taken by large mammals (Pietz and Granfors 2000). Therefore, nests where eggs and/or chicks had disappeared before they were expected to hatch and/or fledge were assumed to have been depredated (Ricklefs 1969).

3.3 Vegetation Measurements

To gain the most relevant data, vegetation measurements should be taken as soon as a nest is found. However, to reduce the disturbance to the nest and the likelihood of abandonment or predation, vegetation measurements were made at each nest within two weeks of the completion of the nesting attempt. I collected data in a 1-m² area both at the

nest, and at two random locations within 50 mof the nest. Random distances and angles

from nests were determined using Microsoft Excel®. Measurements included height of

the tallest vegetation, percent cover of different vegetation classes, litter depth at the nest

(or at center of random location), and vegetation density (modified from Robel et al.

1970). I also measured percent ground cover of shrubs, forbs, grass, biocrust (*Selaginella*

spp. and lichen), bare ground, and dead vegetation (i.e. litter). Percentages of each type of

ground cover were binned into ten cover classes to aid in estimation (Table 2).

Table 2. Percentages for estimation of ground cover at songbird nests in southwestern Saskatchewan, Canada, 2009 and 2010.

% Ground Cover	Cover Class
0 – 0.1	1
0.1 – 1	2
1 – 3	3
3 – 10	4
10 – 25	5
25 – 50	6
50 – 75	7
75 – 95	8
95 – 99	9
100	10

3.4 Data Analyses

Pre-Grazing

To determine if any results were due to conditions other than cattle grazing, I used the logistic exposure method (PROC NLMIXED; SAS Institute, Inc. 2008) to analyze nesting data collected at my study sites in 2006 and 2007, prior to the introduction of cattle. I analyzed the pre-cattle data using future stocking rates as the independent variable to determine whether any pre-existing patterns might result in a spurious relationship between stocking rate and nesting success of grassland songbirds. Since stocking rates were, on average, 0.03 AUM/ha higher in 2009 than in 2010, I used the average value of the two years. For these, and all other analyses, I used an alpha (α) of 0.10 to determine statistical significance.

Nest Site Selection

To determine whether the monitored species selected areas with specific vegetation characteristics in which to place their nests, I used generalized estimating equations (GEEs) (PROC GENMOD; SAS Institute, Inc. 2008) to compare vegetation at nest sites with that of the random sites. In each GEE, I used the nest as the repeated variable. Vegetation variables that I analyzed included vegetation height and density; shrub, forb, grass, biocrust, litter, and bare cover; and litter depth.

For any vegetation characteristics at the nest of a given species that were found to be significantly different than the random sites, I used generalized linear mixed models (PROC GLIMMIX; SAS Institute, Inc. 2008) to determine whether grazing intensity had

a significant effect on these differences. I used stocking rate as the independent variable and pasture as the random variable.

Nesting Success

I used logistic exposure models (PROC NLMIXED; SAS Institute, Inc. 2008) to determine effects of stocking rates and grazing durations on overall nesting success for both individual and collective species (Dinsmore et al. 2002, Shaffer 2004). Unlike previous methods for estimating nesting success (e.g., Mayfield 1961), this method does not assume that day of initiation and day of nest completion (i.e., fledged or depredated) are precisely known. It also reduces overestimation of nesting success that otherwise accompanies the lack of detection of nests that fail early in the incubation stage (Mayfield 1961).

I used two species assemblages to analyze collective nesting success. Sprague's Pipits, Chestnut-collared Longspurs, and Vesper Sparrows were grouped because they utilize nest sites that have shorter vegetation height and litter depth, and greater biocrust cover relative to Savannah and Baird's Sparrows, which represent the second group (Table 4, also see Lusk 2009).

Nonlinear effects of grazing were modeled using polynomials (quadratic and cubic models). A variable of these analyses was the total nesting time required for the analyzed species, averaged from the minimum and maximum days needed to incubate and fledge chicks (see Appendix I). Where more than one species was combined for analyses, the average total nesting time among species was used. I used the vegetation characteristics measured at each nest to group species into assemblages based upon

similar nest site selection. This helped not only to increase sample size and statistical power, but also to gain insights that may be more beneficial to wildlife managers. Often, managers seek to maintain species diversity, so management plans based on a single species are not always valuable.

I evaluated effects of grazing on nesting success for any monitored species where the outcome was determined for 15 or more nests. Hensler and Nichols (1981) recommended a minimum of 20 nests as fewer nests represents a sample size too small to have high statistical power. However, due to the difficulty in locating large numbers of ground nests, 15 was a more achievable number for this research. Nests for which either the species or the outcome remained unknown were excluded from analysis.

4.0 RESULTS

4.1 Pre-Grazing Data

In 2006 and 2007, 226 nests of Sprague's Pipits, Chestnut-collared Longspurs, Vesper Sparrows, Savannah Sparrows, and Baird's Sparrows were monitored at my study site (Lusk 2009). The nesting success of Sprague's Pipits and Chestnut-collared Longspurs in 2006 and 2007 was not influenced by stocking rate or the duration of grazing that was later imposed in those pastures (Appendix II). The nesting success of Savannah and Baird's Sparrows was likewise unaffected by stocking rate and years grazed in 2006, though neither had sample sizes large enough to analyze nests in 2007. Therefore, there were no pre-existing patterns in the landscape to explain any results observed on these species during my study. The nesting success of Vesper Sparrows was negatively correlated with stocking rate in 2007 but not 2006, and was not affected by years grazed in either 2006 or 2007.

4.2 Nest Monitoring

In 2009 and 2010, 376 nests were found, 300 of which were monitored (see Appendices III and IV). Not included in this number were nests found in Mankota pasture 10, which were excluded from nest success analyses because the pasture's grazing management changed over time (but comprised an additional 26 combined monitored nests). Chestnut-collared Longspur nests were found most frequently, while McCown's Longspur nests were the least abundant.

Among 300 monitored nests of six species, 49% were successful, whereas 44% were depredated (Table 3). Predation was the leading cause of nest failure. Baird's Sparrows had the highest nesting success and lowest predation rates (75% and 19%, respectively). Chestnut-collared Longspurs had the lowest nesting success and highest predation rates (41% and 50%, respectively).

Table 3. Songbird nest fates in southwestern Saskatchewan, Canada, 2009 and 2010.Where more than one cause of nest failure was recorded (e.g., parasitized, then depredated), only the cause judged to be the primary reason for failure was counted. Thus, depredation of parasitized nests was considered the primary cause of nest failure in most cases, as depredation typically removed all eggs/young of host birds.

Nest Fate	Baird's Sparrow		Chestnut-collared Longspur		McCown's Longspur		Savannah Sparrow		Sprague's Pipit		Vesper Sparrow	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Successful	6	18	30	25	1	0	6	14	16	13	7	11
Depredated	2	4	36	31	2	2	4	7	16	13	8	9
Weather	0	0	0	7	0	0	0	0	0	2	0	1
Abandoned	0	1	0	4	0	0	0	0	0	0	0	1
Livestock	0	1	0	0	0	0	0	0	0	2	0	0
Parasitized	0	0	0	0	0	0	0	0	0	0	0	1
Inviable	0	0	0	0	0	0	0	0	0	1	0	0

4.3 Nest Site Selection

Baird's and Savannah Sparrows nested in sites with the tallest and most dense vegetation, whereas Chestnut-collared Longspurs used sites with the shortest and sparsest vegetation (Table 4). Baird's Sparrows used nest sites with the lowest percentage of forb cover, whereas Chestnut-collared Longspurs used sites with the greatest. Percentage of grass cover was greatest at Baird's and Savannah Sparrow nests, and lowest at Chestnut-collared Longspur and Vesper Sparrow nests. Percentage of biocrust cover was greatest at Chestnut-collared Longspur nests and lowest at Savannah Sparrow nests. Percentage of litter cover and litter depth was greatest at Savannah Sparrow nests and lowest at Chestnut-collared Longspur nests.

Each species consistently chose nest sites where vegetation was significantly taller and denser, litter depth was greater, and there was less biocrust or bare cover than random locations within 50 m (Tables 5-9). Sprague's Pipits also chose sites with significantly greater grass cover than random sites, and both this species and Vesper Sparrows chose sites with less forb cover.

In most cases, there was no correlation between stocking rate and differences in vegetation structure at nest and random sites within 50 m of the nest. However, there were some exceptions. The difference between percent bare cover at nest and random sites for Chestnut-collared Longspurs was negatively correlated with stocking rate ($P = -1.49$ +/- 1.25, P-*value* = 0.0204, $n = 101$), showing that as stocking rate increased, selected nest sites became similar to random sites. Similarly, the difference between litter depth at nest and random sites for Sprague's Pipits was negatively correlated with stocking rate ($P = -1.53$ +/- 1.56, P-*value* = 0.0539, $n = 47$), so as stocking rate increased,

selected nest sites became more similar to random sites. The difference between percent

biocrust cover at nest and random sites for Savannah Sparrows was positively correlated

with stocking rate (P = 3.37 +/- 3.53, *P-value* = 0.0604, n = 27), so as stocking rate

increased, selected nest sites became less similar to available sites. Differences between

vegetation characteristics at nest and random sites were not correlated with stocking rate

for Baird's or Vesper Sparrows.

Table 4. Vegetation characteristics at songbird nests in southwestern Saskatchewan, Canada, 2009 and 2010. Mean +/- S.D. Dashed lines represent variables that were not measured.

Landscape Characteristic at Nest	Sprague's Pipit $n = 50$	Chestnut-collared Longspur $n = 114$	Baird's Sparrow $n = 27$	Savannah Sparrow $n = 28$	Vesper Sparrow $n = 32$
Vegetation Height[1]	46.09 +/- 11.55	43.76 +/- 14.5	60.44 +/- 15.59	59.55 +/- 18.56	47.67 +/- 12.48
Vegetation Density[2]	2.65 +/- 0.70	2.14 +/- 0.73	3.73 +/- 1.09	3.75 +/- 1.08	3.19 +/- 1.01
Shrub Cover[3]	-	-	-	1.52 +/- 1.95	3.85 +/- 2.05
Forb Cover[3]	3.27 +/- 1.30	3.60 +/- 1.14	2.69 +/- 1.72	3.17 +/- 1.43	2.96 +/- 1.36
Grass Cover[3]	5.31 +/- 0.74	4.92 +/- 0.94	5.65 +/- 0.45	5.72 +/- 1.01	4.95 +/- 0.66
Biocrust Cover[3]	4.76 +/- 1.56	5.37 +/- 1.51	2.99 +/- 2.22	1.97 +/- 2.20	5.12 +/- 1.87
Litter Cover[3]	5.84 +/- 1.21	4.76 +/- 1.04	6.01 +/- 1.06	6.19 +/- 0.93	5.15 +/- 1.17
Bare Cover[3]	-	1.08 +/- 1.39	-	-	1.56 +/- 1.65
Litter Depth[1]	2.48 +/- 1.72	1.51 +/- 1.51	3.63 +/- 2.00	3.80 +/- 1.57	1.87 +/- 1.24

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

Table 5. Differences between Sprague's Pipit nests and random sites in southwestern Saskatchewan, Canada, 2009 and 2010 ($n = 50$).

Parameter	Estimate	Lower CL	Upper CL	*P-value*
Vegetation Height[1]	5.143	2.342	7.944	0.0003
Vegetation Density[2]	0.688	0.457	0.918	< 0.0001
Shrub Cover[3]		Not significant		
Forb Cover[3]	-0.373	-0.738	-0.008	0.046
Grass Cover[3]	0.208	0.0324	0.383	0.020
Biocrust Cover[3]	-0.508	-0.904	-0.111	0.012
Litter Cover[3]	0.785	0.5198	1.050	< 0.0001
Bare Cover[3]		Not significant		
Litter Depth[1]	0.988	0.608	1.367	< 0.0001

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

Table 6. Differences between Chestnut-collared Longspur nests and random sites in southwestern Saskatchewan, Canada, 2009 and 2010 (n =114).

Parameter	Estimate	Lower CL	Upper CL	*P-value*
Vegetation Height[1]	5.355	3.367	7.343	< 0.0001
Vegetation Density[2]	0.428	0.287	0.570	< 0.0001
Shrub Cover[3]		Not significant		
Forb Cover[3]		Not significant		
Grass Cover[3]		Not significant		
Biocrust Cover[3]		Not significant		
Litter Cover[3]	0.245	0.074	0.415	0.005
Bare Cover[3]	-0.218	-0.433	-0.003	0.047
Litter Depth[1]	0.469	0.251	0.686	< 0.0001

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

Table 7. Differences between Vesper Sparrow nests and random sites in southwestern Saskatchewan, Canada, 2009 and 2010 ($n = 32$).

Parameter	Estimate	Lower CL	Upper CL	*P-value*
Vegetation Height[1]	6.895	1.555	12.236	0.011
Vegetation Density[2]	1.135	0.704	1.566	< 0.0001
Shrub Cover[3]	2.547	1.768	3.326	< 0.0001
Forb Cover[3]	-0.477	-0.973	0.020	0.060
Grass Cover[3]		Not significant		
Biocrust Cover[3]		Not significant		
Litter Cover[3]	0.598	0.144	1.050	0.010
Bare Cover[3]	-0.750	-1.374	-0.126	0.018
Litter Depth[1]	0.921	0.524	1.318	< 0.0001

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

Table 8. Differences between Savannah Sparrow nests and random sites in southwestern Saskatchewan, Canada, 2009 and 2010 ($n = 28$).

Parameter	Estimate	Lower CL	Upper CL	*P-value*
Vegetation Height[1]	6.9625	1.4792	12.4458	0.0128
Vegetation Density[2]	0.8683	0.3285	1.4081	0.0016
Shrub Cover[3]		Not significant		
Forb Cover[3]		Not significant		
Grass Cover[3]		Not significant		
Biocrust Cover[3]	-1.381	-2.1839	-0.578	0.0007
Litter Cover[3]	0.5089	0.1513	0.8666	0.0053
Bare Cover[3]	-0.5015	-0.958	-0.0449	0.0313
Litter Depth[1]	1.3884	0.7488	2.028	< 0.0001

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

Table 9. Differences between Baird's Sparrow nests and random sites in southwestern Saskatchewan, Canada, 2009 and 2010 ($n = 27$).

Parameter	Estimate	Lower CL	Upper CL	*P-value*
Vegetation Height[1]		Not significant		
Vegetation Density[2]	0.912	0.546	1.279	< 0.0001
Shrub Cover[3]		Not significant		
Forb Cover[3]		Not significant		
Grass Cover[3]		Not significant		
Biocrust Cover[3]	-0.796	-1.407	-0.186	0.011
Litter Cover[3]	0.634	0.240	1.029	0.002
Bare Cover[3]		Not significant		
Litter Depth[1]	1.225	0.638	1.812	< 0.0001

[1] Measured in centimeters.
[2] Modified from Robel et al. (1970).
[3] Cover classes from estimated percentages of ground cover (see Table 2).

4.4 Nesting Success

Individual Species

     I detected some effects of grazing on nesting success of individual species, though

not for every species, and not in both years (Table 10). Logistic exposure models

indicated a nonlinear effect of grazing intensity on nesting success of Sprague's Pipits in

2009, with greater success ($P = 0.55$) observed in both ungrazed pastures and those with

moderate stocking rates, and lower success ($P = 0.00$) observed in pastures with low

stocking rates (Fig. 2). There was a negative correlation between years grazed and

nesting success of Chestnut-collared Longspurs in 2009, and Vesper Sparrows in 2010,

with greater success ($P_{average} = 0.70$ and $P_{average} = 0.67$, respectively) observed in pastures

that had been grazed for 2-3 years rather than >15 years (Fig. 3 and 4). There were no

effects of either stocking rate or years grazed on the nesting success of either Baird's or

Savannah Sparrows in 2010, though sample sizes were too small to analyze nests in 2009.

Species Combined

     I detected some effects of grazing on nesting success of species assemblages

(Table 11). Collectively, there was a nonlinear correlation between nesting success of

Sprague's Pipits, Vesper Sparrows, and Chestnut-collared Longspurs and stocking rate in

2009, with greatest success observed in pastures with high stocking rates of 0.8 AUM/ha

($P = 0.89$), and lowest success observed in pastures with stocking rates of $0.3 - 0.4$

AUM/ha ($P = 0.35$) (Fig. 5). There was no effect of stocking rate on nesting success of

these collective species in 2010, nor was there an effect of years grazed in either 2009 or

2010. Collectively, there was no effect of either stocking rate or years grazed on

Savannah and Baird's Sparrow nesting success in either 2009 or 2010.

Table 10. Effects of grazing on nesting success of individual songbird species in southwestern Saskatchewan, Canada, 2009 and 2010. Dashed lines represent years where sample sizes were not sufficient to conduct analyses. Years grazed data from Koper et al. (2008).

Species	2009		2010	
	Stocking Rate	Years Grazed	Stocking Rate	Years Grazed
Sprague's Pipit	Nonlinear	None	None	None
Chestnut-collared Longspur	None	Negative	None	None
McCown's Longspur	-	-	-	-
Baird's Sparrow	-	-	None	None
Savannah Sparrow	-	-	None	None
Vesper Sparrow	None	None	None	Negative

Table 11. Effects of grazing on nesting success of collective songbird species in southwestern Saskatchewan, Canada, 2009 and 2010. Years grazed data from Koper et al. (2008).

Species Assemblage	2009		2010	
	Stocking Rate	Years Grazed	Stocking Rate	Years Grazed
Sprague's Pipit/Chestnut-collared Longspur/Vesper Sparrow	Nonlinear	None	None	None
Savannah Sparrow/Baird's Sparrow	None	None	None	None
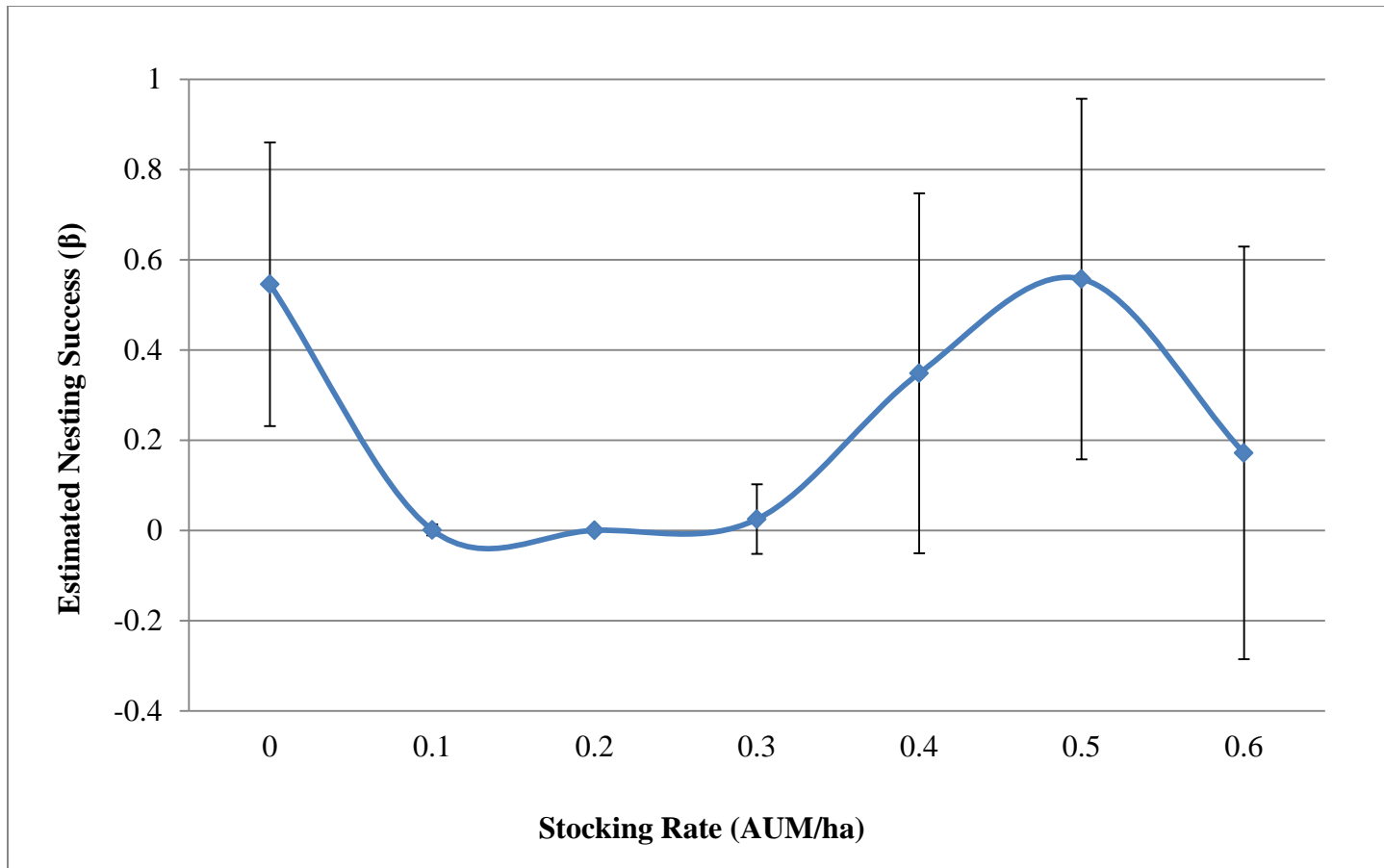
Figure 2. Effects of stocking rate on Sprague's Pipit nesting success in southwestern Saskatchewan, Canada (2009).
Model = (beta0 +bintensity*stockingrate + bintensity2*stockingrate*stockingrate + btimegrazed*yearsgrazed)*totalnestingtime.
$P_{bintensity} = 0.0027$, $P_{bintensity2} = 0.0080$, $P_{btimegrazed} = 0.3346$. $\beta \pm$ 90% CI, $n = 122$ (31 nests).
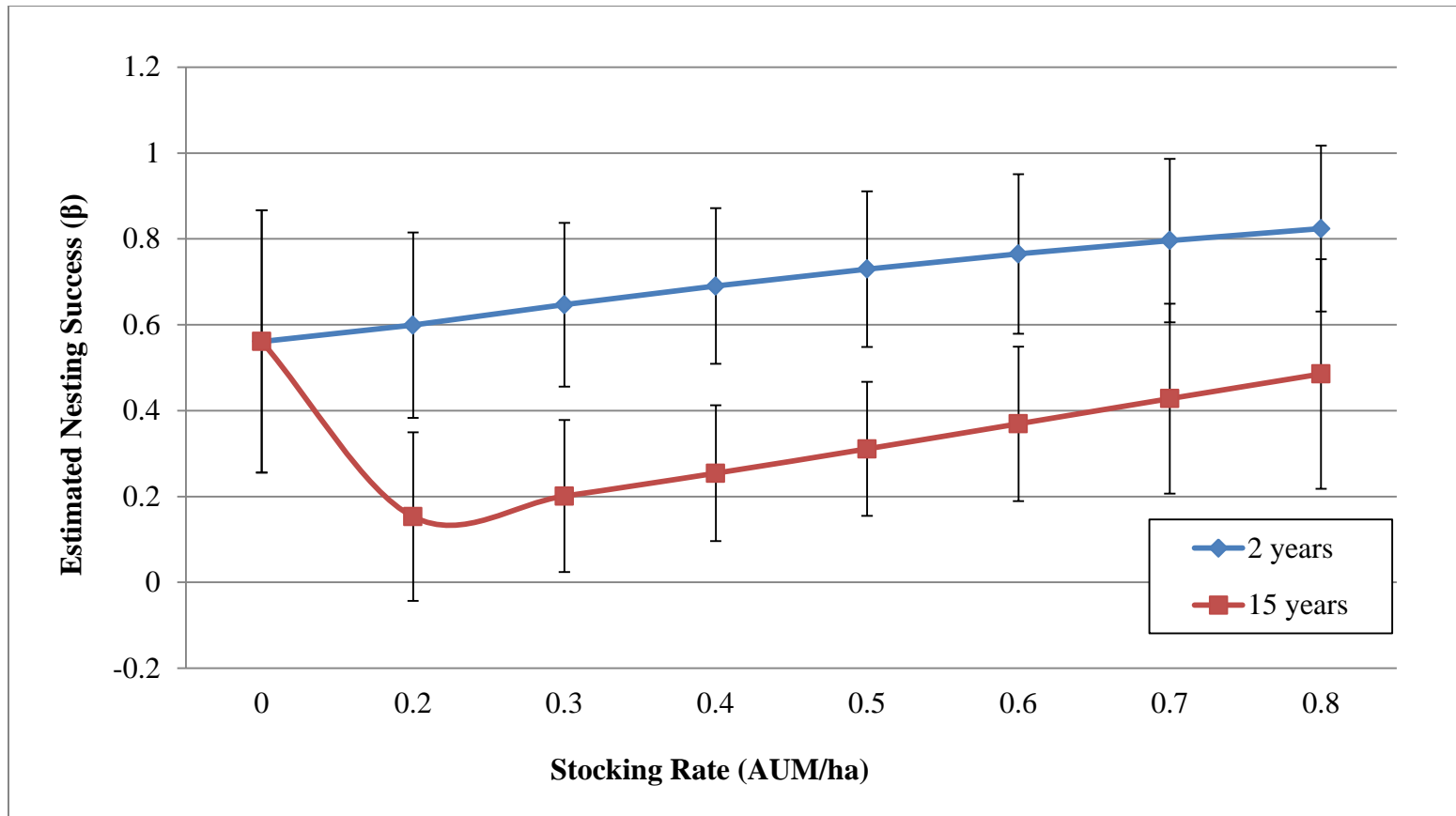
Figure 3. Effects of years grazed on Chestnut-collared Longspur nesting success in southwestern Saskatchewan, Canada (2009). Model = (beta0 + bintensity*stocking_rate + btimegrazed*yearsgrazed)*totalnestingtime. $P_{bintensity} = 0.2192$, $P_{btimegrazed} = 0.0152$. $\beta \pm$ 90% CI, $n = 179$ (49 nests). Years grazed data from Henderson et al. (2006) and Koper et al. (2008).
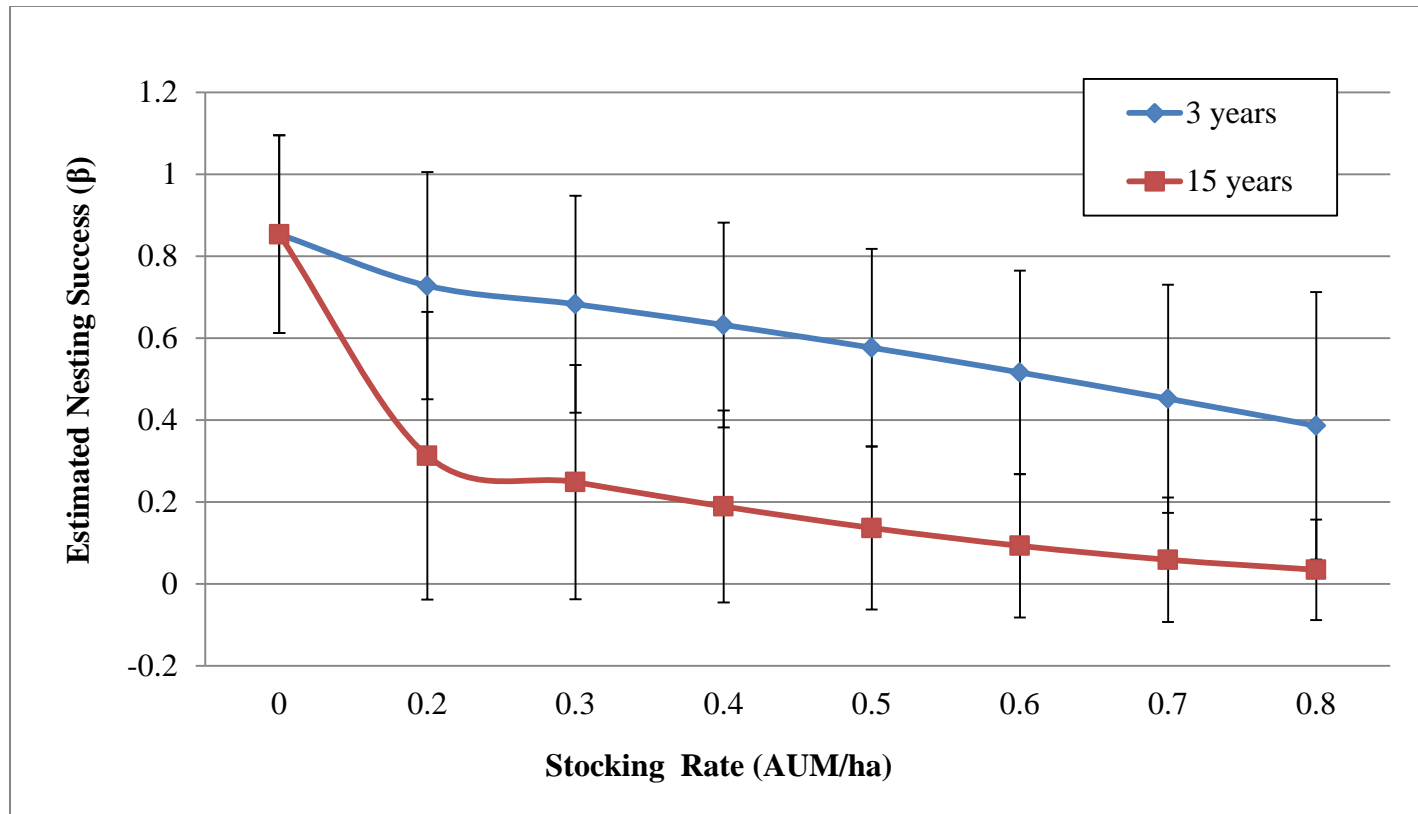
Figure 4. Effects of years grazed on Vesper Sparrow nesting success in southwestern Saskatchewan, Canada (2010).
Model = (beta0 + bintensity*stocking_rate + btimegrazed*yearsgrazed)*totalnestingtime. $P_{bintensity} = 0.1694$, $P_{btimegrazed} = 0.0430$.
$\beta \pm 90\%$ CI, $n = 100$ (23 nests). Years grazed data from Henderson et al. (2006) and Koper et al. (2008).
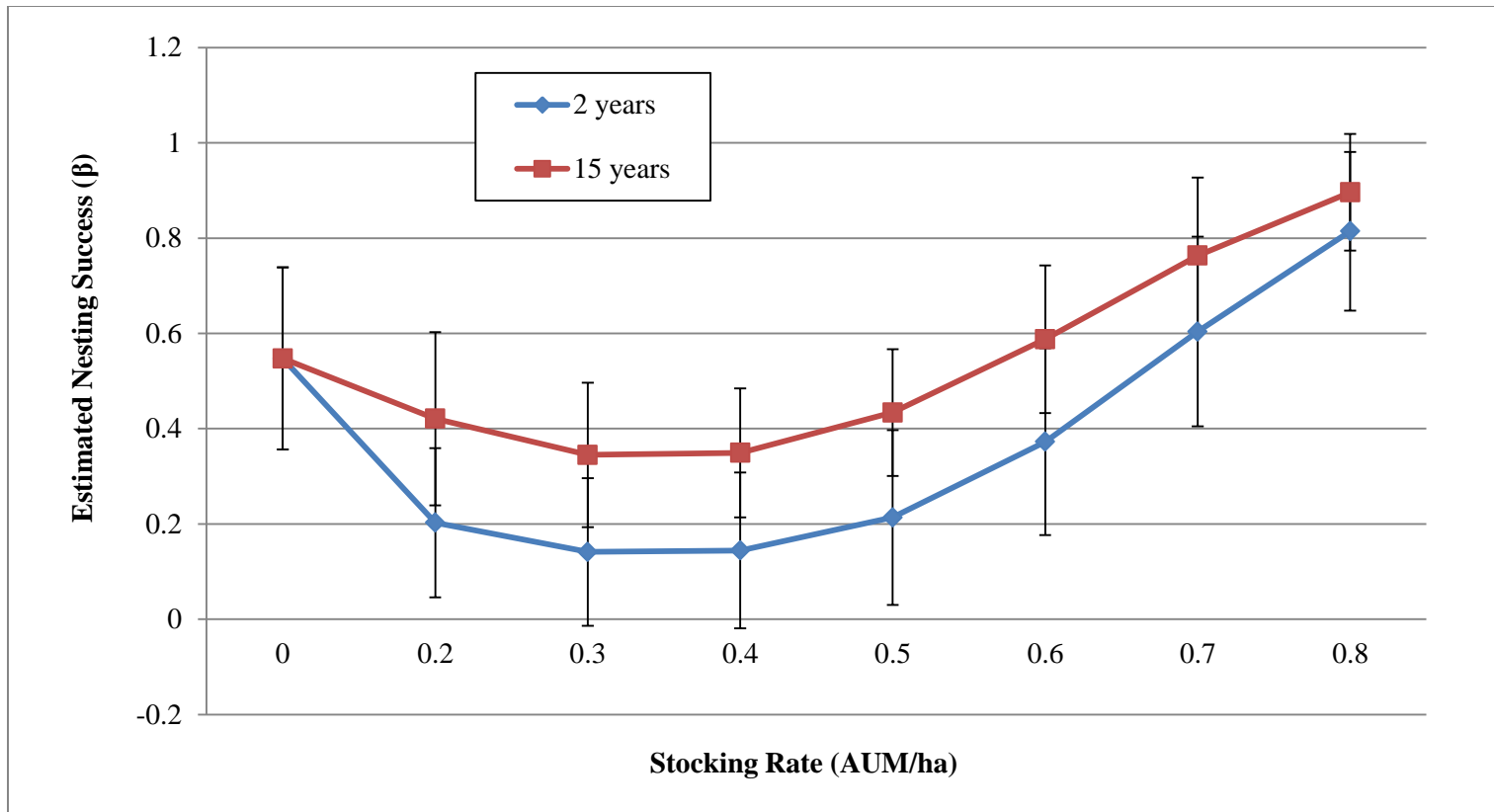
Figure 5. Effects of stocking rate on collective Sprague's Pipit, Chestnut-collared Longspur, and Vesper Sparrow nesting success in southwestern Saskatchewan, Canada (2009). Model = (beta0 +bintensity*stockingrate + bintensity2*stockingrate*stockingrate + btimegrazed*yearsgrazed)*totalnestingtime. $P_{bintensity}$ = 0.0056, $P_{bintensity2}$ = 0.0025, $P_{btimegrazed}$ = 0.1321. $\beta \pm$ 90% CI, n = 357 (89 nests). Years grazed data from Henderson et al. (2006) and Koper et al. (2008).

5.0 DISCUSSION

5.1 Pre-grazing data

Pre-existing patterns did not explain the 2009 influence of stocking rate and years grazed on Sprague's Pipit and Chestnut-collared Longspur nesting success, respectively. This is evidence that the significant effects I observed for these two species in 2009 were driven by stocking rate. The conflicting results seen in different years may be explained by the drastic difference in weather observed between 2009 and 2010 (see Section 5.4).

The pre-grazing nesting success of Vesper Sparrows exhibited a response to the post-grazing stocking rate data (though for 2007 only). However, as Vesper Sparrows responded to years grazed rather than stocking rate, this likely does not explain the effects seen in the post-grazing data.

5.2 Nest Site Selection

The choice of nest sites by grassland songbirds can have a strong influence on their reproductive success. Predation is the leading cause of nest failure for ground-nesting species, and the placement of each nest can influence whether or not it is depredated (e.g., Martin 1993, With 1994, but see Vickery et al. 1992). Exposure may also play a role in nest site selection, particularly when birds are prone to heat stress in open prairie habitats that provide little to no cover (George et al. 1992, With and Webb 1993). Therefore, it was no surprise that each of my study species chose nest sites that differed significantly from the immediately surrounding landscape. This is consistent

with past studies that demonstrated that grassland birds are selective in their habitat use (e.g., Cody 1985, Martin 1993, Sutter 1997, Lusk et al. 2003, Fisher and Davis 2011).

All of my study species chose nest sites with significantly greater vegetation height and density, greater litter depth, and sites with significantly less biocrust or bare cover, compared with unused microhabitats. These types of nest sites may provide general protection from both predators and heat stress (Sutter 1997), consistent with the results of previous studies (e.g., Dieni and Jones 2003, Lusk et al. 2003, Davis 2005, Fisher and Davis 2011).

Of all my focal species, Chestnut-collared Longspurs chose sites with the shortest vegetation height and density, grass and litter cover, and litter depth. Davis (2005) also found that along a vegetation gradient of nest sites, this species was at the lowest end of all the songbirds studied. In GNPC, they are more abundant in pastures with higher stocking rates than those with low stocking rates (Sliwinski 2011), suggesting that they prefer to both inhabit and nest in heavily grazed areas. Despite this, Chestnut-collared Longspurs typically place their nest alongside either a clump of taller vegetation (e.g., DuBois 1935) or a cow patty (e.g., Davis 2005), most likely to aid in nest concealment. Because of this, the maintenance of a heterogeneous habitat within grazed pastures is essential. Even though they prefer heavily grazed habitat, Chestnut-collared Longspurs still benefit from patches of vegetation that are less disturbed.

Savannah and Baird's Sparrows chose sites with the greatest vegetation height and density, grass and litter cover, and litter depth, which is consistent with Davis (2005). In GNPC, the abundance of Savannah Sparrows was greatest in pastures with low stocking rates, while the abundance of Baird's Sparrows was greatest in ungrazed

pastures (Sliwinski 2011). Sprague's Pipits alone chose nest sites with significantly greater live grass cover than random sites. This may be due to the unique domed nest built by this species, the dome of which is typically made from live grasses (Sutter 1997, Robbins and Dale 1999). In GNPC, Sprague's Pipits were most abundant in ungrazed pastures (Sliwinski 2011). Each songbird species in GNPC utilizes a slightly different habitat in which to nest in, emphasizing the need to maintain a heterogeneous landscape with a range of vegetation structures and communities.

Effects of stocking rate on nest site selection

Each species consistently chose nest microhabitats that differed from the surrounding available habitat. However, stocking rate had no effect on the differences between nest and random sites for Vesper and Baird's Sparrows. This suggests that nest site selection for these species was generally relative to the available habitat structure, rather than reflecting absolute vegetation preferences. Harrison et al. (2011) found that grazing actually reduced the available nesting habitat for Vesper Sparrows, though their study took place in British Columbia and utilized much higher stocking rates (1.2 – 3.3 AUM/ha) than those in GNPC.

For Sprague's Pipits, Chestnut-collared Longspurs, and Savannah Sparrows, however, stocking rate did affect nest site selection. This may mean that these species are sensitive to absolute microhabitat conditions, and select nest sites somewhat independently of the vegetation available in the surrounding landscape. Madden et al. (2000) found that the occurrence of Sprague's Pipits and Baird's Sparrows correlated with previously unknown limits in vegetation height and density on the landscape. Fisher

and Davis (2011), when conducting a study on the habitat use of Sprague's Pipits in native pastures and non-native hay fields, found that the birds used the same nest characteristics regardless of habitat type. This further suggests that some prairie songbirds respond to absolute, rather than relative, measures of vegetation for both their habitat and nest site requirements.

Regardless of how reproductively successful a bird may be in a given habitat, some habitats may have a greater availability of suitable nest sites than others due to differences in vegetation structure. Based upon the nest site requirements observed in my study, pastures with higher stocking rates may therefore have a greater availability of suitable nest sites for both Sprague's Pipits and Chestnut-collared Longspurs, while pastures with lower stocking rates may have a greater availability of nest sites for Savannah Sparrows.

5.3 Grazing

Grazing is an ecologically important disturbance in grassland ecosystems (e.g., Milchunas et al. 1988, Fuhlendorf et al. 2006, Koper et al. 2008). Grazing by cattle can increase the heterogeneity of the prairie landscape (e.g., Fuhlendorf et al. 2006), thereby creating a mosaic of different habitat types. Nesting success of grassland birds can differ among habitat types (e.g., Pasitschiak-Arts and Messier 1995), emphasizing the need to determine how nesting success is affected by different grazing regimes. Cattle grazing has been observed to have mainly negative (e.g., Walsberg 2005, Rahmig et al. 2008, Kerns et al. 2010, Harrison et al. 2011) and neutral (e.g. Koper and Schmiegelow 2007,

Lusk 2009) effects on reproductive success of prairie birds. However, none of those studies utilized a gradient of stocking rates such as those found in GNPC.

Effects of stocking rate on nesting success

Birds may be more sensitive to grazing treatments than other grassland fauna (Milchunas et al. 1998) However, I found only weak evidence that stocking rate affected nesting success of grassland songbirds. Only Sprague's Pipits responded significantly to stocking rate, and only in 2009.

Nests of ducks and grouse, when placed in dense vegetation, exhibit higher nest success when the primary nest predators are birds (Stokes and Boersma 1998), but lower success when the primary predators are small mammals (Schieck and Hannon 1993). Therefore, the impact of nest cover on the success of ground-nesting bird species is variable depending upon the type of predators present, though this effect may differ somewhat for songbirds. Small mammals use vegetative cover as shelter against aerial predators, which rely upon visual acuity to detect prey (With 1994, Dion et al. 2000). Prairie songbird nests placed in dense vegetation may lead to higher nest predation rates by small rodents such as ground squirrels. Conversely, nests placed in areas with sparse vegetation are more likely to be depredated by other birds (Dion et al. 2000). Large mammals and birds of prey occur mostly at low densities in GNPC (Henderson et al. 2006), and are likely not important nest predators. Richardson's ground squirrels, which occur at much higher densities in GNPC and may be an important nest predator, have not yet been strongly linked to livestock grazing (Henderson et al. 2006).

I speculated that the vegetation structures present in pastures with low stocking rates may result in a more diverse predator community than in pastures with either no grazing, or high stocking rates. High predator diversity can lower the overall nest success of songbirds (Dion et al. 2000), as it may facilitate the finding of nests by both aerial and ground predators. As aerial predators rely on visual acuity to hunt (e.g., Dion et al. 2000), it is possible that aerial predators may be more successful nest predators in pastures with high stocking rates because they can see nests more easily. Small mammals may be more abundant in sites with lower grazing intensities, as they seek out dense cover as protection from predators (e.g., Dion et al. 2000). The pattern observed in 2009 by Sprague's Pipits, and by the Sprague's Pipit – Chestnut-collared Longspur – Vesper Sparrow assemblage may have been due to an overlap in the types of predators able to find and depredate nests. The types of vegetation predominately found at low grazing intensities may facilitate the finding of nests by both visually- and olfactory-dependent predators, depressing nesting success more than in pastures with other grazing intensities. Although many of the bird of prey species in GNPC are low in abundance, the Northern Harrier (*Circus cyaneus*), a known predator of songbirds (Smith et al. 2011), is fairly abundant (personal observation). However, because stocking rate was significantly correlated with nesting success effect in only one year, the patterns observed may have been spurious.

Cattle do not graze uniformly, resulting in a landscape mosaic of varying vegetation structure and communities (Plumb and Dodd 1993). Kerns et al. (2000) hypothesized that nonrandom grazing by cattle may have contributed to the varying response of songbird nesting success to the presence of cattle. Though grassland bird

species tend to prefer to nest in or near a particular plant species or type of vegetation structure (Martin 1993), the heterogeneous landscape resulting from cattle grazing may provide sufficient variation in microhabitat availability such that many songbird species can nest successfully there. Within each pasture, regardless of stocking rate, is a gradient of vegetation structures that may be utilized as nesting habitat by a variety of songbird species. In part, this may explain why stocking rate does not have a strong effect on the nesting success of these species.

Effect of years grazed on nesting success

The number of years grazed had an effect on the nesting success of Chestnut-collared Longspurs and Vesper Sparrows. For both species, nesting success decreased with greater number of years grazed. The negative correlation may have been caused by a time lag in the effects of grazing on vegetation structure. It may take longer than 2 or 3 years (which is how long our short-term pastures were grazed for) for cattle grazing to significantly alter the landscape. A study done in the Kansas tallgrass prairie found a significant increase in many grass, woody, and herbaceous species after light grazing had occurred for ten years, as well as an increase in overall plant diversity (Towne et al. 2005).

Vesper Sparrows were the only of my study species to frequently nest alongside shrubs (see Jones and Cornely 2002). Although cover of woody plants tended to increase with time grazed in the study by Towne et al. (2005), shrub cover in southern Saskatchewan tended to decrease in pastures that had been grazed long-term (e.g., Bleho 2009). This could be in part because the community pastures (adjacent to GNPC) used in

Bleho's study (2009) were grazed at a moderate intensity, while those in Towne et al.'s study (2005) were grazed at a low intensity. If shrub cover is an important nest site characteristic and leads to higher nest success in this species, then it is reasonable to assume that nesting success may be lower in areas where the grazing regime has resulted in a decrease in shrubs.

Some studies have shown that Chestnut-collared Longspurs are more abundant in areas that have been grazed long-term (e.g., Bleho 2009). If long-term grazing negatively affects the nesting success of this species, it is possible that these sites may act as "ecological traps," where an animal preferentially utilizes a habitat where it does poorly relative to other available habitats (Robertson and Hutto 2006). However, as this effect was seen in only one year for both species, it might also have been spurious. In addition, I observed no effect of years grazed on either of the two species assemblages I analyzed. Collectively, years grazed had no significant influence on the nesting success of mixed-grass prairie songbirds.

Grasslands National Park of Canada

Previous grazing studies done in GNPC by other University of Manitoba graduate students may help in interpreting some of my results. Bleho (2009) found that avian diversity was similar in both ungrazed and long-term grazed pastures, suggesting that some habitat heterogeneity existed in areas without cattle. Similarly, Lusk (2009) found no correlation between long-term grazing and nesting success of Sprague's Pipits, Chestnut-collared Longspurs, or Vesper Sparrows. This may explain why I did not find consistent effects of stocking rate on nesting success among both years of my study.

As might be expected, post-grazing treatments in 2009 and 2010 caused a decrease in overall vegetation height, vegetation density, and litter depth (Sliwinski 2011). Habitat structure changed dramatically at a stocking rate of 0.4 AUM/ha, suggesting grazing at this intensity to be an important ecological threshold in GNPC (Sliwinski 2011). In 2009, nesting success of both Sprague's Pipits individually, and the Sprague's Pipit – Chestnut-collared Longspur – Vesper Sparrow assemblage began to increase at this stocking rate. This supports my evaluation that correlations between nesting success and stocking rate are due to changes in vegetation that occur due to grazing.

Although I did not find consistent effects of grazing on nesting success in the two years of my study, two years may still be long enough to observe effects of grazing on songbirds. During the same years as my study, Sliwinksi (2011) found both positive and negative correlations between stocking rate and songbird abundance. Grazing was introduced in 2008, only one year before my study began. It may be beneficial for rangeland managers to observe responses of wildlife and the landscape to grazing immediately following cattle introduction. When populations are declining rapidly and time is valuable, quick responses of wildlife to management may be more beneficial than responses that take a longer time to emerge.

5.4 Weather

Although none of the relationships between nesting success and stocking rate were consistent throughout both years of the study, the weather conditions may have affected this outcome. In 2010, rainfall in southern Saskatchewan was three times greater

than in 2009 (see Appendix V) (Environment Canada 2011), causing 10 nests to fail directly due to weather in 2010. The heavier rainfall could potentially have offset any effects of grazing that I may have seen in a drier year.

My data highlight a common problem in that no amount of management can completely offset natural environmental conditions. However, my results may show the need for rangeland management to be elastic, rather than static. Grasslands may require different management depending on predictions of rainfall for a given year to maintain avian productivity.

6.0 MANAGEMENT IMPLICATIONS

6.1 Stocking Rate

Prairie songbirds evolved alongside free-ranging herds of large grazers (Knapp et al. 1999). However, as there are no longer extensive herds of free-ranging herbivores, management must be refined to preserve wildlife within the fenced rangelands in place today. If managing for a single species alone in this habitat, such as the threatened Sprague's Pipit, I suggest maintaining tracts of either ungrazed prairie or pastures with moderate stocking rates of approximately 0.5 AUM/ha. At these intensities, nesting success may be highest. Pastures in this region should not be grazed at a stocking rate much higher than 0.5 AUM/ha, as nesting success of Sprague's Pipits may decrease. This recommendation supports the findings of Davis et al. (1999), who found that Sprague's Pipits occurred less frequently in heavily grazed pastures.

Songbirds in prairies are declining more steeply and drastically than any other group of birds in North America (Knopf 1992, Fritcher et al. 2004), making their immediate conservation imperative. It may be more prudent, therefore, to manage rangeland for the entire grassland bird community. To do this, we should maintain both ungrazed prairie, as well as pastures (of an appropriate size) with a gradient of stocking rates such as those found in Grasslands National Park of Canada. When combined, the Sprague's Pipit – Chestnut-collared Longspur – Vesper Sparrow assemblage may experience highest nesting success in both ungrazed pastures and pastures with high stocking rates (0.6 – 0.8 AUM/ha). Therefore, if limited rangeland is available, it may be more beneficial to maintain either idle pastures, or those with moderate to high stocking

rates in order to preserve a suite of grassland species. Again, though, this course of action would not be recommended if management is aimed toward the conservation of Sprague's Pipit alone.

Effects of stocking rate on bird populations is not well known or understood (Davis et al. 1999, Sliwinski 2011). Even the few significant effects of grazing on songbird nesting success that I observed were not consistent. In order to combat the uncertainty associated with grazing and songbird nesting success, large tracts of rangeland of varying grazing intensities and durations should be maintained. This tactic also ensures there is sufficient habitat for a diversity of species (Madden et al. 2000), each of which has slightly different spatial and environmental preferences (e.g., Bent 1950, 1968; Davis et al. 1999, Davis 2004). Pastures with different grazing regimes should preferentially be located adjacent to one another rather than separated by large expanses of non-prairie landscape. This may help ensure that areas of suitable habitat are sufficiently large enough to encompass the territories required by many prairie songbirds (e.g., Bent 1968, Herkert 1994). It may also offset other negative impacts, such as the increased predation of nests observed in fragmented areas (Burger et al. 1994).

In addition to wildlife managers, ranchers may also benefit from the use of multiple stocking rates throughout their pastures. At least one study has shown that heavily grazing the same land each year makes little economic sense, giving ranchers an incentive to allow light to moderate grazing on parts of their land (Torell et al. 1991).

Some ranchers may not be aware of the full diversity of songbirds using their pastures for breeding and nesting (personal observation). Apart from economic

incentives, they may be willing to aid in the conservation of these animals simply because they can have a large impact through the management of their land.

6.2 Density versus Nesting Success

The abundance or density of a bird in a given area or habitat may be unrelated to how well it can successfully reproduce there. Within a suite of different grazing regimes, a species may utilize certain pastures over others, even though reproductive success may not be highest in those areas. Theoretically, this could constitute an "ecological trap," though actual cases of ecological traps are rare and difficult to detect.

Managers of wildlife must often choose whether to manage for a single, or a suite, of species. If managing for a single species alone in this habitat, such as the threatened Sprague's Pipit, it is important to recognize discrepancies between nesting density and nesting success. In 2009, nests of Sprague's Pipits were most dense in stocking rates of 0.25 – 0.39 AUM/ha and 0.57 AUM/ha (Figure 6). In 2010, nests were most dense in stocking rates from 0.34 – 0.36 AUM/ha and 0.54 – 0.66 AUM/ha. However, nesting success in 2009, which was significantly correlated with stocking rate, was highest in both ungrazed pastures and those with approximately 0.5 AUM/ha. If the results observed in 2009 were biologically significant rather than spurious, Sprague's Pipits should perhaps utilize pastures with no grazing and moderate intensities, rather than those with low intensities. I suggest that wildlife managers consider excluding low stocking rates from pastures aimed at conserving this species, to prevent it from preferentially nesting in a habitat that yields less than optimal reproductive success. Additionally, both my results and those of Sliwinksi (2011) suggest that a stocking rate of 0.4 AUM/ha may be an

83

important ecological threshold, above which drastic changes in vegetation structure, and consequently nesting success, occur.

My study, along with others (e.g., Davis 2005), revealed that prairie songbirds preferentially utilize nest sites with taller and denser vegetation, as well as sites with reduced biocrust or bare cover. Why, then, should rangeland managers not seek to preserve only those areas with the tallest and most dense vegetation? Davis (2005) and myself both observed that nest sites were partitioned along a vegetation gradient depending upon the species. This could be due in part to a trade-off in those species nesting in areas of more sparse vegetation (e.g., Chestnut-collared Longspur) between nest concealment and the need for attentiveness and escape against predators (Gotmark et al. 1995. A partitioning of nest sites may also result from the selection of songbirds for nest sites that differ from co-existing species to reduce the risk of predation (Martin 1996, Davis 2005). Hence, it is important to maintain grassland with varying vegetation structures and compositions in order to provide nesting habitat for the largest number of species.
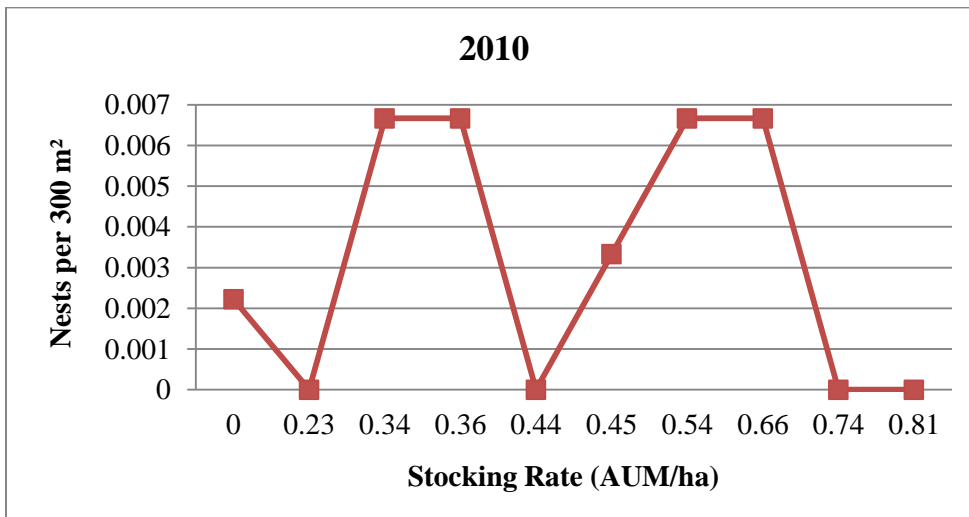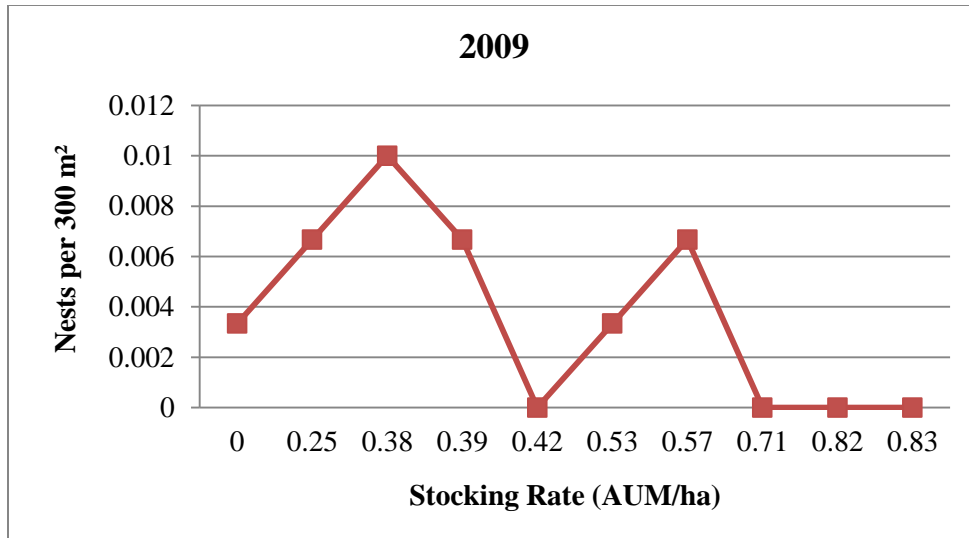
2009

2010

Figure 6. Density of Sprague's Pipit nests in 300-m² nest plots in southwestern Saskatchewan, Canada, 2009 ($n = 13$) and 2010 ($n = 11$). Density does not account for either double-brooding or re-nesting attempts.

6.3 Conclusion

As grazing did not consistently affect the nesting success of any of the most common passerine species in this ecosystem, my results suggest that cattle grazing at moderate stocking rates for a long period of time, or at a range of stocking rates over a short period of time, may be compatible with maintaining productivity of mixed-grass prairie songbirds, including species at risk. However, some stocking rates may produce a more limited availability of nest sites for species that are more discriminatory in their nest site selection.

Knapp et al. (1999) argue that the presence of disturbances, such as grazing and fire, are key to maintaining the integrity of North American grasslands. Utilizing native prairies as rangelands may be among the most sustainable of agricultural practices, as it allows the commercial use of the landscape while still preserving the original floral and faunal species of the prairie ecosystem. In particular, grazing may help conserve sentinel plant species, which are those that are first to disappear when ecological processes are no longer in balance within an ecosystem (USFWS 2010).

Maintaining a gradient of grazing regimes may be the best solution (Madden et al. 2000). The range of microhabitats that result from different intensities of grazing ensures an availability of suitable nest sites for multiple songbird species. It also aids as a buffer against the sometimes drastic yearly variability in environmental factors that can occur in the prairie.

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APPENDIX I.

Days required for prairie songbirds to complete nesting (from Ehrlich et al. 1988). Incubation time does not include laying period.

Species	Incubation		Fledging		Total Time		
	Min.	Max.	Min.	Max.	Min.	Max.	Avg.
Sprague's Pipit	13	14	10	11	23	25	24
Chestnut-collared Longspur	10	13	9	14	19	27	23
McCown's Longspur	12	12	10	12	22	24	23
Vesper Sparrow	11	13	7	14	18	27	22.5
Savannah Sparrow	10	13	7	10	17	23	20
Baird's Sparrow	11	12	8	10	19	22	20.5

Effects of cattle grazing regimes on pre-grazing data to test for pre-existing patterns in nesting success of grassland songbirds in southwestern Saskatchewan, Canada, in 2006 and 2007 (data from Lusk 2009). Dashed lines represent sample sizes too low to analyze.

Species	Year	Parameter	Nests (n)	Estimate	Upper CI	*P-value*
	2006	Stocking rate	18	0.920	3.614	0.572
	2007	Stocking rate	16	2.513	7.903	0.440
Sprague's Pipit	2006	Years grazed	18	0.020	0.125	0.746
	2007	Years grazed	16	0.020	0.232	0.879
	2006	Stocking rate	50	0.775	2.774	0.523
Chestnut-collared	2007	Stocking rate	42	0.310	1.966	0.757
Longspur	2006	Years grazed	50	0.008	0.073	0.829
	2007	Years grazed	42	0.000	0.056	0.992
	2006	Stocking rate	15	0.424	2.510	0.735
	2007	Stocking rate	27	-2.057	-0.049	0.092
Vesper Sparrow	2006	Years grazed	15	0.038	0.134	0.510
	2007	Years grazed	27	0.069	0.144	0.129
	2006	Stocking rate	14	-1.602	1.995	0.458
	2007	Stocking rate	-	-	-	-
Savannah Sparrow	2006	Years grazed	14	-0.008	0.098	0.905
	2007	Years grazed	-	-	-	-
	2006	Stocking rate	22	-1.320	0.312	0.838
	2007	Stocking rate	-	-	-	-
Baird's Sparrow	2006	Years grazed	22	0.098	0.132	0.205
	2007	Years grazed	-	-	-	-

Nests of monitored songbird species found in southwestern Saskatchewan, Canada, May – July, 2009 and 2010. Years grazed data from Henderson et al. (2006) and Koper et al. (2008).

AUM/ha	Location	# Pastures	Years Grazed	Sprague's Pipit		Chestnut-collared Longspur		McCown's Longspur		Vesper Sparrow		Savannah Sparrow		Baird's Sparrow	
				2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
0	GNPC	3	0	7	12	8	11	0	0	4	5	2	5	1	7
0.23	GNPC	1	3	n/a	0	n/a	0	n/a	0	n/a	0	n/a	3	n/a	2
0.25	GNPC	1	2	4	n/a	0	n/a	0	n/a	2	n/a	1	n/a	1	n/a
0.34	Mankota	1	>15	n/a	5	n/a	19	n/a	0	n/a	1	n/a	2	n/a	1
0.36	GNPC	1	3	n/a	3	n/a	1	n/a	0	n/a	1	n/a	2	n/a	2
0.38	Mankota	1	>15	6	n/a	9	n/a	1	n/a	1	n/a	2	n/a	1	n/a
0.39	GNPC	1	2	5	n/a	0	n/a	0	n/a	0	n/a	2	n/a	0	n/a
0.42	Mankota	1	>15	2	n/a	1	n/a	0	n/a	1	n/a	0	n/a	0	n/a
0.44	Mankota	1	>15	n/a	0	n/a	11	n/a	2	n/a	2	n/a	2	n/a	2
0.45	Mankota	1	>15	n/a	5	n/a	6	n/a	0	n/a	4	n/a	3	n/a	1
0.53	Mankota	1	>15	3	n/a	18	n/a	1	n/a	1	n/a	0	n/a	2	n/a
0.54	GNPC	1	3	n/a	4	n/a	2	n/a	0	n/a	2	n/a	2	n/a	6
0.57	GNPC	1	2	2	n/a	2	n/a	0	n/a	0	n/a	0	n/a	0	n/a
0.66	GNPC	1	3	n/a	2	n/a	7	n/a	0	n/a	1	n/a	1	n/a	3
0.71	GNPC	1	2	0	n/a	6	n/a	0	n/a	1	n/a	1	n/a	0	n/a
0.74	GNPC	1	3	n/a	0	n/a	5	n/a	0	n/a	3	n/a	0	n/a	0
0.81	GNPC	1	3	n/a	1	n/a	4	n/a	0	n/a	4	n/a	1	n/a	0
0.82	GNPC	1	2	0	n/a	3	n/a	0	n/a	2	n/a	1	n/a	1	n/a
0.83	GNPC	1	2	0	n/a	2	n/a	0	n/a	2	n/a	0	n/a	1	n/a

APPENDIX IV

Nests of unmonitored species found in southwestern Saskatchewan, Canada, May – July, 2009 and 2010.

Species	2009	2010
Gadwall (*Anas strepera*)	1	1
Northern Shoveler (*Anas clypeata*)	0	2
Sharp-tailed Grouse (*Tympanuchus phasianellus*)	1	2
Swainson's Hawk (*Buteo swainsoni*)	1	1
Willet (*Tringa semipalmata*)	2	0
Upland Sandpiper (*Bartramia longicauda*)	2	4
Marbled Godwit (*Limosa fedoa*)	1	1
Common Nighthawk (*Chordeiles minor*)	1	1
Eastern Kingbird (*Tyrannus tyrannus*)	1	1
Horned Lark (*Eremophila alpestris*)	7	10
Clay-colored/Brewer's Sparrow (*Spizella pallida/breweri*)	11	19
Grasshopper Sparrow (*Ammodramus savannarum*)	1	1
Western Meadowlark (*Sturnella neglecta*)	7	13
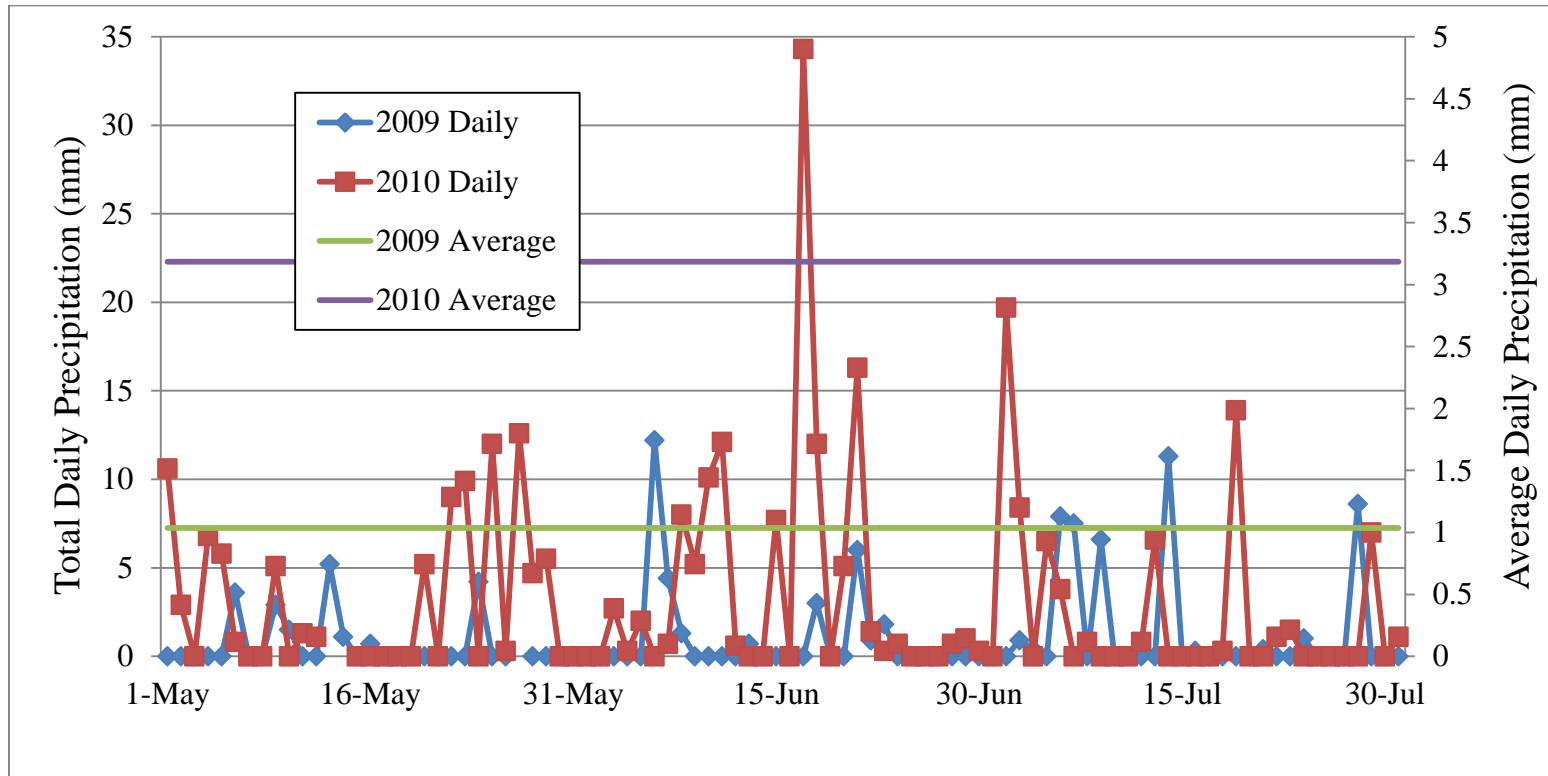
Daily and overall average precipitation in Swift Current, Saskatchewan, Canada, May – July, 2009 and 2010. Swift Current is the nearest large city with complete precipitation data, located approximately 65 km northwest of Mankota, Saskatchewan, Canada.