

**The effects of grazing on songbird nesting success in
Grasslands National Park of Canada**

By

Jennifer Lusk

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

Master of Natural Resource

Management

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FACULTY OF GRADUATE STUDIES

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ABSTRACT

I examined the effects of nest site vegetation structure and cattle grazing on songbird nesting success in native mixed-grass prairie in Grasslands National Park of Canada and Mankota Community Pastures in southwestern Saskatchewan. This is the first study to compare songbird nesting success in season-long grazed and ungrazed native mixed-grass prairie. Sprague's pipit, Baird's sparrow, vesper sparrow, lark bunting, and chestnut-collared longspur all selected for denser vegetation at the nest than was generally available. Sprague's pipit daily nest survival declined with increased vegetation density and litter depth at the nest site. Vegetative cover did not influence daily nest survival of the other species. Environmental conditions during the study may have resulted in an increased risk of predation for Sprague's pipits nesting in greater cover. Grazing did not influence daily nest survival of any of the 5 species. Low-moderate intensity cattle grazing appears compatible with management for prairie songbirds in native mixed-grass prairie.

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1. INTRODUCTION

Context

Populations of grassland birds are declining faster than any other group of North American birds (Knopf 1996). From 1966-2007, the Breeding Bird Survey (BBS) recorded significant survey-wide average annual declines ($P < 0.01$) of 3.9% for Sprague's pipit (*Anthus spragueii*), which is listed as "threatened" under the Canadian Species at Risk Act (Government of Canada 2008, Sauer and Hines 2008). During this period, the BBS also recorded average annual declines of 3.4% for Baird's sparrow (*Ammodramus bairdii*), 0.9% for vesper sparrow (*Pooecetes gramineus*), 2.8% for chestnut-collared longspur (*Calcarius ornatus*), and 1.7% for lark bunting (*Calamospiza melanocorys*) (Sauer and Hines 2008). Factors contributing to these declines likely include habitat loss due to native prairie being converted for agriculture and degradation and fragmentation of the remaining native prairie (Knopf and Samson 1995, Brennan 2005). Many obligate prairie songbirds show a preference for breeding in native prairie over cropland, hayfields, or tame pasture (Owens and Myres 1973, Davis and Duncan 1999). In Saskatchewan, 21% of the native prairie remains, including 31% of the original native prairie in the mixed-grass ecoregion (Hammermeister et al. 2001). A significant portion of Saskatchewan's native prairie is managed for cattle (*Bos Taurus*) grazing (Nernberg and Ingstrup 2005). However, little research has examined how cattle grazing influences songbird nesting success in native prairie habitat.

The majority of songbird nests fail, primarily due to predation (Ricklefs 1969). Thus, evolutionary processes should have led to birds developing strategies to avoid detection of nests by predators (Martin 1993). Potential strategies include secretive

behaviour, crypsis, and the selection of well-hidden nest sites (Weidinger 2002, Winter et al. 2005a). Vegetation at the nest site may influence the availability of visual, auditory, and olfactory cues that predators use to locate nests (Martin 1993). Visual camouflage may be important in reducing nest predation by diurnal predators, which use visual cues for foraging (Murray and Vestal 1979, With 1994). The visibility of nests from above may influence the risk of predation by avian predators (DeLong et al. 1995, Dion et al. 2000). Dense vegetation around a nest may limit the spread of the nest's scent, reducing predation by nocturnal predators relying on olfactory cues to locate prey (Martin 1993, Rangen et al. 2000). Nest sites with taller, denser cover may be better hidden, resulting in lower rates of predation than for nest sites with shorter, sparser vegetation (DeLong et al. 1995).

Previous studies on nest site vegetation structure in native prairie habitat have found that songbirds select for greater cover at nest sites than generally available (e.g. Sutter 1997, Dieni and Jones 2003, Davis 2005). However, studies on the effects of nest site vegetation structure on nesting success have found variable effects of cover. A study in Saskatchewan found that vegetation explained additional variation in Sprague's pipit, Savannah sparrow (*Passerculus sandwichensis*), Baird's sparrow, chestnut-collared longspur, and Western meadowlark (*Sturnella neglecta*) nesting success not explained by time and age effects (Davis 2005). Effects were generally weak as confidence intervals included zero, except in the case of a positive effect of increased distance to nearest shrub and a negative effect of increased cow dung cover on Sprague's pipit nesting success (Davis 2005). A study in Alberta found no significant effects of nest site vegetation on chestnut-collared longspur or Savannah sparrow nesting success but found a negative

effect of increased litter depth on Western meadowlark nesting success (Koper and Schmiegelow 2007). In ungrazed prairie in Montana, Jones and Dieni (2007) found a weak positive relationship between concealment and daily nest survival for species that built dome-nests (Sprague's pipit and Western meadowlark) and a weak negative relationship for open cup-nesting species including Baird's sparrow and chestnut-collared longspur. A study in North Dakota found that vesper sparrow nesting success was higher with increased tall shrub cover and concealment (Grant et al. 2006).

Studies in other prairie ecosystems have found mixed effects of nest site vegetation structure on songbird nesting success. A study in short-grass prairie in Colorado found that McCown's longspur (*Calcarius mccownii*) nesting success was lower when nests were located adjacent to shrubs (With 1994). It was suggested that association with shrubs might increase the risk of incidental predation by thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) which concentrate their activity near shrubs (With 1994). A study in tall-grass prairie in Minnesota and North Dakota found a positive effect of increased vegetative cover on clay-coloured sparrow (*Spizella pallida*) nesting success but no effects on Savannah sparrow or bobolink (*Dolichonyx oryzivorus*) (Winter et al. 2005b). In tall-grass prairie in Missouri, successful dickcissel (*Spiza Americana*) nests had greater visual obstruction, vegetation height, and grass cover than unsuccessful nests but there was no difference in vegetation at successful and unsuccessful Henslow's (*Ammodramus henslowii*) sparrow nests (Winter 1999). A study in southern mixed-grass prairie in Oklahoma found that the sites of successful lark bunting nests had greater litter cover and less bare ground than those of unsuccessful nests (Lusk et al. 2003). Variation in the effects of cover on nesting success among

studies may reflect differences in habitat, land management practices, and predator communities (Crabtree et al. 1989).

Cattle Grazing

A significant portion of Saskatchewan's native prairie is managed for cattle grazing (Nernberg and Ingstrup 2005). Cattle can cause nest failure through trampling (Renfrew and Ribic 2003) and have been observed depredating nests (Nack and Ribic 2005). Cattle grazing may indirectly influence songbird nesting success by changing vegetation structure (Sutter and Ritchison 2005). Vegetation structure influences small mammal community composition and abundance (Grant et al. 1982, Hayward et al. 1997), which may influence the risk of nest predation. Predator search efficiency may be greater in shorter, sparser vegetation, resulting in a higher risk of nest predation (Sutter and Ritchison 2005). Reductions in vegetative cover may also reduce the availability of high quality nest sites, forcing birds to select sites where nests are more vulnerable to predation (Ammon and Stacey 1997).

One study has compared songbird nesting success in grazed and ungrazed native mixed-grass prairie. This Alberta study found that chestnut-collared longspurs had lower nesting success in idled pastures than in pastures subject to deferred grazing (Koper and Schmiegelow 2007). There was no significant effect of grazing on Savannah sparrow or Western meadowlark nesting success (Koper and Schmiegelow 2007). No published studies have compared Sprague's pipit, Baird's sparrow, vesper sparrow, or lark bunting nesting success in grazed and ungrazed native mixed-grass prairie. As all these species are recorded as experiencing population declines (Sauer and Hines 2008), it is important to understand how cattle grazing affects their nesting success.

Studies in other prairie ecosystems have found variable effects of cattle grazing on songbird nesting success. A study in non-native prairie in southwestern Wisconsin found significantly higher nesting success for red-winged blackbird (*Agelaius phoeniceus*) and Savannah sparrow in ungrazed pastures than in continuously grazed and rotationally grazed pastures (Temple et al. 1999). In Kentucky, grasshopper sparrows (*Ammodramus savannarum*) had higher nesting success in ungrazed prairie than grazed prairie (Sutter and Ritchison 2005). In primarily non-native prairie in Montana, daily nest mortality rates were similar on grazed and ungrazed plots for Western meadowlark and higher on grazed plots for Savannah sparrow (Fondell and Ball 2004). Predation rates were similar between grazed and ungrazed pastures but Savannah sparrows experienced greater parasitism by brown-headed cowbirds (*Molothrus ater*) in grazed pastures (Fondell and Ball 2004).

Problem Statement

As of 2003, 42% of the remaining native mixed-grass prairie in Saskatchewan was part of a conservation management program (Gauthier and Wiken 2003). Successful management of habitat for breeding songbirds requires information on factors influencing nesting success. Information on the effects of grazing on nesting success is particularly important in the case of the threatened Sprague's pipit. Identification of land use practices that benefit Sprague's pipits is an essential research objective of the Sprague's pipit Recovery Strategy (Environment Canada 2008).

This research was conducted during 2006 and 2007 as part of an adaptive management grazing experiment at Grasslands National Park of Canada (GNPC) in southwestern Saskatchewan (Henderson 2006). The native mixed-grass prairie in GNPC

had not been grazed in over 15 years as of 2006. The adjacent Mankota Community Pastures undergo season-long low-moderate intensity grazing (Koper et al. University of Manitoba, unpublished data). This presented a unique opportunity to study songbird nesting success in large tracts of grazed and ungrazed native mixed-grass prairie.

Objectives

Management of native mixed-grass prairie for breeding songbirds requires further information on the effects of vegetation structure and cattle grazing on nesting success.

My objectives were:

1. To determine the impact of nest site vegetation structure on songbird nesting success. I predicted that nesting success would be higher for nests located in greater vegetative cover as greater concealment should reduce the risk of predation.
2. To determine the impact of low-moderate intensity cattle grazing on songbird nesting success. As grazing reduces vegetative cover and may influence predator community composition and predation risk, I predicted that nesting success would differ between grazed and ungrazed prairie.
3. To use the results to make recommendations as to how governments and conservation groups can best proceed with management and conservation of habitat for grassland songbirds in Saskatchewan given that much of the remaining native mixed-grass prairie is used for cattle grazing.

Thesis Structure

The second chapter of this thesis presents my introduction, methods, and results relating to the effects of nest site vegetation structure and grazing on the nesting success of 5

focal species. The third chapter concludes with a discussion of the study's implications for management and habitat conservation.

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2. EFFECTS OF GRAZING AND VEGETATION ON NESTING SUCCESS OF GRASSLAND BIRDS IN SOUTHWESTERN SASKATCHEWAN, CANADA

Abstract

Prairie songbirds are experiencing long-term population declines (Knopf 1996, Sauer and Hines 2008). While much of the remaining native mixed-grass prairie is used for cattle grazing, few studies have examined the effects of grazing on songbird nesting success in native mixed-grass prairie. I examined the effects of nest site vegetation structure and cattle grazing on songbird nesting success in native mixed-grass prairie in southwestern Saskatchewan. Vegetation structure at nest sites should provide protection from predators so I hypothesized that nesting success would increase with increased concealment at the nest. As grazing reduces vegetative cover and may influence predator community composition and predation risk, I hypothesized that nesting success would differ in grazed and ungrazed prairie. I estimated nesting success of Sprague's pipit (*Anthus spragueii*), Baird's sparrow (*Ammodramus bairdii*), vesper sparrow (*Poecetes gramineus*), lark bunting (*Calamospiza melanocorys*), and chestnut-collared longspur (*Calcarius ornatus*) using a modified logistic regression approach. All 5 species selected for a narrow range of nest site vegetative cover. Sprague's pipit daily nest survival declined with increased vegetation density and litter depth at the nest site. Vegetative cover did not influence daily nest survival of the other 4 species. Environmental conditions for Sprague's pipits may have been sub-optimal during the years of the study, leading to greater risk of predation at sites located in greater cover. Grazing did not influence daily nest survival of any of the 5 species. Low-moderate intensity cattle

grazing appears compatible with management for prairie songbird species in native mixed-grass prairie.

Introduction

Grassland bird populations are declining faster than any other group of birds in North America (Knopf 1996). Factors contributing to these declines likely include conversion of native prairie for agriculture and degradation and fragmentation of the remaining prairie (Herkert et al. 1996, Brennan and Kuvlesky 2005). In Saskatchewan, 21% of the original native prairie remains, including 31% of the mixed-grass ecoregion (Hammermeister et al. 2001). Many endemic prairie songbirds show a preference for breeding in native prairie over cropland, hayfields, or tame pasture (Owens and Myres 1973, Davis and Duncan 1999).

The majority of songbird nests fail, primarily due to predation (Ricklefs 1969). Evolutionary processes should thus have led to birds developing strategies to avoid detection of nests by predators (Martin 1993). Previous studies have demonstrated that prairie songbirds actively select for nest site vegetation that is taller and denser than generally available (Sutter 1997, Dieni and Jones 2003, Davis 2005). One hypothesis to explain this pattern is that birds are attempting to reduce the risk of nest predation by selecting for nest sites with greater cover, limiting the availability of visual, auditory, and olfactory cues that predators use to locate nests (Martin 1993). The few studies that have examined the role of nest site vegetation structure in songbird nesting success in native mixed-grass prairie have found variable effects of cover on nesting success (Davis 2005, Koper and Schmiegelow 2007, Jones and Dieni 2007).

A significant portion of Saskatchewan's native prairie is managed for cattle grazing (Nerenberg and Ingstrop 2005). Statistics are not available but land managed by the Prairie Farm Rehabilitation Agency is grazed (Prairie Farm Rehabilitation Administration 2006) and it is reasonably safe to assume that all privately held native prairie is grazed (Chet Neufeld, Native Plant Society of Saskatchewan, personal communication). Cattle are known to cause nest failure through trampling (Renfrew and Ribic 2003) and have been observed depredating nests (Nack and Ribic 2005). Cattle grazing may indirectly influence songbird nesting success by reducing vegetative cover (Sutter and Ritchison 2005). Vegetation structure influences small mammal community composition and abundance (Grant et al. 1982, Hayward et al. 1997), which may influence the risk of nest predation. Predator search efficiency may be greater in shorter, sparser vegetation, resulting in a higher risk of nest predation (Sutter and Ritchison 2005). Reductions in vegetative cover may also reduce the availability of high quality nest sites, forcing birds to select sites where nests are more vulnerable to predation (Ammon and Stacey 1997).

Despite the potential for cattle grazing to impact songbird nesting success in much of the remaining native mixed-grass prairie, only one other study has compared songbird nesting success in grazed and ungrazed mixed-grass prairie. The Alberta-based study found that chestnut-collared longspurs had lower nesting success in idled pastures, where cattle are excluded, than pastures subject to deferred grazing (Koper and Schmiegelow 2007). There was no significant effect of grazing ($P > 0.10$) on Savannah sparrow (*Passerculus sandwichensis*) or Western meadowlark (*Sturnella neglecta*) nesting success (Koper and Schmiegelow 2007). No published studies have compared Sprague's pipit,

Baird's sparrow, vesper sparrow, or lark bunting nesting success in grazed and ungrazed native mixed-grass prairie. This is of management and conservation concern because the Breeding Bird Survey has detected long-term population declines for these species (Sauer and Hines 2008).

Management of native mixed-grass prairie habitat for grassland songbird populations requires further information on the effects of cattle grazing on songbird nesting success. This information is especially important in the case of Sprague's pipit (*Anthus spragueii*), which is listed as "threatened" under the Canadian Species at Risk Act (Government of Canada 2008). Information on land use practices that benefit this species is essential for recovery efforts (Environment Canada 2008).

I conducted a two-year study (2006-2007) in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, to examine the role of nest site vegetation structure and cattle grazing on nesting success of 5 songbird species. I predicted that nesting success would be higher for nests located in greater vegetative cover as greater concealment should reduce the risk of predation. As grazing reduces vegetative cover and may influence predator community composition and predation risk, I predicted that nesting success would differ in grazed and ungrazed prairie.

Methods

Study Area

I conducted this study from 2006-2007 as part of a 12-year adaptive management grazing experiment examining the effects of grazing intensity on biodiversity in native mixed-grass prairie (Henderson 2006). The study was located in Grasslands National Park of Canada (49° 10' 37" N, 107° 25' 33" W, 800-m in elevation) and adjacent Mankota Community Pastures in southwestern Saskatchewan.

The study site was located within a large continuous area of ungrazed native mixed-grass prairie in close proximity to grazed prairie. This avoids some of the confounding factors that are associated with studies in fragmented habitat (e.g. predators from non-prairie habitats entering the system along habitat edges; Renfrew and Ribic 2003). The study site consisted of 13, 300-ha units of gently rolling native mixed-grass prairie. The 9 units in the park had not been grazed in over 15 years as of 2006. The 4 units located in the Mankota Community Pastures were grazed annually at low-moderate intensity from May to September, with a management goal of moderate intensity grazing (Koper et al., University of Manitoba, unpublished data). In 2006, the mean stocking rate in the 4 pastures was 930.20 animal unit months per acre (AUM/ac) with a range of 605.90 AUM/ac to 1133.60 AUM/ac (Dwight Gavelin, Saskatchewan Ministry of Agriculture, personal communication). In 2007, the mean stocking rate was 921.60 AUM/ac with a range of 605.90 AUM/ac to 1119.10 AUM/ac (Dwight Gavelin, Saskatchewan Ministry of Agriculture, personal communication). Ungrazed units were unfenced, while grazed units were subsamples within larger fenced pastures. All ungrazed units were east of the grazed units, as ungrazed prairie in the region is limited to

the park. However, the grazed units were both south-west and north-west of the park and contained similar proportions of upland, lowland, and riparian habitats, compared with ungrazed units. Wildfires burned portions of a grazed unit (55.9 ha), and 2 ungrazed units (110.3 ha, 3.6 ha) in July 2006 (Robert Sissons, Parks Canada, personal communication).

The region is semi-arid with high winds. Annual precipitation averages 350 mm (Henderson 2006). Riparian shrub communities are dominated by western snowberry (*Symphoricarpos occidentalis*), prairie rose (*Rosa acicularis*), and sagebrush (*Artemisia cana*). This habitat is also characterized by Canada bluegrass (*Poa compressa*), Canada goldenrod (*Solidago Canadensis*), and wild licorice (*Glycyrrhizae lepidota*) (Henderson 2006). Upland areas are characterised by speargrass (*Stipa comata*), northern wheatgrass (*Elymus lanceolatus*), blue grama (*Bouteloua gracilis*), June grass (*Koeleria macrantha*), and Western wheatgrass (*Pascopyrum smithii*) (Henderson 2006). Forbs include fringed sagebrush (*Artemisia frigida*), moss phlox (*Phlox hoodii*), scarlet globemallow (*Sphaeralcea coccinea*), and clubmoss (*Selaginella densa*) (Henderson 2006). Elevated salt flats support cactus (*Opuntia* spp.) and shrubs (*Artemisia cana*, *Atriplex* spp., *Chrysothamnus nauseosus*, *Sarcobatus vermiculatus*), along with wheatgrasses, bluegrasses (*Poa sandbergii*, *P. compressa*), and salt grasses (*Distichlis stricta*, *Puccinella nuttallii*) (Henderson 2006).

Potential or suspected terrestrial nest predators include badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), red fox (*Vulpes vulpes*), swift fox (*Vulpes velox*), coyote (*Canus latrans*), mice and voles (*Peromyscus*, *Clethrionomys*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), Richardson's ground squirrel (*Spermophilus richardsonii*), and garter snake (*Thamnophis*). Avian predators such as

Northern harrier (*Circus cyaneus*), short-eared owl (*Asio flammeus*), burrowing owl (*Athene cunicularia*), Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), golden eagle (*Aguila chrysaetos*), prairie falcon (*Falco mexicanus*), peregrine falcon (*Falco peregrinus*), and Western meadowlark (*Sturnelia neglecta*) were observed on, or in close vicinity to the study site.

Nest Location and Measurements

I established a 300 x 300-m nest-searching plot in the upland and lowland of each study unit to sample species breeding in each habitat. Plot locations were determined using a random method constrained by the location and shape of the study units (Henderson 2006). Starting points for each plot were randomly selected in Microsoft Excel® based on the UTM lines on study area maps. The plots had a north-south orientation and slight adjustments were made to incorporate data transects from the grazing experiment to allow future reference to associated vegetation and insect data. Plots were also adjusted to avoid non-grassland habitats, such as ponds, streams, shrub-dominated habitat along-side water bodies, and slopes where vegetation transitioned from lowland to upland. Nest-searching plots therefore represented 2 forms of mixed-grass prairies (upland and lowland). One upland grazed plot burned during a wildfire in 2006 after it had been searched once. A new plot was established after the fire and searched once that year. In 2007, an additional upland plot was established in the ungrazed pasture that burned in 2006. The plots in the burnt habitat were also searched in 2007 to provide baseline data for future research.

I searched the plots twice between May and August 2006. To increase the sample size, in 2007, I moved the plots to areas of higher Sprague's pipit densities if no nests

were found during the first round of nest searching. I used 2007 point count survey data from the adaptive management grazing experiment to determine areas of higher Sprague's pipit densities (Koper et al., University of Manitoba, unpublished data). I searched the plots in each unit at least 3 times between May and July 2007. Nest searching was conducted using the rope-drag method (Davis 2003). Two observers stretched a 20-m rope between them or 3 observers used 2 ropes to walk transects across the entirety of each plot. Incidental nests in the study area, found during other research activities, were also monitored to increase the sample size.

The study was limited to ground-nesting species. Sprague's pipit, Baird's sparrow, vesper sparrow, lark bunting, and chestnut-collared longspur had large enough sample sizes for analysis in the 2006 season ($n \geq 15$). Nest monitoring was limited to these species and McCown's longspur (*Calcarius mccownii*) in 2007. McCown's longspur nests were monitored as this species is of conservation concern (Government of Canada 2009). However, no analyses were conducted as the total number of nests found was very low ($n = 3$). Horned lark (*Eremophila alpestris*), Savannah sparrow, and Western meadowlark had small sample sizes in 2006 ($n < 14$) so their nests were not monitored in 2007.

Nests were marked 10-m west with a survey flag and 10-m south with a bamboo stake to assist with relocation, while minimizing the risk of attracting cattle or predators to the nest (Hein and Hein 1996, Koper and Schmiegelow 2006). Nests were monitored every 2-4 days. Behavioural and nest site cues were used to determine nest success and failure. If nestlings disappeared while too young to fledge, the cause of nest failure was

assumed predation (Jones and Dieni 2007). The University of Manitoba Animal Care Committee (Protocol F06-005) approved these research methods.

Structural vegetation data were collected within 2 weeks of nest termination. A single observer collected data in 2006 and 3 observers collected data in 2007. Data were collected at the nest and at a control site randomly located within 50-m of the nest. I increased the number of control sites per nest to 2 in 2007, using the averaged data for analyses. The visibility of the nest from 1-m above was measured using a plastic lid that was placed on top of the nest cup (modified from Davis and Sealy 1998). The lid was divided into 4 equal pie-shaped sections and alternating sections were filled in with permanent marker (modified from Davis and Sealy 1998). For nests with roofs or partial roofs, separate measurements were taken for the roof and the nest cup. The height of the tallest vegetation directly over the nest was measured from ground level using a metre stick (Sutter 1997). Density was measured using visual obstruction readings taken with a Robel pole (divided into 5-cm increments; modified from Robel et al. 1970). Percent cover measurements were taken for the 1-m² area around the nest (Fondell and Ball 2004, Koper and Schmiegelow 2006). Two metre sticks were centered at the nest, creating a cross in the cardinal directions and percent cover was measured in each quadrant (Fondell and Ball 2004). The variables measured included cover by shrubs, forbs, live grass, dead grass, moss, cacti, litter, cow patties, rocks, and bare ground. I measured each of these separately as they provide cover at different heights. The mean values of the 4 quadrants were used for analyses. Litter depth was measured with a 30-cm ruler at the nest and at the ends of each metre sticks (Koper and Shmiegelow 2006), with litter defined as any dead vegetation that was not attached to the ground (Sutter 1997).

Statistical Analysis

Nesting Success Model

I analysed the effects of nest site vegetation structure and grazing on success or failure of each nest using modified logistic regression in PROC NLMIXED in SAS 9.12 (SAS Institute, Cary, NC) following the approach of Dinsmore et al. (2002). As Shaffer (2005) noted, this method requires no assumptions about the date of nest loss, avoiding the issue of bias in nest failure dates that occurs with use of logistic regression. It also allows inclusion of categorical and continuous covariates in the models (Dinsmore et al. 2002, Rotella et al. 2004).

Analyses were conducted for the 5 species in the study. Models only examined nests known to be successful or depredated except in the case of additional calculations of daily nest survival and nesting success, which included nests that failed due to all causes except researcher disturbance. I eliminated nests found in the burnt plots from analyses. Parasitized nests were considered successful if they fledged at least one young of the host species. Nests that failed due to parasitism were excluded ($n = 4$). Studies have found that nest concealment does not affect the likelihood of parasitism, as brown-headed cowbirds locate nests by observing host behaviour (Clotfelter 1998, Banks and Martin 2001). Nests found during the laying stage were excluded from analysis if they were depredated prior to the first nest check, as they may have been abandoned prior to the predation event due to researcher disturbance (Grant et al. 2005). While controlling for observer-induced nest failure, the disadvantage of this approach is that it may have excluded nests that were depredated while still active, biasing analyses towards nests that survive longer.

I developed and evaluated models using a statistical hypothesis testing approach. This allows examination of specific covariates that may influence daily nest survival while avoiding some potential problems associated with use of an information-theoretic (IT) paradigm approach (Guthery et al. 2005). The IT approach, using Akaike's Information Criterion (AIC), has a tendency to over fit models and include variables of no ecological significance in the best model (Guthery et al. 2005).

To prevent pseudoreplication due to intervals from the same nest being related, I used the number of nests to determine the degrees of freedom as opposed to the number of nest visit intervals (Dinsmore et al. 2002, Shaffer 2004). The length of a nest cycle varies by species so I estimated the probability of each nest surviving for 1 day so that I could compare survival among species (Koper and Schmiegelow 2007). I also estimated nesting success for the whole nesting period for each species in grazed and ungrazed prairie. I converted parameter estimates and confidence intervals to log odds ratios for ease of interpretation except for daily nest survival and nesting success rates in grazed and ungrazed prairie. I used a significance level of 0.10 for all analyses as species at risk may have little margin for recovery if management activities are not undertaken due to acceptance of a false null hypothesis (Taylor and Gerrodette 1993).

Previous studies have calculated nesting success solely for the incubation and nestling periods. I removed nest visits that occurred during laying from this analysis so that my results would be comparable with other studies. A visit was considered to have taken place during laying if more eggs were found in the nest at the next nest check. I had very few nests with known incubation ($n = 3$) and nestling periods ($n = 12$) (Appendix A). Therefore, I used average incubation and nestling periods from previous studies in

combination with my data. Davis (in press) found that Sprague's pipits had a mean incubation period of 13 days and a mean nestling period of 12 days in southern Saskatchewan so I used a nest period of 25 days. I used a 20-day period for Baird's sparrow (Ehrlich et al. 1988, Davis 2003, Baicich and Harrison 2005), vesper sparrow (Ehrlich et al. 1988, Baicich and Harrison 2005), and lark bunting (Yackel Adams et al. 2001, Yackel Adams et al. 2007). I used a 22-day period for chestnut-collared longspur (Davis 2003).

Preliminary Analyses

I ran preliminary models to determine whether year and seasonality (visit date) influenced daily nest survival and needed to be included in the main models (Koper and Schmiegelow 2007). I used a polynomial equation for visit date, as there may be nonlinear trends in daily nest survival throughout the season (Dinsmore et al. 2002, Rotella et al. 2004). I centered visit date when there was high correlation between linear and quadratic effects of date in the models.

Nest age may be a confounding factor if it is not included in nest survival analyses. Predation rates may be higher in the nestling stage due to the noise and activity of nestlings (Haskell 1994) and increased parental visits (Skutch 1949, Martin et al. 2000). However, inclusion of nest age in the models is problematic because of difficulties inherent in correctly aging nests at the time of failure. As well, the effect of nest age is not always linear (Davis 2005, Grant et al. 2005) and improving the fit by adding quadratic or cubic terms to the model would further reduce degrees of freedom and statistical power. As I had small sample sizes, this would reduce or eliminate my ability to examine variables of interest. To address this issue in the vegetation models, I ran

preliminary models to determine whether nest age influenced daily nest survival. I included linear, quadratic, and cubic effects of age (Davis 2005, Grant et al. 2005). If there were significant effects of age for a species, then I included age in the vegetation model. To address this issue in the grazing models, I conducted preliminary analyses to determine if exclusion of nest age would confound the results. I estimated nest age at nest checks and calculated the average age for each nest. I used the nest status at previous nest checks and notes on nestling characteristics to help narrow down nest age. The median date between the last 2 nest checks was considered the last age at which failed nests were active. I then used a 2-sample *t*-test in S-PLUS to examine whether there was a significant difference in a species' average age in grazed and ungrazed prairie ($P < 0.10$). If there was no significant difference in the average age in grazed and ungrazed prairie then I did not include nest age in the grazing models as any increased variance due to nest age was equally dispersed across the treatments and should not confound the results.

ANOVAs showed that vegetation structure in upland habitat was significantly different from that in lowland habitat for all species combined ($P \leq 0.005$) (Appendix B) so upland/lowland habitat was included in the vegetation models for all species except lark bunting, which only nested in lowland habitat. ANOVAs also showed that measures of litter depth and visibility from above varied by observer ($P < 0.02$) in 2007. Observer was therefore included as a variable in the vegetation models. The models failed to converge when observer was included as an interaction term, probably due to overparameterization, so it was included only as a main effect.

Nest Site Selection

To determine whether songbirds select for specific types of nest site vegetation, I compared nest site vegetation characteristics with those at random sites using paired *t*-tests in SAS 9.12 (SAS Institute, Cary, NC). All monitored nests were included regardless of their fate. Precision is greater for the random data in 2007 as I used the averaged data from the 2 random sites monitored for each nest.

Vegetation Structure, Grazing, and Nesting Success

I examined *a-priori* predictions that greater vegetative cover at the nest would provide greater cover from predators, resulting in higher nesting success. Due to small sample sizes, I was limited in the number of variables that I could include in the models. I wanted to examine the same variables for all species and have at least 4 nests per variable. I was limited to 3 vegetation variables for Sprague's pipit, vesper sparrow, lark bunting, and chestnut-collared longspur models. I selected litter depth at the nest, vegetation density, and visibility from above because combined; they represent cover at the nest site from the ground up. I was unable to examine vegetation structure for Baird's sparrow due to small sample size ($n = 31$), because I needed to include year and date in analyses, and additional vegetation variables resulted in overparameterization.

As I measured several other vegetation variables at nest sites, I could have used a multivariate approach such as principal components analysis (PCA) to produce a smaller set of variables for analysis (Quinn and Keough 2006). However, it can be difficult to make biological interpretations (James and McCulloch 1990, Rexstad et al. 1990) and management recommendations based on the new variables.

It is possible that vegetation variables left out of the main models could have a confounding effect on the results. Following selection of the 3 vegetation variables, as part of the model diagnostics, I checked whether there was high correlation ($r > 0.60$; Quinn and Keough 2006) between those 3 and the 7 variables that I measured but did not include in the models. If high correlation was present then I could not be certain whether any observed effects of the variables included in the models were attributable to those variables or variables with which they were correlated.

I conducted similar analyses comparing nesting success in grazed and ungrazed prairie. I included year and visit date as covariates in the Baird's sparrow model and visit date for the vesper sparrow, lark bunting, and chestnut-collared longspur models.

To determine whether grazing influenced the structure of generally available vegetation, I compared vegetation characteristics from the random samples in grazed prairie with those in ungrazed prairie using 2-sample *t*-tests in S-PLUS.

The sample size for each species is low. This results in low power and I will take this to consideration when interpreting results.

Results

In 2006 and 2007, 360 nests of 21 species were found (Table 1). This number includes nests that we were unable to relocate, those for which we could not establish the fate, and those that failed due to causes other than predation. We found 31 Sprague's pipit, 31 Baird's sparrow, 41 vesper sparrow, 50 lark bunting, and 75 chestnut-collared longspur nests that were either successful or depredated.

Table 1. Nests found in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	Grazed prairie	Ungrazed prairie	Total
	<i>n</i>	<i>n</i>	
Baird's sparrow ^a	11	34 ^d	45
Brewer's sparrow	2	0	2
Chestnut-collared longspur ^a	74	23 ^d	97
Clay-coloured sparrow	6	6	12
Common nighthawk	2	0	2
Eastern kingbird	0	2	2
Horned lark	8	3	11
Lark bunting ^a	41	16	57
Long-billed curlew	1	1	2
Mallard	0	1	1
Marbled godwit	0	2	2
McCown's longspur ^a	3	0	3
Northern harrier	0	2	2
Northern pintail	0	1	1
Savannah sparrow ^b	13	15	28
Sharp-tailed grouse	0	1	1
Short-eared owl	0	1	1
Sprague's pipit ^a	15 ^c	20 ^d	35
Vesper sparrow ^a	19	25	44
Western meadowlark ^b	4	7	11
Willet	0	2	2

^a Monitored in 2006 and 2007

^b Monitored in 2006

^c Includes 1 nest outside the study area

^d Includes 2 nests outside the study area

Predation accounted for 84% of all known nest failures (Table 2). Parasitism resulted in the failure of 1 Baird's sparrow nest and 3 vesper sparrow nests. Among

abandoned nests, 3 out of 5 were attributed to severe weather events (i.e. heavy rain and hailstorms). Thirteen nests had an unknown fate.

Table 2. Songbird nest failure in southwestern Saskatchewan, Canada, 2006 and 2007 (%).

Species	Predation	Cowbird Parasitism	Weather	Trampling	Inviability	Abandoned	Unknown
Sprague's pipit (<i>n</i> = 11)	7 (64)	0 (0)	2 (18)	0 (0)	0 (0)	2 (18)	0 (0)
Baird's sparrow (<i>n</i> = 28)	19 (68)	1 (4)	0 (0)	0 (0)	2 (7)	2 (7)	4 (14)
Vesper sparrow (<i>n</i> = 28)	25 (89)	3 (11)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lark bunting (<i>n</i> = 18)	17 (94)	0 (0)	0 (0)	1 (6)	0 (0)	0 (0)	0 (0)
Chestnut-collared longspur (<i>n</i> = 54)	47 (87)	0 (0)	1 (2)	0 (0)	0 (0)	1 (2)	5 (9)

Preliminary Analyses

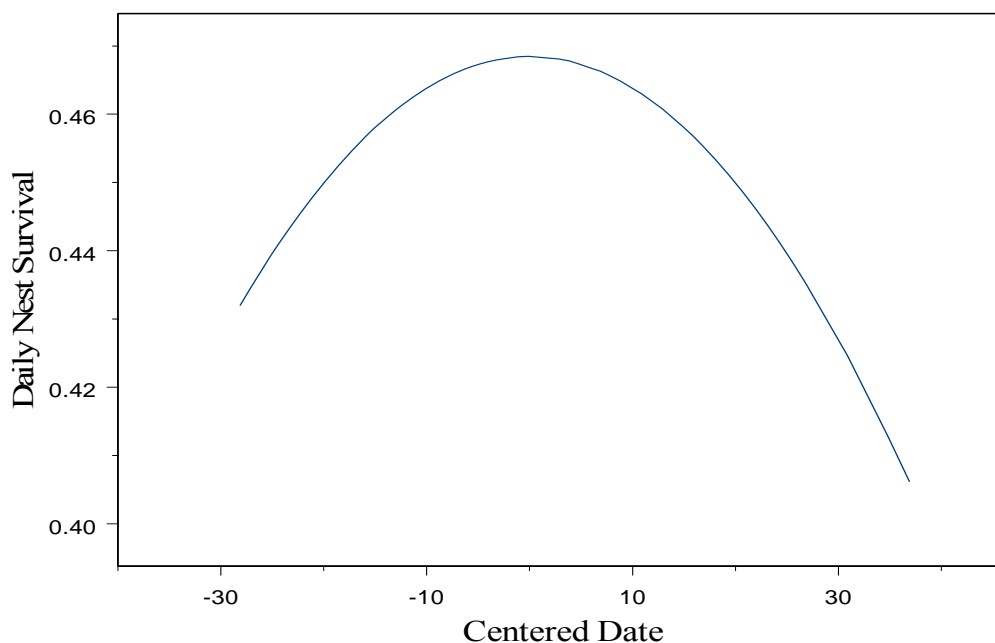
There was no significant effect of year on daily nest survival ($P > 0.35$) except for Baird's sparrow (Table 3). There was no significant effect of visit date on Sprague's pipit daily nest survival ($P \geq 0.16$) however; there was a significant linear effect of visit date on Baird's sparrow, lark bunting, and chestnut-collared longspur daily nest survival (Table 3). The odds of daily survival decreased by 0.075% over the course of the season for Baird's sparrow ($P = 0.05$), 0.058% for lark bunting ($P = 0.075$), and 0.015% for chestnut-collared longspur ($P = 0.075$). There was a quadratic effect of date on vesper sparrow with daily nest survival increasing to a peak near the middle of the season and declining thereafter (Figure 1). Visit date and year were included in the main models for

those species for which P values for those variables were significant ($P < 0.10$). All further results are reported for combined 2006 and 2007 data.

Table 3. Odds ratios describing effects of year and linear and quadratic effects of date on nesting success of songbirds in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	n	Parameter	Odds Ratio	Lower CL of Odds Ratio	Upper CL of Odds Ratio	P
Sprague's pipit	31	Year	1.063	0.279	4.053	0.939
		Date	0.965	0.891	1.045	0.454
		Date ²	1.004	0.999	1.010	0.215
Baird's sparrow	31	Year	3.266	1.158	9.214	0.062
		Date	0.925	0.866	0.987	0.050
		Date ²	1.003	0.999	1.006	0.210
Vesper sparrow	41	Year	1.003	0.613	1.640	0.992
		Date	0.994	0.951	1.040	0.832
		Date ²	1.028	1.020	1.036	<0.001
Lark bunting	50	Year	1.746	0.655	4.654	0.345
		Date	0.942	0.892	0.995	0.075
		Date ²	1.000	0.994	1.004	0.756
Chestnut-collared longspur	71	Year	0.955	0.553	1.651	0.889
		Date	0.985	0.968	1.003	0.075
		Date ²	1.000	0.999	1.001	0.756

Figure 1. The quadratic trend in daily nest survival of vesper sparrow nests relative to visit date in southwestern Saskatchewan, 2006 and 2007.



There was a significant effect of nest age on Baird's sparrow, vesper sparrow, lark bunting, and chestnut-collared longspur daily nest survival (Table 4). The effect of nest age on Baird's sparrow, lark bunting, and chestnut-collared longspur was best explained by a quadratic effect (Table 4). Nest survival was lowest at intermediate stages for Baird's sparrow in 2006 (Figure 2) and 2007 (Figure 3) and lark bunting (Figure 4). Chestnut-collared longspur nest survival was highest at intermediate stages (Figure 5). The effect of nest age on vesper sparrow was best explained by a cubic effect (Table 4) with daily nest survival rising quickly from the beginning of the season and then levelling off before rising again slightly later on (Figure 6). I included age covariates in the vegetation models for vesper sparrow, lark bunting, and chestnut-collared longspur.

Table 4. Odds ratios describing effects of linear, quadratic, and cubic effects of nest age on nesting success of songbirds in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	Parameter	Odds Ratio	Lower CL of Odds Ratio	Upper CL of Odds Ratio	<i>P</i>
Sprague's pipit	31	Age	0.000	0.279	4.053	0.939
		Age ²	0.965	0.891	1.045	0.454
		Age ³	1.004	0.999	1.010	0.215
Baird's sparrow ^a	31	Age	3.266	1.158	9.214	0.062
		Age ²	0.925	0.866	0.987	0.050
		Age ³	1.003	0.999	1.006	0.210
Vesper sparrow	41	Age	1.003	0.613	1.640	0.992
		Age ²	0.994	0.951	1.040	0.832
		Age ³	1.028	1.020	1.036	<0.001
Lark bunting	50	Age	1.746	0.655	4.654	0.345
		Age ²	0.942	0.892	0.995	0.075
		Age ³	1.000	0.994	1.004	0.756
Chestnut-collared longspur	71	Age	0.955	0.553	1.651	0.889
		Age ²	0.985	0.968	1.003	0.075
		Age ³	1.000	0.999	1.001	0.756
All species	224	Age	0.874	0.824	0.926	<0.001
		Age ²	1.006	1.001	1.011	0.066
		Age ³	1.000	1.000	1.001	0.048

^a There were fewer than 4 nests per covariate for this analysis.

Figure 2. The quadratic trend in daily nest survival of Baird's sparrow nests relative to nest age in southwestern Saskatchewan (2006).

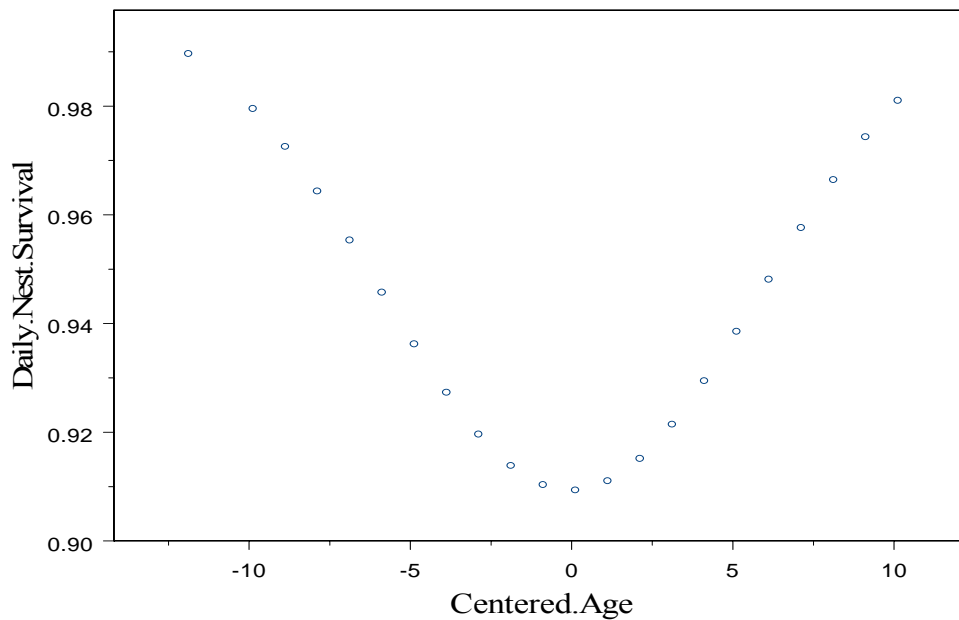


Figure 3. The quadratic trend in daily nest survival of Baird's sparrow nests relative to nest age in southwestern Saskatchewan (2007).

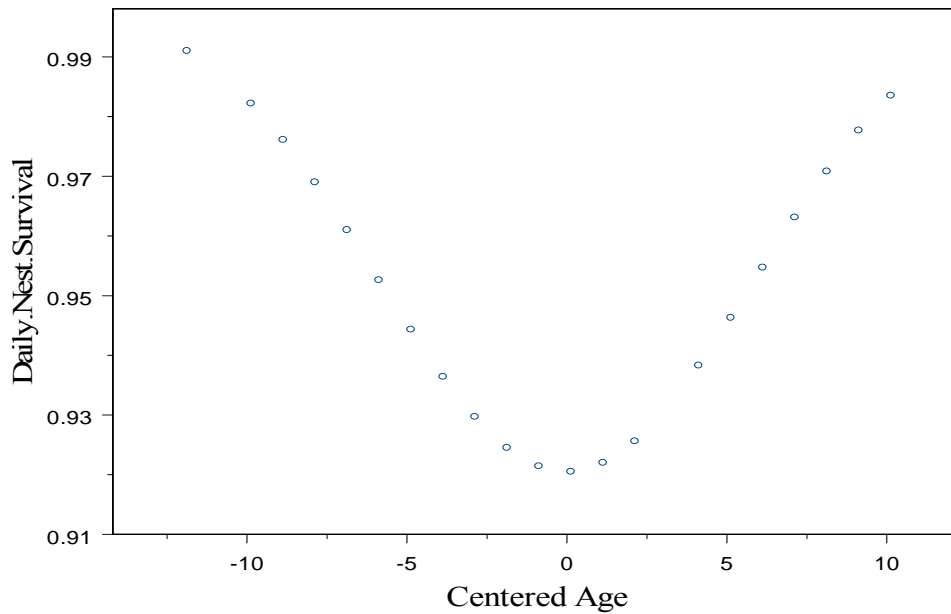


Figure 4. The quadratic trend in daily nest survival of lark bunting nests relative to nest age in southwestern Saskatchewan, 2006 and 2007.

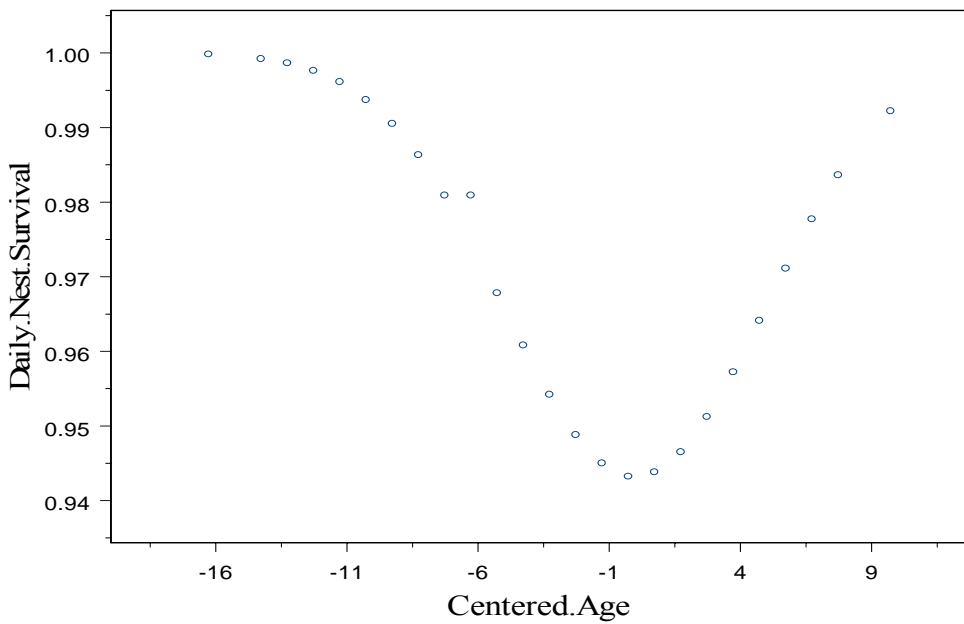


Figure 5. The quadratic trend in daily nest survival of chestnut-collared longspur nests relative to nest age in southwestern Saskatchewan, 2006 and 2007.

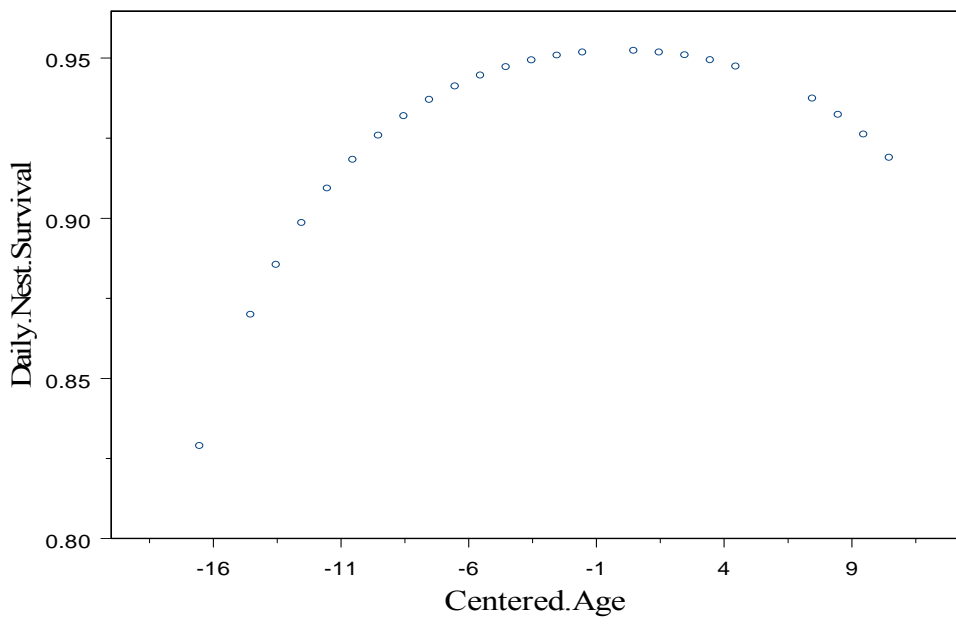
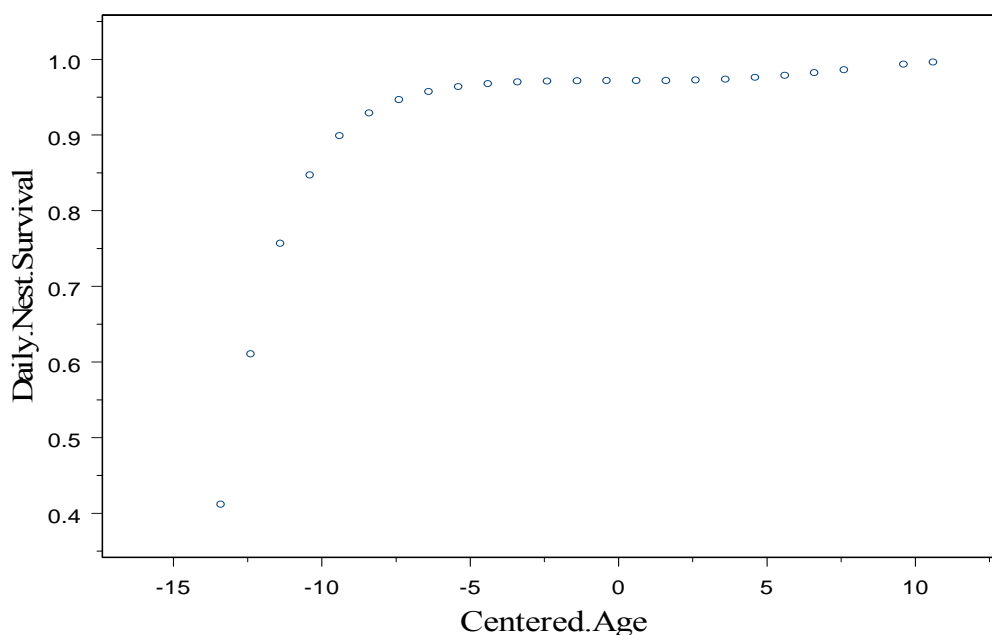


Figure 6. The cubic trend in daily nest survival of vesper sparrow nests relative to nest age in southwestern Saskatchewan, 2006 and 2007.



There was no significant difference ($P \geq 0.13$) in the average age of nests monitored in grazed and ungrazed prairie for any species (Table 5) so I did not include nest age in the grazing models.

Table 5. Comparison of average songbird nest age in grazed and ungrazed prairie in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	<i>t</i>	Lower CL	Upper CL	<i>P</i>
Sprague's pipit	31	-1.449	-4.82	0.35	0.152
Baird's sparrow	31	0.954	1.48	4.16	0.353
Vesper sparrow	41	-0.852	-4.62	1.45	0.401
Lark bunting	50	0.847	-1.15	3.02	0.403
Chestnut-collared longspur	71	-0.394	-2.92	1.70	0.698

Vegetation

A subsample of 263 nests were used to explore effects of vegetation on nesting success: 36 Sprague's pipit nests, 49 Baird's sparrow nests, 43 vesper sparrow nests, 52 lark bunting nests, and 89 chestnut-collared longspur nests. All 5 species selected for nest

sites with significantly greater vegetation density ($P \leq 0.001$) and litter depth ($P < 0.06$) than the average available vegetation (Table 6). See Appendix C for comparisons of all vegetation variables at nest and random locations.

Table 6. Vegetation structure at songbird nests in southwestern Saskatchewan, Canada, compared with random locations, 2006 and 2007.

Species	Location	Litter depth (mm)			Vegetation density (units of 5-cm increments)		
		\bar{x}	LCL ^a	UCL ^b	\bar{x}	LCL ^a	UCL ^b
Sprague's pipit ($n = 36$)	Nest	18.167	13.559	22.774	2.243	1.978	2.508
	Random	10.292	7.526	13.058	1.271	1.011	1.531
	P^c	0.012			≤ 0.001		
Baird's sparrow ($n = 43$)	Nest	29.837	25.067	34.608	2.940	2.734	3.147
	Random	22.407	17.350	27.463	2.023	1.735	2.312
	P^c	0.058			≤ 0.001		
Vesper sparrow ($n = 44$)	Nest	23.818	19.665	27.972	3.170	2.853	3.488
	Random	8.909	6.923	10.895	1.344	1.027	1.661
	P^c	≤ 0.001			≤ 0.001		
Lark bunting ($n = 44$)	Nest	21.231	17.219	25.242	2.736	2.472	3.000
	Random	8.500	6.034	10.966	0.858	0.624	1.093
	P^c	≤ 0.001			≤ 0.001		
Chestnut-collared longspur ($n = 87$) ^d	Nest	12.176	10.144	14.209	1.456	1.354	1.559
	Random	9.556	6.514	12.598	0.804	0.676	0.932
	P^c	≤ 0.001			≤ 0.001		

^a Lower 90% CL.

^b Upper 90% CL.

^c Calculated using paired t-tests.

^d $n = 85$ for litter depth analysis.

Effects of Vegetation Structure on Daily Nest Survival

Sprague's pipit daily nest survival declined by 76.4% per 5-cm increment increase in vegetation density ($\beta = 0.236$, CI: 0.069-0.802, $P = 0.055$). Sprague's pipit daily nest survival also declined by 11.0% per 1-mm increase in litter depth ($\beta = 0.890$, CI: 0.816-0.972, $P = 0.033$). There were no significant effects of vegetation structure on daily nest survival ($P > 0.10$) for vesper sparrow, lark bunting, chestnut-collared longspur, or all species combined.

I checked for correlation between the vegetation variables included in the models and those that were excluded. Correlation in the vegetation variables was not high (< 0.6) for Baird's sparrow, vesper sparrow, and chestnut-collared longspur. Sprague's pipits had high correlation between litter depth and 3 variables: shrub cover ($r = -0.788$), forb cover ($r = 0.835$), and live grass cover ($r = -0.766$). There was also high correlation between vegetation density and forb cover ($r = -0.766$) and dead grass cover ($r = -0.753$). Lark bunting had high correlation between vegetation density and shrub cover ($r = 0.68$). Effects of vegetation density and litter depth on Sprague's pipit nesting success may actually reflect effects of vegetation variables that I excluded from the model.

Grazing

Vegetation density measured at random locations was not significantly different in grazed and ungrazed prairie ($P \leq 0.10$) for any of the 5 species. The only species for which there was a significant difference in litter depth at random sites in grazed and ungrazed prairie was vesper sparrow ($t = -2.043$, CI: $-8.575 - -0.832$, $P = 0.047$, $df = 41$). Mean litter depth was lower in grazed prairie (6.24, CI: 4.66 - 7.82) than ungrazed prairie (7.73, CI: 7.73 - 14.16)

A total of 199 nests were found in grazed prairie and 161 nests were located in ungrazed prairie. Perhaps because vegetation structure had little effect on nesting success, there was no significant effect ($P < 0.10$) of grazing on nesting success for any of the 5 species in the study for 2006, 2007, or both years combined (Table 7).

Table 7. Odds ratios describing daily nest survival of songbirds in grazed prairie relative to ungrazed prairie in southwestern Saskatchewan, Canada, 2006, 2007, and both years combined.^a

Species	Year	<i>n</i>	Parameter estimate	Lower CL	Upper CL	<i>P</i>
Sprague's pipit	2006	15	0.521	1.833	4.619	0.606
	2007	16	3.412	0.441	26.385	0.309
	combined	31	1.456	0.393	5.394	0.629
Baird's sparrow	2006 ^b	17	2.384	0.310	18.320	0.467
	2007 ^b	14	2.732	0.407	18.360	0.366
	combined ^c	31	2.187	0.564	8.473	0.334
Vesper sparrow	2006 ^e	16	1.403	1.912	5.027	0.648
	2007 ^e	25	2.116	0.798	5.612	0.201
	combined ^e	41	1.853	0.872	3.942	0.252
Lark bunting	2006 ^e	32	0.273	0.041	1.843	0.257
	2007 ^d	18	0.584	0.131	2.609	0.537
	combined ^e	50	0.300	0.083	1.091	0.124
Chestnut-collared longspur	2006 ^e	38	1.319	0.541	3.216	0.603
	2007 ^e	33	1.121	0.464	2.713	0.827
	combined ^e	71	1.214	0.654	2.255	0.602
All species combined	2006 ^e	118	0.816	0.477	1.397	0.532
	2007 ^e	106	1.169	0.881	2.255	0.602
	Combined ^c	224	0.133	0.810	1.584	0.539

^a Estimated odds ratios using modified logistic regression (Dinsmore et al. 2002).

^b Preliminary analysis found an effect of date and year on daily nest survival for this species. There were insufficient nests to include these variables in this model.

^c Includes date and year covariates.

^d Preliminary analysis found an effect of date on daily nest survival for this species. There were insufficient nests to include date in this model.

^e Includes date.

Nesting Success

Daily nest survival differed for each species in grazed and ungrazed prairie when the cause of nest failure was limited to predation (Table 8) and when all causes of predation were included (Table 9). This was also the case for nesting success (Tables 10 and 11).

Table 8. Daily nest survival of successful and predated songbird nests in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	Parameter	Parameter estimate	Lower CL	Upper CL
Sprague's pipit	14	Grazed	0.989	0.978	1.000
	17	Ungrazed	0.984	0.970	0.997
Baird's sparrow ^a	8	Grazed	0.959	0.905	1.012
	23	Ungrazed	0.914	0.862	0.966
Vesper sparrow ^b	18	Grazed	0.968	0.947	0.989
	23	Ungrazed	0.947	0.920	0.975
Lark bunting ^b	35	Grazed	0.964	0.943	0.985
	15	Ungrazed	0.989	0.976	1.003
Chestnut-collared longspur ^b	57	Grazed	0.946	0.927	0.965
	14	Ungrazed	0.933	0.894	0.972

^a Includes year and date covariates.

^b Includes date covariates.

Table 9. Songbird daily nest survival in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	Parameter	Parameter Estimate	Lower CL	Upper CL
Sprague's pipit	14	Grazed	0.989	0.978	1.000
	19	Ungrazed	0.977	0.961	0.993
Baird's sparrow ^a	11	Grazed	0.970	0.942	0.998
	28	Ungrazed	0.916	0.874	0.957
Vesper sparrow ^b	19	Grazed	0.955	0.921	0.988
	25	Ungrazed	0.940	0.909	0.971
Lark bunting ^b	36	Grazed	0.965	0.944	0.985
	15	Ungrazed	0.995	0.986	1.004
Chestnut-collared longspur ^b	63	Grazed	0.940	0.921	0.959
	14	Ungrazed	0.938	0.901	0.975

^a Includes year and date covariates.

^b Includes date covariates.

Table 10. Nesting success of successful and predated songbird nests in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	Parameter	Parameter estimate	Lower CL	Upper CL
Sprague's pipit	14	Grazed	0.753	0.544	0.965
	17	Ungrazed	0.663	0.431	0.894
Baird's sparrow ^a	8	Grazed	0.429	-0.051	0.909
	23	Ungrazed	0.165	-0.022	0.352
Vesper sparrow ^b	18	Grazed	0.523	0.299	0.746
	23	Ungrazed	0.340	0.139	0.540
Lark bunting ^b	35	Grazed	0.482	0.272	0.693
	15	Ungrazed	0.803	0.585	1.021
Chestnut-collared longspur ^b	57	Grazed	0.301	0.170	0.432
	14	Ungrazed	0.225	0.022	0.428

^a Includes year and date covariates.

^b Includes date covariates.

Table 11. Songbird nesting success in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, Canada, 2006 and 2007.

Species	<i>n</i>	Parameter	Parameter estimate	Lower CL	Upper CL
Sprague's pipit	14	Grazed	0.753	0.544	0.965
	19	Ungrazed	0.663	0.431	0.894
Baird's sparrow ^a	11	Grazed	0.539	0.229	0.850
	28	Ungrazed	0.172	-0.016	0.328
Vesper sparrow ^b	19	Grazed	0.395	0.116	0.675
	25	Ungrazed	0.289	0.097	0.482
Lark bunting ^b	36	Grazed	0.486	0.278	0.693
	15	Ungrazed	0.900	0.736	1.063
Chestnut-collared longspur ^b	63	Grazed	0.257	0.140	0.373
	14	Ungrazed	0.244	0.032	0.456

^a Includes year and date covariates.

^b Includes date covariates.

Discussion

Nest Site Selection

All 5 species selected for greater litter depth and vegetation density than was generally available. This is consistent with the results of other studies (Davis 2005, Dieni and Jones 2003). There was no overlap in the 90% confidence intervals for vegetation density at nest and random locations for any of the 5 species. This was also the case for nest litter depth at Sprague's pipit, vesper sparrow, and lark bunting nests. This indicates that all 5 species were selecting for a relatively narrow gradient of dense vegetative cover.

Vegetation Structure and Nesting Success

My results do not support the hypothesis that nesting success would be higher for nests located in greater cover due to decreased risk of predation. There was no effect of vegetation structure on vesper sparrow, lark bunting, or chestnut-collared longspur nesting success. Sprague's pipit nesting success declined with increased vegetation density and litter depth. Effects of vegetation variables that were not included in the model may have driven the effects of vegetation on Sprague's pipit nesting success. Litter depth was correlated with shrub cover, which has been associated with reduced nesting success (With 1994). Regardless, the results suggest that nest site vegetation structure influenced Sprague's pipit nesting success in the study area.

Sprague's pipits may be selecting for nest sites that are optimal over the long-term (Clark and Shutler 1999) but were sub-optimal over the years of the study. Small mammals are associated with greater cover (Murray and Vestal 1979, With 1994, Johnson and Horn 2008) and their populations can fluctuate dramatically from one year to the next (Bowman et al. 2001, Poulin et al. 2001). Small mammal populations may

have been high during the years of the study, resulting in higher risk of predation for Sprague's pipit nests located in denser cover.

The lack of effects of vegetation structure on chestnut-collared longspur nesting success is consistent with the results of a study in mixed-grass prairie in Alberta (Koper and Schmiegelow 2007). However, Jones and Dieni (2007) found a weak negative relationship between concealment and chestnut-collared longspur nesting success in Montana. Davis (2005) found a positive relationship between increased visibility and chestnut-collared longspur nesting success in southern Saskatchewan, although the 90% confidence limit included zero. While I found no effects for vesper sparrow or lark bunting, a study in North Dakota found that vesper sparrow nesting success increased with increased concealment (Grant et al. 2006) and a study in southern mixed-grass prairie in Oklahoma found that successful lark bunting nests had greater litter cover than unsuccessful nests (Lusk et al. 2003).

There are different ways to interpret the lack of effects of vegetation structure on nesting success for these species. One is that low sample sizes prevented the models from detecting effects of vegetation structure. However, in the case of chestnut-collared longspur, I had a large sample size so I should have been able to detect effects if they were present. One possibility is that selection of a relatively narrow gradient of vegetation structure by these species results in a similar risk of predation across nest sites. Alternatively, the relatively homogenous vegetation in this system may support similar predator communities and predator movement across the landscape, resulting in a similar risk of nest predation regardless of nest placement. Finally, predation risk may be similar across nests if nest site vegetative cover does not act to camouflage nests from predators.

Studies on the effects of nest site vegetation structure on nesting success in mixed-grass prairie suggest that the role of nest-site vegetation structure in nesting success may be less important than other factors. Nesting success can vary across years (Davis 2005), possibly reflecting fluctuations in predation pressures (Clark and Shutler 1999). Seasonality also affects nesting success, possibly through seasonal changes in vegetative cover and predation pressure (Grant et al. 2005). Nest age influences predation risk as adult behaviour differs between stages and nestling noise and activity can draw attention to the nest (Haskell 1994, Grant et al. 2005). Vegetation structure at the patch or landscape level may affect nesting success through its influence on predator abundance and movement through an area (Johnson and Temple 1990, Johnson and Horn 2008). As well, the wide range of predators present in this ecosystem may make it difficult for birds to select safe nest sites (Filliater et al. 1994, Dion et al. 2000). Different predators have varying search strategies and nest sites may reduce predation by some predators and not others (Filliater et al. 1994). Birds may have responded to the difficulty of locating safe nest sites by selecting sites that maximize microclimatic benefits (Nelson and Martin 1999). A study in an agricultural field in South Dakota found a significant positive correlation between lark bunting nestling survival and cover from above (Pleszczyńska 1978). This was attributed to improved microclimatic conditions with increased shading of the nest (Pleszczyńska 1978).

Cattle Grazing and Nesting Success

Cattle grazing appeared to have little direct impact on breeding songbirds in this region. There was only one known case of nest failure due to cattle trampling during the 2 years of the study. However, cattle may depredate nests (Nack and Ribic 2005) and I was

unable to distinguish between predation by cattle and other predators. In addition, predators may consume the contents of nests following trampling (Fondell and Ball 2004). Higher rates of trampling in some studies (e.g. LaPointe et al. 2000, Renfrew and Ribic 2003) may reflect higher stocking rates or grazing intensities than were present in the current study or are typical of grazing intensities in northern mixed-grass prairies.

There was no effect of grazing on nesting success of any of the 5 species in the study. My results do not support the hypothesis that nesting success would vary between ungrazed prairie and prairie grazed at low-moderate intensity. Grazing at low-moderate intensity appears to have had little impact on generally available vegetation, as there were few differences in the vegetation at random locations near nests in grazed and ungrazed prairie. This may allow birds to find nest sites of similar quality in both habitats. Predator communities may also be similar in grazed and ungrazed habitat if low-moderate intensity grazing has little impact on vegetation structure (Grant et al. 1982).

The results are consistent with a study in primarily non-native prairie in Montana that found that Western meadowlark and Savannah sparrow had similar rates of nest predation in grazed and ungrazed plots (Fondell and Ball 2004). While other studies have found higher nesting success in ungrazed prairie (e.g. Temple et al. 1999, Sutter and Ritchison 2005), this may reflect higher grazing intensities that have a larger effect on vegetation structure than the low-moderate intensity grazing in the current study.

Nesting Success

Sprague's pipit nesting success was much higher than the 24% reported for southern Saskatchewan by Davis (2003) and was relatively high for prairie birds (25-50%; Vickery et al. 1992, Martin 1995). This suggests that the study area provides high

quality nesting habitat for Sprague's pipits. Baird's sparrow nesting success in other studies was intermediate to that found in grazed and ungrazed prairie in the current study: 37% in southwestern Manitoba (Davis and Sealy 1998) and 21.7% in southern Saskatchewan (Davis 2003). Grant et al. (2006) reported similar nesting success (44.9%) for vesper sparrows in North Dakota. Koper and Schmiegelow (2007) reported slightly lower daily nest survival (0.935) for vesper sparrows in Alberta. Lark bunting nesting success was higher than that reported for early nests (30.7%) and later nests (31.7%) in short-grass prairie in northeast Colorado (Yackel Adams et al. 2007). Koper and Schmiegelow (2007) reported similar daily nest survival (0.935) for chestnut-collared longspur in Alberta. Chestnut-collared longspur nesting success was also similar in southern Saskatchewan (21.6%; Davis 2003). Differences in nesting success across studies may reflect variations in climatic conditions, habitat, predator communities, and land management practices (Renfrew and Ribic 2003). Whether the level of nesting success observed in this study is sufficient to maintain stable populations in the study area without immigration depends on seasonal fecundity, annual adult survival, and annual juvenile survival (Yackel Adams et al. 2007).

Study Limitations

Fates of nests from the same nest-searching plots were assumed independent. This approach is similar to that of other recent studies (Koper and Schmiegelow 2007, Fondell and Ball 2004, Dinsmore et al. 2002). However, if more than one nest was located within the territory of a single predator, then their fates may have been correlated.

Caution is required in interpreting the results because the unpredictable nature of weather in the prairies means that they may reflect responses to short-term climatic

variations and associated variation in vegetation structure, prey, and predator abundance rather than long-term trends (Van Horne 1983, Cody 1985). As well, other factors that I did not measure, such as landscape vegetation structure and predator community composition and abundance, may have a greater influence on nesting success than nest site vegetation structure or grazing.

In the spring of 2008, cattle were reintroduced to fenced pastures in GNPC to monitor the effects of grazing intensity on ecosystem health and cattle production (Henderson 2006). Three pastures were retained as ungrazed controls while the others were subjected to a range of grazing intensities ranging from light to heavy (Henderson 2006). The long-term study, with its larger dataset and wider range of grazing intensities, will be better equipped to provide recommendations for future land management and policy directions.

This is the first study to compare songbird nesting success in season-long grazed and ungrazed mixed-grass prairie. Further research is essential for effective management of habitat for declining prairie songbird populations. Horned lark, Savannah sparrow, and Western meadowlark nested in the study area and few studies have examined the effects of cattle grazing on these species (e.g. Fondell and Ball 2004, Koper and Schmiegelow 2007). Research comparing nesting success under a range of grazing intensities is required to determine optimum intensities for songbird nesting success. Study in other regions is also required as variable climatic conditions and predator communities (Renfrew and Ribic 2003) may result in different effects of the same grazing intensity. By combining research across regions, we can determine whether management recommendations can be based on regional patterns or whether local studies are required.

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3. MANAGEMENT IMPLICATIONS

Introduction

Wildlife management is a concern for conservation groups and Provincial and Federal governments that own and manage native mixed-grass prairie. As of 2003, 42% of the remaining native prairie in Saskatchewan was included in a conservation management program (Gauthier and Wiken 2003). As of 2005, Grasslands National Park of Canada (GNPC) in Saskatchewan protected 49,730 ha of native mixed-grass prairie, and will cover an anticipated 90,640 ha of land when complete (Parks Canada 2005, 2008a). Parks Canada's mandate includes the maintenance of ecological integrity within Canada's national parks and protected areas (Parks Canada 2008b). The Prairie Farm Rehabilitation Administration (PFRA) manages 929,000 ha of community pasture throughout the country, 84% of which is native prairie (Luciuk et al. 2003). This includes 592,967 ha of native prairie in Saskatchewan (Luciuk et al. 2003). PFRA has a multiple use mandate with priorities including livestock grazing and the conservation of plant and animal biodiversity (Prairie Farm Rehabilitation Administration 2006). Management of federal lands must also abide by the Species at Risk Act, which requires that managers maintain healthy populations and recover declining populations of species at risk (Agriculture and Agri-Foods Canada 2004). My research on the effects of cattle grazing on songbird nesting success in native mixed-grass prairie will assist in developing recommendations for management of native prairie for songbird populations.

Birds breeding in native mixed-grass prairie evolved with the disturbance created by grazing bison (*Bison bison*) and wildfire (Knopf and Samson 1997, Askins 2000). Cattle grazing may or may not be an appropriate replacement for the disturbance created

by these events. Nevertheless, grazing has been used as a tool for managing biodiversity and wildlife populations. In Saskatchewan, grazing is used to maintain desired vegetation structure in land planted for nesting cover as part of the North American Waterfowl Management Plan (Saskatchewan Watershed Authority 2009). As part of the Chase Lake Prairie Project in North Dakota, 27,785 ha of previously overgrazed prairie are managed under rotational grazing systems, benefiting ground-nesting birds (Kresl et al. 1996, United States Fish and Wildlife Service 2009).

Studies specific to mixed-grass prairie are required to determine whether grazing influences songbird nesting success. However, only a single study has examined songbird nesting success in native mixed-grass prairie and it examined the effects of timing of grazing rather than effects of traditional season-long grazing (Koper and Schmiegelow 2007). Little is known about effects of nest site vegetation structure and cattle grazing on the 5 species studied. The results of my study will assist managers at GNPC in determining whether grazing is an appropriate management tool for the park and will provide a point of comparison for other studies. Caution is required in making management recommendations based on this study, as sample sizes were small.

Results and Management Implications

Vegetation Structure

All 5 species selected for nest sites with taller and denser structure than average, suggesting that this type of habitat is important for nesting success. It may be important to ensure that preferred habitat is available for these species. Managers may be able to influence the availability of preferred nest sites by managing vegetation structure.

Grazing, fire, and mowing are tools that managers can use to manipulate vegetation structure.

Sprague's pipit was the only species for which there were effects of vegetation structure on nesting success. The negative trend in nesting success with increased vegetation density and litter depth was the opposite of that predicted. There are different ways to interpret this information. There may have been an intermediate level of litter depth and vegetation density that optimized Sprague's pipit nesting success.

Alternatively, environmental conditions may not have been conducive to high nesting success in dense vegetation during the years of the study or predators may have been abundance in this habitat during the study. Further research should be able to determine whether the negative impact of increased cover on Sprague's pipit nesting success is a long-term trend.

Grazing

The nesting success models did not find an effect of grazing on nesting success for the 5 study species. This indicates that effects of low-moderate intensity grazing on vegetation structure and predator communities are insufficient to influence nest predation risk relative to that in ungrazed prairie in the study area. It also indicates that grazing at this

intensity itself, independent of the effect that it has on vegetation structure, has no effect on nesting success. Low-moderate intensity cattle grazing may be compatible with management for these species in the study area. This information is especially important in the case of Sprague's pipits as information on land use practices that benefit this species is essential for recovery efforts (Environment Canada 2008).

The long-term adaptive management experiment at GNPC will provide the opportunity to study nesting success under a wide range of grazing intensities (Henderson 2006). Comparison with the results of the current study will permit the creation of guidelines for managing native mixed-grass prairie for grassland songbirds.

Discussion

Low-moderate intensity grazing did not influence nesting success in this study. This indicates that low-moderate intensity grazing may be compatible with management for breeding grassland songbirds in this region. This has implications for the management of existing conservation areas and future approaches to managing native mixed-grass prairie habitat on private and public lands.

Agriculture has great economic importance in this region. Allowing cattle grazing in protected areas, including GNPC, could have economic benefits in the form of revenue for conservation organizations and local ranchers who have access to the land to graze cattle. There may also be social benefits in the form of improved relationships between conservation organizations and ranchers. The economic benefit to ranchers may also help maintain communities in rural areas where populations are declining for economic reasons (Bryant and Joseph 2001).

Of the remaining native mixed-grass prairie in Saskatchewan, 58% is not managed under a specific conservation management program (Gauthier and Wiken 2003). If agricultural practices are compatible with wildlife conservation, then conservation organizations may be able to meet their objectives more effectively by promoting conservation on private lands. Ranchers who understand the value of biodiversity in the sustainability of their operations may be willing to alter their cattle management practices to promote biodiversity (Stinner et al. 1997). Conservation programs can also be implemented that reward ranchers for the conservation value of their land.

One approach is to use voluntary conservation agreements, where land remains in private ownership with land trusts or government agencies granted certain interests in the property, which restrict land use (Gustanski and Squires 2000). The landowner can be paid for entering the agreement or they can receive tax benefits (Rissman et al. 2007). In the case of managing prairie for grassland songbirds, the holder of the easement could restrict the landowner from ever cultivating existing native prairie and require specific stocking rates for grazing operations that create high quality habitat for grassland birds.

Another approach is to provide incentives for ranchers to maintain or create wildlife habitat on their land. Incentive programs can encourage ranchers to engage in practices that promote biodiversity. An example of such an approach is the alternate land use services (ALUS) program, which Prince Edward Island has adopted (Prince Edward Island 2008). This program offers incentives to farmers in recognition of the environmental services that they provide, including biodiversity (Prince Edward Island 2008).

An incentive program could be implemented in Saskatchewan to help conserve or create habitat for breeding grassland songbirds. Further research would be required to determine optimal grazing intensities that provide habitat for species of conservation concern. Guidelines could then be established that set out vegetation structure requirements or grazing intensities that create preferred nesting habitat for species of conservation concern. Participating ranchers would have their land monitored to determine whether their grazing practices create habitat consistent with the guidelines. If monitoring indicates that birds would benefit from reduced grazing intensity then ranchers could be paid to reduce the number of cattle that they graze on that land.

Approaches that allow ranchers to continue grazing their land while achieving conservation objectives have environmental, economic, and social benefits. Conservation organizations may be able to increase the overall amount of land managed under conservation programs if the cost of working with ranchers is less than the cost of purchasing and managing land specifically for the purpose of conservation.

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APPENDICES

Appendix A – Nesting Ecology

Introduction

There is limited information available on the nesting ecology of the 5 study species in this region (e.g. Sealy 1999). Results from this study may be of use to future researchers for comparative purposes. This section contains information on clutch size, hatch rates, and fledging rates, as well as information on the length of incubation and nestling periods, and brown-headed cowbird parasitism.

Methods

Data were collected using the methods described in chapter 2. The following describes the calculation of nesting ecology results. The mean number of eggs laid was only calculated for nests that were found during the laying or incubation stages as adults may remove infertile eggs from the nest following hatching (C.W. Huntley, personal communication in Shane 2000). Nests parasitized by brown-headed cowbirds were also excluded, as cowbirds are known to remove host eggs from nests (Sealy 1992). The mean number of eggs hatched was calculated for all nests and for those nests monitored during incubation that were known to have survived until the nestling stage. Mean fledging success per nest was calculated both for successful nests and for all nests with known fates (Winter et al. 2004).

Incubation periods were only calculated for nests found during the laying period that had known hatch dates. I used these restrictions, as my research permit did not permit candling of eggs, which would have provided more accurate estimates of the age of nests found during the incubation period (Lokemoen and Koford 1996). The mean

length of nestling periods was only calculated for those nests for which the hatch and fledge dates were known. A visit date was considered hatch day if a nest had partially hatched and more young were present at the following nest check. A visit date was considered the date of fledging if some young had fledged and other young were still in the nest and were found to have fledged by the next visit. As well, when nest checks occurred 2 days apart and cues indicated that the nest had fledged, the day in-between the 2 nest checks was considered the fledge date. Finally, a visit date was considered the date of fledging if fledglings were observed in the immediate vicinity of the nest (< 6 m). A previous study on post-fledging dispersal in lark buntings (Yackel Adams et al. 2001) found that the mean distance travelled the day of fledging was 27.4 m (SE \pm 9.2, range = 0.25-90 m, n = 13) and the mean distance travelled the following day was 53.9 m (SE \pm 8.7, range = 1-127 m, n = 17). Davis and Fisher (2009) found that the mean distance travelled by Sprague's pipits fledglings the day of fledging was 19 m (SE \pm 22, range = 0.1-54 m, n = 6) with a mean distance of 53 m travelled the following day (SE \pm 56, range = 3-123 m, n = 4). Assuming that other species follow a similar pattern, I could be reasonably confident that fledging occurred the day of the nest check or the previous day when nests were checked every 2 days.

Results

All 5 species generally laid 4 eggs (Table 12). Clutch sizes ranged from 2 to 6 eggs with Sprague's pipits showing the greatest variation in the number of eggs laid. The mean number of eggs hatched ranged from 3.2 to 4.0 (Tables 13 to 17). The mean number of young fledged per nest ranged from 0.7 to 2.9 for nests of all fates, while the mean number of young fledged from successful nests ranged from 2.7 to 3.7 (Tables 13 to 17).

Table 12. Clutch size of 5 grassland songbirds nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Species	Regime	Clutch size (%)					\bar{x}	SD	<i>n</i>
		2	3	4	5	6			
Sprague's pipit	Grazed	-	1 (7.6)	7 (53.8)	4 (30.8)	1 (7.7)	4.384	0.768	13
	Ungrazed	-	-	11 (64.7)	6 (35.3)	-	4.353	0.493	17
Baird's sparrow	Grazed	-	-	5 (55.6)	4 (44.4)	-	4.444	0.527	9
	Ungrazed	-	1 (4.3)	13 (56.5)	9 (39.1)	-	4.348	0.573	23
Vesper sparrow	Grazed	-	6 (37.5)	8 (50.0)	2 (12.5)	-	3.750	0.683	16
	Ungrazed	-	3 (17.6)	9 (52.9)	5 (29.4)	-	4.118	4.118	17
Lark bunting	Grazed	-	9 (33.3)	15 (55.5)	3 (11.1)	-	3.778	0.641	27
	Ungrazed	-	1 (7.1)	12 (85.7)	1 (7.1)	-	4.000	0.392	14
Chestnut-collared longspur	Grazed	1 (1.9)	11 (21.2)	35 (67.3)	5 (9.6)	-	3.846	0.607	52
	Ungrazed	1 (7.1)	3 (21.4)	10 (71.4)	-	-	3.643	0.633	14

Table 13. Hatching success and fledging success of Sprague's pipits nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Regime	Eggs hatched/nest ^a				Eggs incubated full term that hatched/nest ^b				Young fledged/nest			Young fledged/successful nest		
	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	<i>n</i>	\bar{x}	SD	<i>n</i>
Grazed	3.462	1.330	78.95	13	3.750	0.866	88.2	12	2.923	1.605	13	3.455	1.036	11
Ungrazed	3.588	1.004	82.43	17	3.588	1.004	82.4	17	2.588	1.906	17	3.667	0.985	12

^a Only calculated for nests that were monitored during the incubation period.

^b Only calculated for nests that were monitored during both the incubation and the nestling periods.

Table 14. Hatching success and fledging success of Baird's sparrows nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Regime	Eggs hatched/nest ^a				Eggs incubated full term that hatched/nest ^b				Young fledged/nest			Young fledged/ successful nest		
	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	<i>n</i>	\bar{x}	SD	<i>n</i>
Grazed	3.111	2.028	70	9	4.000	1.155	87.5	7	1.909	1.921	11	3.500	0.837	6
Ungrazed	2.870	1.914	66	23	3.882	3.882	88	17	0.741	1.509	27	3.333	1.211	6

^aOnly calculated for nests that were monitored during the incubation period.

^bOnly calculated for nests that were monitored during both the incubation and the nestling periods.

Table 15. Hatching success and fledging success of vesper sparrows nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Regime	Eggs hatched/nest ^a				Eggs incubated full term that hatched/nest ^b				Young fledged/nest			Young fledged/ successful nest		
	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	<i>n</i>	\bar{x}	SD	<i>n</i>
Grazed	2.688	1.621	71.67	16	3.308	1.032	86	13	2.385	1.758	13	3.444	0.726	9
Ungrazed	3.235	1.715	78.57	17	3.929	0.829	94.4	14	1.214	1.968	14	3.143	1.574	7

^aOnly calculated for nests that were monitored during the incubation period.

^bOnly calculated for nests that were monitored during both the incubation and the nestling periods.

Table 16. Hatching success and fledging success of lark buntings nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Regime	Eggs hatched/nest ^a				Eggs incubated full term that hatched/nest ^b				Young fledged/nest			Young fledged/ successful nest		
	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	<i>n</i>	\bar{x}	SD	<i>n</i>
Grazed	2.688	1.621	87.25	16	3.560	0.712	94.7	25	2.087	1.756	23	3.200	1.014	15
Ungrazed	3.235	1.715	85.71	17	3.429	1.016	85.7	14	2.643	1.499	14	3.083	1.084	12

^aOnly calculated for nests that were monitored during the incubation period.

^bOnly calculated for nests that were monitored during both the incubation and the nestling periods.

Table 17. Hatching success and fledging success of chestnut-collared longspurs nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Regime	Eggs hatched/nest ^a				Eggs incubated full term that hatched/nest ^b				Young fledged/nest			Young fledged/ successful nest		
	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	%	<i>n</i>	\bar{x}	SD	<i>n</i>	\bar{x}	SD	<i>n</i>
Grazed	2.865	1.60	74.50	52	3.548	0.832	91.4	42	1.400	1.646	40	2.947	1.026	19
Ungrazed	2.462	1.561	66.66	13	3.182	0.751	86.5	10	1.000	1.414	8	2.667	0.577	3

^aOnly calculated for nests that were monitored during the incubation period.

^bOnly calculated for nests that were monitored during both the incubation and the nestling periods.

Incubation periods were known for 3 nests. A vesper sparrow nest had an incubation period of 11 days. One chestnut-collared longspur nest had an incubation period of 10 days while another had an incubation period of 14 days. Nestling periods were known for 12 nests and ranged from 8 to 11 days (Table 18).

Table 18. Nestling periods of 5 grassland songbirds nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Species	Nestling Period in Days			
	8	9	10	11
Sprague's pipit				1
Baird's sparrow			2	
Vesper sparrow	1		1	
Lark bunting		2	2	
Chestnut-collared longspur			1	2

Brown-headed cowbirds parasitized 2 Baird's sparrow and 5 vesper sparrow nests in ungrazed prairie and 3 vesper sparrow nests and 5 lark bunting nests in grazed prairie (Table 19). In 2007, a lark bunting nest was found containing 4 eggs with a cowbird egg lying 10-cm from the nest. The number of cowbird eggs present in nests monitored during laying and/or incubation ranged from 1 to 3. Of the 3 host species, only vesper sparrow nests fledged cowbird young (Table 20).

Table 19. Nests parasitized by brown-headed cowbirds in grazed and ungrazed native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Species	Regime	2006	2007
Baird's sparrow	Ungrazed		2
Vesper sparrow	Grazed	1	2
	Ungrazed	2	3
Lark bunting	Grazed	1	4

Table 20. Frequency and intensity of cowbird parasitism and cowbird productivity in nests of 3 songbird species nesting in native mixed-grass prairie in southwestern Saskatchewan, 2006 and 2007.

Species	Nests parasitized (%)	Total number of cowbird eggs laid	Number of cowbird eggs laid/parasitized nest		Parasitized nests with >1 cowbird egg laid (%)	Cowbird eggs laid that fledged (%)	Cowbirds fledged/parasitized nest		Number of cowbirds fledged/successful parasitized nest ^b	
	<i>n</i>	<i>n</i>	\bar{x}	SD	<i>n</i>	<i>n</i>	\bar{x}	SD	\bar{x}	SD
Baird's sparrow (<i>n</i> = 39)	2 (5.1)	2	2	0	2 (100)	0 (0)	0	0	0	0
Vesper sparrow (<i>n</i> = 44)	8 (18.2)	14	2	0.577	7 (85.7)	6 (42.9)	0.75	1.00	1.50	1.00
Lark bunting (<i>n</i> = 51)	5 (9.8)	6	1.2	0.447	5 (20.0)	0 (0)	0	0	0	0

^aFledged at least one host or cowbird young.

Study Limitations

It is possible that nests were force-fledged as researchers approached the nest during later nest checks, resulting in a shorter nestling period than would occur naturally. As well, using the intermediate date between nest checks may result in nestling periods appearing a day shorter or longer than they actually were. In the case of the vesper sparrow nest that had an 8 day nestling period, the nest could have fledged earlier on the day of the final nest check, as the nest was not checked until 1325. That would have resulted in a 9-day nestling period. The nest was located under a shrub next to an area relatively bare of vegetation (based on the map of the nest), reducing the likelihood of my approach causing force-fledging and my failing to notice said force-fledging. In the case of lark buntings, it was my observation that they were developing faster and had a shorter nestling period than the other species. I tried to check lark bunting nests every 2 days during the entire nestling period whereas I only did this later in the nestling period for the other 4 species. That being said, one lark bunting with a 9-day nestling period was checked at 1600 on the day of fledging. Two nestlings were still present and 1 fledgling was observed 5-m from the nest. The fledgling could have force-fledged as I approached the nest. In the case of the other lark bunting nest with a 9-day nestling period, the nest checks were 2 days apart and the final nest check occurred at 0950. One dead nestling remained in the nest at that time. This was an early nest check, so I am relatively confident that the other young fledged the previous day and a 9-day nestling period is accurate.

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Appendix B

Vegetation structure for all songbird species combined in upland habitat ($n = 148$) compared with lowland habitat ($n = 115$) in southwestern Saskatchewan, Canada 2006 and 2007.

Vegetation Variable	Location	\bar{x}	SE	LCL ^a	UCL ^b
Vegetation Density	Upland ($n = 146$)	2.062	0.081	1.928	2.196
	Lowland	2.722	0.115	2.530	2.913
	P ^c	≤0.001			
Visibility From Above	Upland ($n = 145$)	67.276	2.292	63.481	71.071
	Lowland ($n = 114$)	57.877	2.399	53.899	61.856
	P ^c	0.005			
Litter Depth	Upland	17.973	1.279	15.857	20.089
	Lowland	21.852	1.638	19.136	24.569
	P ^c	0.055			

^a Lower 90% CL.

^b Upper 90% CL.

^c Calculated using ANOVA.

Appendix C

Vegetation structure at Sprague's pipit nests compared with random locations in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 36$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Nest	2.243	1.978	2.508
	Random	1.271	1.011	1.531
	P ^d	≤0.001		
Shrub Cover	Nest	2.799	1.9347	3.662
	Random	2.715	1.884	3.546
	P ^d	0.865		
Forb Cover	Nest	2.736	1.87	3.603
	Random	2.559	1.821	3.297
	P ^d	0.718		
Live Grass Cover	Nest	25.979	21.994	29.964
	Random	19.6145	16.493	22.736
	P ^d	0.004		
Dead Grass Cover	Nest	41.257	33.863	48.651
	Random	36.601	29.783	43.419
	P ^d	0.2368		
Moss Cover	Nest	85.424	80.436	90.411
	Random	84.837	78.493	91.180
	P ^d	0.826		
Bare Ground ^a	Nest	0.044	0.01	0.078
	Random	0.058	0.007	0.109
	P ^d	0.578		
Litter Depth	Nest	18.167	13.559	22.774
	Random	10.292	7.526	13.058
	P ^d	0.012		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at Baird sparrow nests in southwestern Saskatchewan, compared with random locations in southwestern Saskatchewan, Canada 2006 and 2007 (n = 43).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Nest	2.940	2.734	3.147
	Random	2.0233	1.7345	2.312
	P^d	≤0.001		
Shrub Cover	Nest	3.488	1.807	5.170
	Random	3.276	2.206	4.346
	P^d	0.834		
Forb Cover	Nest	2.977	2.192	3.761
	Random	2.849	2.006	3.692
	P^d	0.8022		
Live Grass Cover	Nest	37.267	32.209	42.326
	Random	30.494	25.186	35.802
	P^d	0.008		
Dead Grass Cover	Nest	64.453	58.355	70.552
	Random	52.576	45.331	59.820
	P^d	0.003		
Moss Cover	Nest	63.895	54.684	73.107
	Random	78.038	71.391	84.684
	P^d	0.008		
Bare Ground ^a	Nest	0.004	0.001	0.007
	Random	0.0207	0.005	0.036
	P^d	0.068		
Litter Depth	Nest	29.837	25.067	34.608
	Random	22.407	17.350	27.463
	P^d	0.058		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at vesper sparrow nests compared with random locations in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 44$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Nest	3.170	2.853	3.488
	Random	1.344	1.0270	1.661
	P^d	≤0.001		
Shrub Cover	Nest	13.563	11.227	15.898
	Random	5.489	3.763	7.215
	P^d	≤0.001		
Forb Cover	Nest	3.301	2.029	4.573
	Random	3.392	2.361	4.423
	P^d	0.9213		
Live Grass Cover	Nest	27.932	23.550	32.314
	Random	18.295	15.302	21.289
	P^d	≤0.001		
Dead Grass Cover	Nest	39.159	33.133	45.185
	Random	29.582	23.038	36.127
	P^d	0.022		
Moss Cover	Nest	64.082	55.007	73.158
	Random	68.25	58.552	77.948
	P^d	0.2875		
Bare Ground ^a	Nest	0.097	0.025	0.168
	Random	0.218	0.128	0.307
	P^d	0.003		
Litter Depth	Nest	23.818	19.665	27.972
	Random	8.909	6.923	10.895
	P^d	≤0.001		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at lark bunting nests compared with random locations in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 53$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Nest	2.736	2.472	3.000
	Random	0.858	0.624	1.093
	P ^d	≤0.001		
Shrub Cover	Nest	13.509	11.801	15.218
	Random	5.887	4.897	6.877
	P ^d	≤0.001		
Forb Cover	Nest	1.241	0.779	1.702
	Random	1.363	0.915	1.811
	P ^d	0.6969		
Live Grass Cover	Nest	28.415	23.544	33.286
	Random	24.0047	19.402	28.607
	P ^d	0.115		
Dead Grass Cover	Nest	37.231	31.203	43.259
	Random	26.019	21.244	30.793
	P ^d	0.005		
Moss Cover	Nest	75.462	68.888	82.037
	Random	72.943	65.827	80.060
	P ^d	0.486		
Bare Ground ^a	Nest	0.111	0.055	0.167
	Random	0.166	0.099	0.232
	P ^d	0.103		
Litter Depth ($n = 52$)	Nest	21.231	17.219	25.242
	Random	8.5	6.034	10.966
	P ^d	≤0.001		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at chestnut-collared longspur nests compared with random locations in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 87$)

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Nest	1.456	1.354	1.559
	Random	0.804	0.676	0.932
	P ^d	≤0.001		
Shrub Cover	Nest	3.609	2.893	4.325
	Random	2.761	2.138	3.3848
	P ^d	0.1086		
Forb Cover	Nest	2.570	2.034	3.104
	Random	2.527	2.106	2.950
	P ^d	0.860		
Live Grass Cover	Nest	20.940	18.518	23.361
	Random	19.549	17.01	22.081
	P ^d	0.263		
Dead Grass Cover	Nest	22.902	20.187	25.617
	Random	22.8247	19.424	26.226
	P ^d	0.968		
Moss Cover	Nest	90.356	88.205	92.508
	Random	90.191	87.872	92.510
	P ^d	0.908		
Bare Ground ^a	Nest	0.018	0.009	0.027
	Random	0.028	0.011	0.044
	P ^d	0.152		
Litter Depth ($n = 85$)	Nest	12.176	10.144	14.209
	Random	9.556	6.514	12.598
	P ^d	≤0.001		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Appendix D

Vegetation structure at random locations near Sprague's pipit nests in grazed and ungrazed prairie in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 31$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Grazed	1.392	0.949	1.835
	Ungrazed	1.185	0.846	1.523
	P^d	0.521		
Shrub Cover	Grazed	2.925	1.056	4.794
	Ungrazed	2.565	1.877	3.254
	P^d	0.724		
Forb Cover	Grazed	3.5	2.181	4.819
	Ungrazed	1.887	1.045	2.728
	P^d	0.083		
Live Grass Cover	Grazed	24.625	18.014	31.236
	Ungrazed	16.036	13.816	18.256
	P^d	0.020		
Dead Grass Cover	Grazed	30.642	19.485	41.798
	Ungrazed	40.857	31.960	49.755
	P^d	0.221		
Moss Cover	Grazed	75.208	60.718	89.698
	Ungrazed	91.714	88.843	94.586
	P^d	0.028		
Bare Ground ^a	Grazed	0.115	-0.01	0.239
	Ungrazed	0.0169	0.004	0.030
	P^d	0.112		
Litter Depth	Grazed	9.567	5.127	14.007
	Ungrazed	10.810	7.018	14.601
	P^d	0.713		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at random locations near Baird's sparrow nests in grazed and ungrazed prairie in southwestern Saskatchewan, Canada 2006 and 2007 (n = 43).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Grazed	2.94	1.450	2.595
	Ungrazed	2.023	1.668	2.369
	P^d	0.991		
Shrub Cover	Grazed	1.534	0.132	2.936
	Ungrazed	3.974	2.647	5.3
	P^d	0.092		
Forb Cover	Grazed	5.193	2.345	8.042
	Ungrazed	2.093	1.559	2.627
	P^d	0.005		
Live Grass Cover	Grazed	41.284	26.991	55.577
	Ungrazed	27.22	21.983	32.456
	P^d	0.050		
Dead Grass Cover	Grazed	60.477	43.062	77.892
	Ungrazed	50.088	42.0	58.176
	P^d	0.348		
Moss Cover	Grazed	77.284	61.280	93.288
	Ungrazed	77.731	70.263	85.200
	P^d	0.964		
Bare Ground ^a	Grazed	0.001	-0.0006	0.004
	Ungrazed	0.028	0.007	0.048
	P^d	0.215		
Litter Depth	Grazed	20.455	12.613	28.297
	Ungrazed	23.078	16.662	29.495
	P^d	0.652		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at random locations near vesper sparrow nests in grazed and ungrazed prairie in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 41$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Grazed	1.151	0.550	1.753
	Ungrazed	1.49	1.142	1.838
	P^d	0.380		
Shrub Cover	Grazed	6.197	2.877	9.518
	Ungrazed	4.95	3.071	6.829
	P^d	0.554		
Forb Cover	Grazed	4.263	2.426	6.100
	Ungrazed	2.73	1.516	3.944
	P^d	0.238		
Live Grass Cover	Grazed	17.875	13.209	22.541
	Ungrazed	18.615	14.474	22.756
	P^d	0.839		
Dead Grass Cover	Grazed	18.441	12.052	24.830
	Ungrazed	38.05	28.201	47.899
	P^d	0.012		
Moss Cover	Grazed	69.026	54.599	83.454
	Ungrazed	60.325	48.097	72.553
	P^d	0.432		
Bare Ground ^a	Grazed	0.242	0.079	0.405
	Ungrazed	0.199	0.092	0.306
	P^d	0.708		
Litter Depth	Grazed	6.237	4.656	7.818
	Ungrazed	10.94	7.725	14.155
	P^d	0.047		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at random locations near lark bunting nests in grazed and ungrazed prairie in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 53$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Grazed	0.931	0.627	1.234
	Ungrazed	0.675	0.332	1.018
	P^d	0.341		
Shrub Cover	Grazed	6.487	5.332	7.642
	Ungrazed	4.367	11.258	18.809
	P^d	0.115		
Forb Cover	Grazed	1.441	0.882	1.999
	Ungrazed	1.167	0.375	1.959
	P^d	0.627		
Live Grass Cover	Grazed	26.809	21.396	32.222
	Ungrazed	16.9	8.064	25.736
	P^d	0.108		
Dead Grass Cover	Grazed	28.033	22.724	33.342
	Ungrazed	20.917	10.089	31.744
	P^d	0.314		
Moss Cover	Grazed	69.464	60.354	78.573
	Ungrazed	81.758	71.480	92.037
	P^d	0.130		
Bare Ground ^a	Grazed	35.092	0.091	0.259
	Ungrazed	7.167	0.0316	0.253
	P^d	0.686		
Litter Depth ($n = 52$)	Grazed	9.041	5.705	12.376
	Ungrazed	7.167	4.425	9.908
	P^d	0.569		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.

Vegetation structure at random locations near chestnut-collared longspur nests in grazed and ungrazed prairie in southwestern Saskatchewan, Canada 2006 and 2007 ($n = 87$).

Vegetation Variable	Location	\bar{x}	LCL ^b	UCL ^c
Vegetation Density	Grazed	0.743	0.604	0.873
	Ungrazed	1.006	0.668	1.344
	P^d	0.152		
Shrub Cover	Grazed	2.621	2.111	3.163
	Ungrazed	3.231	1.051	5.411
	P^d	0.497		
Forb Cover	Grazed	2.497	1.970	3.002
	Ungrazed	2.625	1.976	3.274
	P^d	0.833		
Live Grass Cover	Grazed	21.063	18.004	24.214
	Ungrazed	14.475	11.177	17.773
	P^d	0.068		
Dead Grass Cover	Grazed	21.097	17.290	24.540
	Ungrazed	28.613	19.978	37.247
	P^d	0.179		
Moss Cover	Grazed	89.873	87.484	92.979
	Ungrazed	91.256	87.015	95.497
	P^d	0.643		
Bare Ground ^a	Grazed	0.029	0.007	0.047
	Ungrazed	0.023	-0.002	0.048
	P^d	0.802		
Litter Depth ($n = 85$)	Grazed	9.054	5.261	12.847
	Ungrazed	11.025	6.709	15.341
	P^d	0.651		

^a I used an arcsine transformation to transform % bare ground to normalize data.

^b Lower 90% CL.

^c Upper 90% CL.

^d Calculated using paired t-tests.