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Effects of natural gas development on three grassland bird species in CFB Suffield, Alberta, Canada

by

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Abstract

I investigated the effect of energy sector development and introduced crested wheatgrass (*Agropyron cristatum*) on grassland birds on Canadian Forces Base Suffield. I conducted point counts and mapped breeding territories in 2007 and 2008 for Savannah sparrows (*Passerculus sandwichensis*), chestnut-collared longspurs (*Calcarius ornatus*), and Sprague's pipits (*Anthus spragueii*). I found that Savannah sparrows favored areas with taller vegetation, human disturbances and crested wheatgrass in both years. Longspurs used shorter vegetation and in were tolerant of disturbance. Crested wheatgrass was avoided by longspurs in both years. Pipit territories contained similar vegetation to longspurs, were sensitive to disturbance, and avoided placing territories in areas containing crested wheatgrass or trails in both years. Well sites, pipelines and junctions were not avoided by the three species. My research suggests that reducing the number of trails and the spread of crested wheatgrass will increase habitat availability for sensitive species of grassland birds.

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Chapter 1

Introduction

Grassland birds have suffered greater population declines in more species than any other avian guild in North America (Sauer et al., 2008). Steady declines, especially in the last 20 years (Sauer et al., 2008), have become a serious concern for biologists despite the majority of habitat loss occurring in the late 1800s and early 1900s (as reviewed by Samson et al., 2004). In order to preserve remaining populations of grassland birds, research has focused on the effects of fragmentation and degradation of the remaining native grasslands (as reviewed by Samson et al., 2004; Askins et al., 2007). Researchers throughout the prairies have attempted to define the effect of edge and patch size upon bird populations (as reviewed by Askins et al., 2007). The introduction of non-native grass species that are associated with edge habitats has potentially aggravated the loss of grassland bird populations (Wilson and Belcher, 1989; Sutter and Brigham, 1998; Madden et al., 2000; Lloyd and Martin, 2005; Flanders et al., 2006). There remains as little as 43% of native prairie in Alberta (~ 160,000 km^2) and only 1.1% (~1,800 km^2) of that is managed for conservation purposes (Gauthier and Wiken, 2003).

Despite the prevalence of oil and gas development in the Canadian prairies, the effects of this industry on grassland birds has rarely been studied (Askins et al., 2007). Infrastructure associated with natural gas extraction in this study consists primarily of below ground well sites, pipelines, junctions and access trails for well maintenance. These disturbances may persist for more than 30 years after their initial creation, such as in the case of pipelines (Rowland, 2008). Studies that have investigated the effects of oil and gas development in open country habitat have found that songbirds avoid roads, off-road vehicle trails, seismic lines, and wells (Ingelfinger and Anderson 2004, Ashenhurst and Hannon, 2008, Linnen 2008), and populations decrease with increased infrastructure and activity (Dale et al., 2009).

In this study, I investigated the effects of oil and gas development on the occurrence of birds at point counts, placement of territories, and nesting success of three grassland species. Three study species, Savannah sparrow (*Passerculus sandwichensis*), chestnut-collared longspur (*Calcarius ornatus*) and Sprague's pipit (*Anthus spragueii*), were chosen to represent different responses to vegetation and human disturbances found on Canadian Forces Base Suffield in southeast Alberta.

Study area

On Canadian Forces Base (CFB) Suffield, 458 km^2 of mixed and short grass prairie has been set-aside in a National Wildlife Area (NWA) to preserve and protect native habitat. There are 20 "species at risk" listed under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) found in the NWA. The NWA was officially established in 2003 and has been off-limits to military troop activities since 1971. Soils are composed primarily of orthic brown chernozems formed on glacial tills or sand dunes (Rowland, 2008). Cattle currently graze on the southern block of the NWA at low densities to simulate the grazing pressure of bison that no longer occur on the base (CEAR, 2007).

The first well sites were established in the NWA in 1975 and currently there are 1154 wells, with the structure mainly below ground. The average number of wells was originally set at 4 wells/square mile but currently ranges as high as 16 wells/sq. mile although the current average in the NWA is 8 wells/sq. mile. The energy sector recently applied for more wells to be drilled to raise the density of well sites to approximately 16 wells/ sq. mile (CEAR, 2009). This request was denied due to lack of information regarding on the impact of development on sensitive species, including Sprague's pipit (CEAR, 2009).

A bird inventory began on CFB Suffield in 1994 and 1995 as part of a larger project to determine which species occurred on the base. Annual bird monitoring began in 2000 and continues to the present. Annual bird surveys are performed between mid-May to early June on both the north and south block of the NWA. These data were recently used to develop a series of habitat models using landscape variables (Wiens et al., 2008) and to determine how well-density affected abundance of grassland songbirds (Dale et al., 2009). The latter study found that increased well density was associated with increased abundance of Savannah sparrows and decreased abundance of Sprague's pipit. Linnen (2008) determined that traditional oil wells on CFB Suffield, and associated trails, were avoided by Sprague's pipit and chestnut-collared longspur. Despite this, the effects of individual components of infrastructure associated with the wells, including trails, exotic species spread, pipelines and vehicle traffic on the grassland birds are poorly understood.

Crested wheatgrass

Crested wheatgrass (*Agropyron cristatum*) is a Eurasian C_3 grammanoid that is persistent where it has been planted throughout the North American prairies, primarily as forage for cattle (Henderson and Naeth, 2005; Ambrose and Wilson, 2003). Crested wheatgrass is taller, has more standing dead vegetation, and leaves more bare ground than native vegetation in the mixed-grass prairies (Sutter and Brigham, 1998; Christian and Wilson, 1999; but see Lloyd and Martin, 2005). It is associated with lower native vegetation diversity (Christian and Wilson, 1999; Heidinga and Wilson, 2002; Henderson and Naeth, 2005), low arthropod diversity (McIntyre and Thompson, 2003; Flanders et al., 2006), decreased abundance of grassland birds (Sutter and Brigham, 1998), may alter grassland bird diversity (Chapman et al., 2004) and lowers nesting success of some species (Lloyd and Martin, 2005). Crested wheatgrass spreads primarily through the dispersal of seeds (as reviewed by Henderson and Naeth, 2005).

Crested wheatgrass is present on CFB Suffield as it was used to remediate areas following disruption by oil and gas disturbances. The presence of crested wheatgrass on CFB Suffield is of concern due to its spread to areas that had not been directly seeded with the species (Smith, 2007). Roads and trails can serve as vectors for the transportation of exotic species (Trombulak and Frissell, 2000; von der Lippe and Kowarik, 2007) and crested wheatgrass is commonly associated with drainage ditches alongside roads (Henderson and Naeth, 2005). As off-road vehicle trails are common throughout the NWA, there is a potential for crested wheatgrass to spread and affect breeding bird habitat.

Study species

Savannah sparrow

The Savannah sparrow is a small passerine in the family *Emberizidae* and is the only member of its genus found in North America (Wheelwright and Rising, 2008). There are 28 subspecies of *Passerculus sandwichensis* recognized in North America (Wheelwright and Rising, 2008). Based on the distribution the subspecies, the Savannah sparrows in this study were *P. s. nevadensis*. The breeding and wintering range for Savannah sparrows extends from the high arctic to Mexico and from the east to the west coast (Figure 1.1). Nesting occurs on the ground in open habitat throughout their range and typically occurs in tall, lush non-woody vegetation (as reviewed by Wheelwright and Rising, 2008).

The Savannah sparrow populations are significantly decreasing throughout its range in North America at a rate of 1.0% per year between 1966 and 2006 (Sauer et al., 2008). Breeding bird surveys in Alberta, however, have a non-significant rate of decline of 0.3% per year (Sauer et al., 2008).

Savannah sparrows have a wide geographic distribution and are tolerant of a range of vegetation conditions, including human disturbance (Wheelwright and Rising, 2008). They can be found in both native and non-native vegetation and restored prairie, such as the Conservation Reserve Program (CRP) in the United States (Fletcher and Koford, 2002) and planted pastures or the Permanent Cover

Program (PCP) in Canada (Sutter and Brigham, 1998; McMaster and Davis, 2001; McMaster et al., 2005). Throughout the prairies, Savannah sparrows do not appear to be sensitive to small habitat patch sizes (Madden et al., 2000; Davis, 2004; Koper and Schmiegelow, 2006) and are more common in taller planted vegetation found near roads or in hayfields in Saskatchewan (Dale et al., 1997; Sutter et al., 2000). In this thesis, I use the term “sensitive” to describe a species that is highly responsive to a given change in its habitat whereas “tolerant” denotes a species that does not change its behaviour noticeably in the face of habitat alteration.

Chestnut-collared longspur

The chestnut-collared longspur is a small passerine in the family *Emberizidae* with four species occurring within the genus *Calcaria* in North America (Hill and Gould, 1997). There are no recognized subspecies according to Hill and Gould (1997). *Calcarius ornatus* breeds throughout the short and mixed-grass prairie and overwinters in the southern U.S. and in Mexico (Figure 1.2). Nests are located on the ground in partially grazed or sparsely vegetated areas with shorter grasses and more bare ground than surrounding prairie (Hill and Gould, 1997; Davis 2005; Lloyd and Martin, 2005)

The chestnut-collared longspur population significantly decreased throughout its range at a rate of 2.9% per year between 1966 and 2006 (Sauer et al., 2008). In Alberta there is a similar rate of decline of 2.7% per year, however, the population decrease is non-significant (Sauer et al., 2008).

Chestnut-collared longspurs are somewhat sensitive to small patch sizes in Saskatchewan (Davis, 2004; Davis et al., 2006) and are known to avoid roads and oil development in Alberta and Saskatchewan (Sutter et al., 2000; Koper and Schmiegelow, 2006; Linnen, 2008). They will nest in taller non-native vegetation (Davis et al., 1999) although there is some evidence that nests located in exotic grasses produce fewer and smaller young at fledging (Lloyd and Martin, 2005). Longspurs will nest in restored prairie, in the form of the Permanent Cover Program, in Saskatchewan (McMaster and Davis, 2001; McMaster et al., 2005).

Sprague's pipit

Sprague's pipit is a small passerine in the family *Motacillidae* which contains three species in the genus *Anthus* in North America with no recognized subspecies (Robbins and Dale, 1999). The breeding range for *Anthus spragueii* is limited to short and mixed-grass prairie that has not been heavily disturbed whereas the wintering range occurs in open habitat in the southern U.S. and Mexico (Robbins and Dale, 1999; Figure 1.3). Nests are built on the ground with a domed canopy of standing dead vegetation (Sutter, 1997). Breeding habitat is characterized by intermediate vegetation height, less bare ground, more standing dead vegetation and greater litter depth than surrounding prairie (Dale, 1983; Sutter, 1997; Robbins and Dale, 1999; Dieni and Jones, 2003; Davis, 2005).

Sprague's pipit is significantly decreasing throughout its range at a rate of 3.9% per year between 1966 and 2006 (Sauer et al., 2008). Breeding bird surveys in Alberta indicated a higher rate of decline of 4.5% per year (Sauer et al., 2008).

Sprague's pipit are sensitive to small patch sizes (Davis, 2004; Davis et al., 2006), avoids roads (Sutter et al., 2000), and Linnen (2008) found pipits were more common further from oil and gas development in CFB Suffield and Saskatchewan. Higher densities of natural gas wells were correlated with reduced pipit abundance (Dale et al., 2009) and a decreased probability of occurrence (CEAR, 2009) on CFB Suffield. Pipits were uncommon on restored prairie, in the form of the Permanent Cover Program, in Saskatchewan (McMaster and Davis, 2001). Sprague's pipit is currently listed as "threatened" under the Species At Risk Act in Canada (COSEWIC, 2000) and provincially is listed as a "species of special concern" (Prescott, 1997).

Thesis goals and outline

The goal of my study was to determine if Savannah sparrows, chestnut-collared longspurs and Sprague's pipits avoid disturbances to grasslands caused by natural gas extraction and to identify which types of disturbance are avoided or used by birds establishing breeding territories. In Chapter 2, I examine the distribution of the three study species within the south block of the NWA on CFB Suffield. In this chapter I use point counts to detail the relative abundances of the species as well as to create a series of *a priori* generalized linear mixed-effect models to determine what, if any, landscape features or human disturbances may affect the occurrence of any of the species.

In Chapter 3, to further determine the effect of human disturbances on breeding males, I investigate where breeding territories were established and defended, in the south block of the NWA on CFB Suffield. I focus on distance from territory edge to the nearest well site, pipeline, junction and off-road vehicle trail. I also compare actual territories to simulated territories to determine what habitat features the study species were or were not including within their territories. Additionally, the relative amount of crested wheatgrass present in the territories was compared both to areas surrounding the territories (landscape scale) and to neighboring areas that males did not defend (local scale).

Chapter 4 presents nest data for chestnut-collared longspurs and Sprague's pipit from nests found incidentally during territory surveys. Prior to my work, there was a lack of nesting information for CFB Suffield. Finally, Chapter 5 provides a synthesis of my research results as well as offering management recommendations for the mixed-grass prairie found on CFB Suffield as impacts to the National Wildlife Area may decrease its value for preserving grassland birds and their breeding habitat.

The effect of energy development on grassland birds is poorly understood, especially the effects of well sites, pipelines, junctions and access trails. My study seeks to identify landscape variables which can be used to predict the occurrence of Savannah sparrows, chestnut-collared longspurs and Sprague's pipit rather than using only fine-scale local vegetation. Additionally, I seek to determine if human disturbances are affecting breeding territories of the three species and which forms of disturbance have the greatest effects upon territory placement, a relationship that has not been studied in the mixed-grass prairie.

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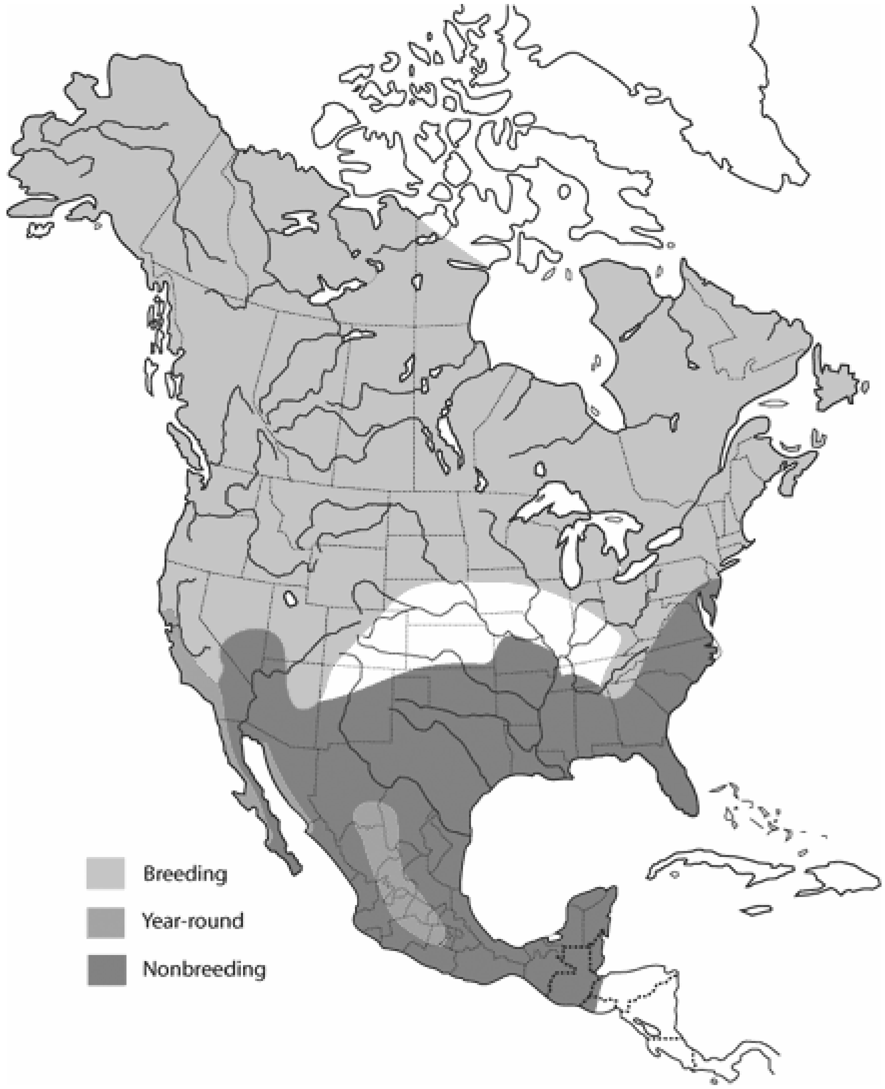

Figure 1.1: Distribution map of the Savannah sparrow (*Passerculus sandwichensis*) in North America (Distribution map reprinted with permission from http://bna.birds.cornell.edu and the Cornell Lab of Ornithology).

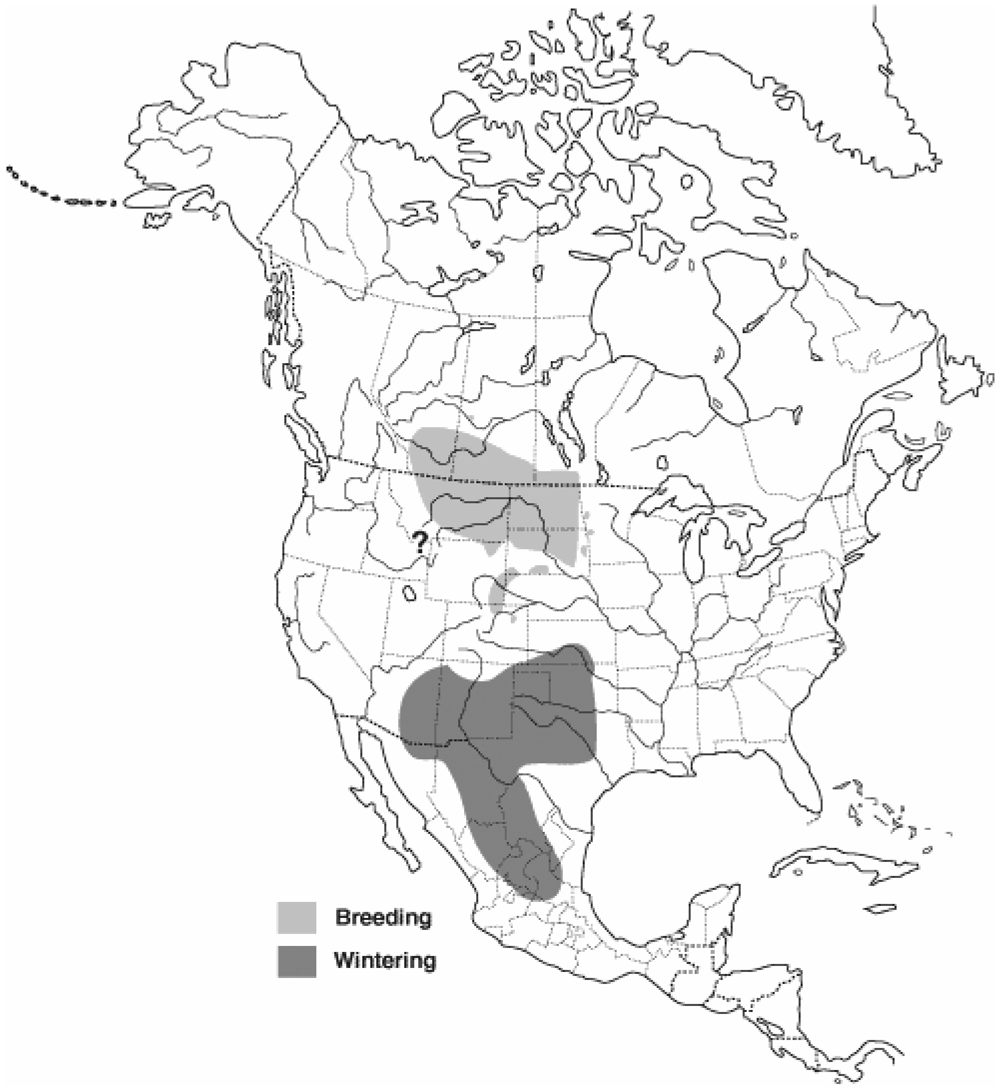

Figure 1.2: Distribution map of the chestnut-collared longspur (*Calcarius ornatus*) in North America (Distribution map reprinted with permission from http://bna.birds.cornell.edu and the Cornell Lab of Ornithology).

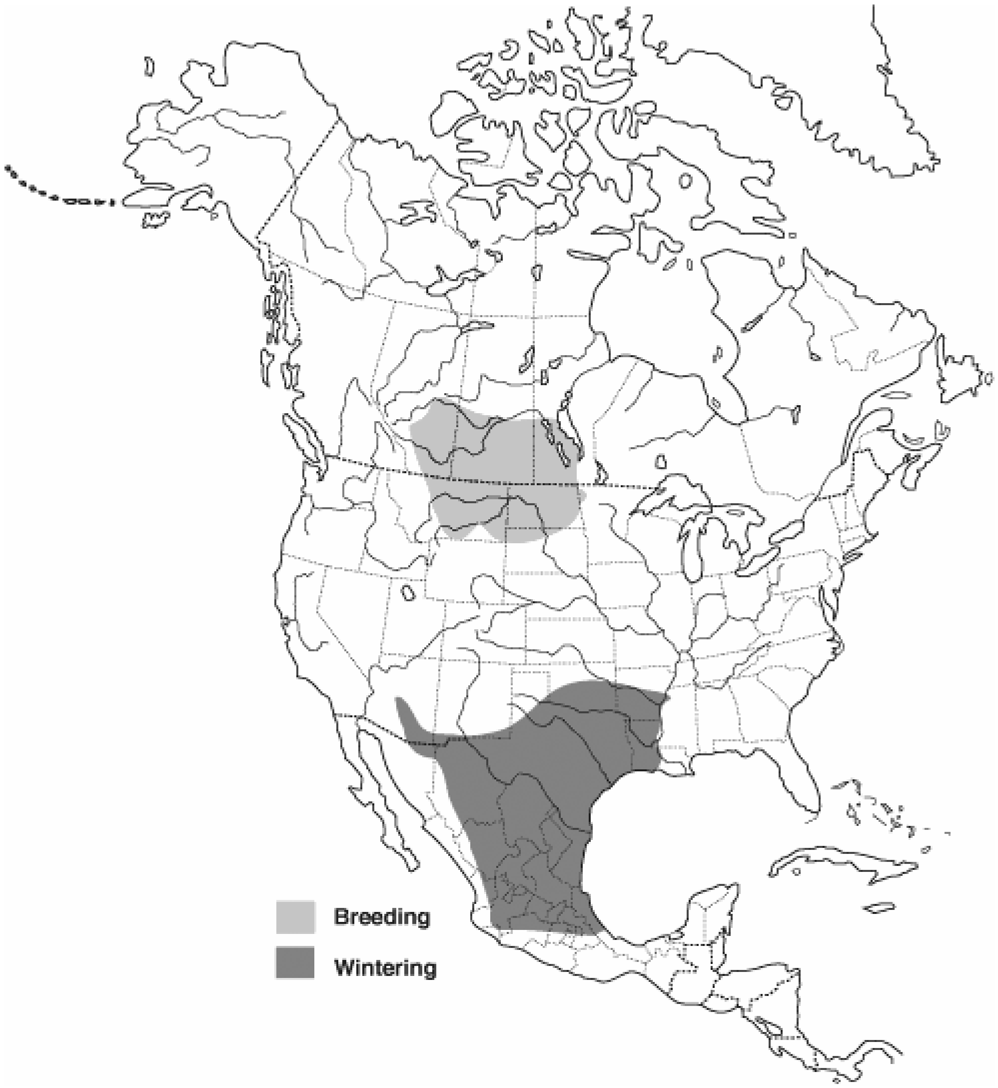

Figure 1.3: Distribution map of the Sprague's pipit (*Anthus spragueii*) in North America (Distribution map reprinted with permission from http://bna.birds.cornell.edu and the Cornell Lab of Ornithology).

Chapter 2
Patterns of habitat and landscape use by three grassland songbirds on CFB Suffield

Introduction

Population declines of grassland birds have been linked to direct habitat loss and habitat degradation (as reviewed by Samson et al., 2004; Brennan and Kuvlesky, 2005; Askins et al., 2007). Avoidance of human disturbance by birds may be triggered by two factors: the complete replacement of one habitat by another or subtle changes to a portion of the remaining habitat, such as the creation of edge habitat. Edges created by habitat fragmentation are linked to lower densities of grassland birds due to increased predation of nests (Winter et al., 2000; Herkert et al., 2003; Renfrew et al., 2005; Winter et al., 2006), lower nesting success (Winter et al., 2000; Perkins et al., 2003; Patten et al., 2006), and avoidance of non-native or altered native vegetation (Sutter et al., 2000; Fletcher and Koford, 2003; Renfrew et al., 2005; Winter et al., 2006).

Road edges are areas of severe habitat loss with margins that often contain different vegetation from native prairies (Reijen et al., 1996; Sutter et al., 2000; Ingelfinger and Anderson, 2004; Koper and Schmiegelow, 2006; Barton and Holmes, 2007). Grassland birds may avoid roads not only due to the loss of habitat but due to noise associated with vehicle traffic (Reijen et al., 1996; Miller et al., 1998). However, off-road vehicle trails are assumed to have less of an impact than gravel or paved roads due to the lack of large structural vegetation changes (Sutter et al., 2000) but they are not without effect (Miller et al., 1998;

Barton and Holmes, 2007). While roads edges are associated with oil and gas development, which is common throughout Alberta, the effects of other features of oil and gas development have not been well studied, including the cumulative effects of these disturbances (Askins et al., 2007).

While it supports some oil and gas development, Canadian Forces Base (CFB) Suffield remains important to grassland bird conservation as it contains one of the largest remaining tracts of native mixed-grass prairie in Canada with 458 km^2 of the base designated as a National Wildlife Area (NWA). Dale et al. (2009) found that higher levels of natural gas development on CFB Suffield are connected with decreases in abundances of sensitive species. In an earlier study of oil and gas development in CFB Suffield and Saskatchewan, only the effects of access trails and well sites on grassland birds were considered; pipelines, junctions and level of trail use were excluded (Linnen, 2008).

Studies of habitat and landscape effects upon occurrence of grassland species have previously used ground measurements such as vegetation height, cover by standing dead vegetation and bare ground to determine habitat preferences (for examples see Davis et al., 1999; Davis, 2004; Winter et al., 2005; Koper and Schmiegelow, 2006). Measuring these features on a large scale is time consuming and expensive while indirect measures of landscape features are in many cases already available and may yield accurate predictors of occurrence. Where larger scale landscape features have been included in studies of grassland birds, they typically focus upon the composition of the landscape, patch size and distance to edge or disturbed habitat (for examples see Winter et al., 2000; Davis, 2004; Davis et al., 2006; Koper and Schmiegelow, 2006; Winter et al., 2006) rather than variables associated with topography, such as Wiens et al. (2008). Additionally, this study examines cumulative human disturbances rather than focusing on the effects of any individual disturbance and thus avoids over or under emphasizing specific forms of human alteration.

To assess how human-related disturbances affected the presence or absence of grassland birds in CFB Suffield on a landscape level, I studied three species. I conducted point count surveys for Savannah sparrows (*Passerculus sandwichensis*), chestnut-collared longspurs (*Calcarius ornatus*), and Sprague's pipit (*Anthus spragueii*) throughout May and early June in 2007 and 2008. While human disturbance can affect the presence of grassland birds at a site, site characteristics were expected to be more influential (for examples see Madden et al., 2000; Fletcher and Koford, 2002; Winter et al., 2005, Linnen, 2008). I expected the occurrence of Savannah sparrow at a location to be positively related to increased human disturbance as the species is tolerant to human activity such as roads (Sutter et al., 2000) and oil and gas development (Linnen, 2008). Longspurs are tolerant of some forms of human disturbance, such as off-road vehicle trails, but are less tolerant of roads (Sutter et al., 2000) and oil and gas development (Linnen, 2008), thus occurrence of this species was expected to show a modest response to human disturbance. Sprague's pipit was expected to occur less frequently than longspurs in areas with high levels of human disturbance as pipits are typically less tolerant of non-native habitat than longspurs (McMaster and Davis, 2001). Other research on CFB Suffield found pipits to be less common in areas of high well-density (Dale et al., 2009) and to avoid oil and gas wells and trails (Linnen, 2008).

Methods

The study site was located in the south block of CFB Suffield, in southern Alberta, near Medicine Hat. This site was chosen because of the presence of the NWA and a recent proposal to increase the density of wells in the area (CEAR, 2007). CFB Suffield NWA was established in June 2003 and is composed of a south and a north block with a total area of 458 km^2 (CEAR, 2007). The south block is located approximately 50 km northwest of Medicine Hat and 250 km southeast of Calgary (T.15 to T.19 and R.3 to R.9 W4M). This area has been out of bounds for military ground training since 1972 and has light to moderate cattle grazing (CEAR, 2007). Using ArcGIS (9.2), I defined my study sites as eight 3km^2 plots in the NWA and in an adjacent area outside of the NWA, but on the military base and similarly out of bounds for ground training (Figure 2.1). Each plot was designated as low impact (n=5) or high impact (n=3) based on natural gas well density, provided by Canadian Wildlife Services. Low impact sites had a maximum of 8 wells/square mile whereas high impact sites had a maximum of 16 wells/sq. mile. Vegetation was similar for all 8 plots and soil type was matched as closely as possible.

I conducted point counts from 15th - 26th May 2007 and from 9th of May - 5th June 2008 to document the distribution and relative abundances of the three target species on the eight study plots. The extended period for point counts in

2008 was required because large portions of the study area were closed for safety reasons due to adjacent military training; heavy rainfall also interfered with sampling. The counts began as close to sunrise as possible (~0530), and ended no later than 1100. Point counts were conducted in a grid of 6 points by 6 points, yielding 36 point counts per plot. The grid of point counts was 250m from the edge of the plot and each series of points were 500m apart. At the beginning of the 2007 field season, wildfires occurred at some of our study points. Due to these fires, some of the study sites were moved in 2008 to avoid the burned areas. During each 5 minute count, we recorded start and end time as well as cloud cover and wind speed according to the Beaufort Scale. Point counts were halted if wind exceeded a Beaufort class of 4 (~24km/hr). Each point was a circle with a 100 meter radius, and all three species were recorded for a point if they were seen or heard within the circle. We recorded if a bird was seen, heard singing or calling, if it was moving and if there was a chase. We recorded a bird's sex when possible. Observers estimated the number of breeding pairs within each point count immediately upon return from the field based on the behavior observed. I conducted counts in both 2007 and 2008 ("observer L", below); the other two observers ("A" and "S", below) were present during one field season each. Each 36 point plot was divided between two observers. Training of observers occurred prior to the beginning of data recording and concentrated on distance estimation, identification, behaviour and the data recording protocol.

Statistical analysis

Analyses in this study were carried out using SPSS 16.0 for Windows (SPSS Inc. Chicago, IL USA) and all values are presented as mean ± standard error unless otherwise noted. Species were analyzed separately throughout.

Burns in the study area occurred prior to May 15th in 2007, and prior to May 9th in 2008. Point count stations that had a burned area within 250m were removed prior to analysis as recently burned areas were generally uninhabited by most species of birds present. Therefore I analyzed 267 point counts in 2007 and 277 point counts in 2008. Each year was analyzed for differences in the number of birds of the three study species seen per point to determine the effects of well-density (low vs. high) on the number of birds. Mann-Whitney U tests compared the effect of well-density on the estimated number of birds per point count within each year. To test between years, I used a Wilcoxon Signed-Ranks Test on 205 paired points that were not visibly influenced by burning in either year. Points were paired whenever a point from 2008 fell within 250m of a point from 2007. A two-way contingency table (Goodness of fit test) determined if differences in the presence-absence of the three study species differed between years and between well-densities using the 205 paired points.

Generalized linear modeling

All 288 point counts were used in analysis. I used generalized linear model (GLMM) regressions based on a binomial logit-link function (R version 2.9.1; glmmML written by Göran Broström, Umeå University, Sweden) to compare a series of *a priori* habitat models created to determine how the presence of a species is related to both oil and gas development and landscape characteristics. I used the glmmML package as it fits models using maximum likelihood, thus allowing use of information theoretic approaches for model selection. Categorical variables included in analysis included burned (yes or no), and observer (A, L or S). For all categorical variables, one category was set as the reference for determining the coefficients and odds ratios. Unburned vegetation was the reference for burned areas. Observer L, who was present in both sampling seasons, served as the reference for observers.

Covariates included elevation, topographic index, soil particle size, and human footprint. Elevation was the mean value within 100m of the location of the point count obtained from a digital elevation map of the area (provided by CWS). The topographic index, following Wiens et al. (2008), was a measure of the flatness of an area calculated by dividing the surface area of the landscape by the area of the 100m radius point count. Thus hillier areas were associated with higher topographic value. Soil particle size, following Wiens et al. (2008), was a relative soil-texture index derived from a weighted average of soil texture for each soil horizon in profile, generated from soil-texture information provided by Alberta Soil Information Center (2001). Therefore an increase in the index corresponded to an increase in soil particle size with larger soil particles reflecting soils that, in the case of CFB Suffield, contain more sand. Human footprint was calculated by assigning each potential disturbance (well site, pipeline, junction, trail, and road) with a fixed area of effect taken from personal observation, environmental assessment reports for CFB Suffield's NWA (CEAR, 2007). The sum of disturbances was used to determine the proportion of each point count area that was considered disturbed by human activities. Well sites were assigned a disturbance surface area of 860m^2 while junctions were assigned a disturbance area of 400m^2 (CEAR, 2007). Pipelines were assigned a standard width of 2.5m, whereas roads, including drainage ditches, were assumed to be 25m in width. Trail class was based the Department of National Defense classification of the impact of the trail (class 1 – 5). Each trail class was assigned a width based on the level of impact to determine the area directly impacted by the trail (Class 1 = 40cm; Class 2 = 1.5m; Class 3 = 2m; Class 4 = 3m; Class 5 = 4m). Class 1 trails were defined by DND as cattle or animal trails, but they were included as human footprint as cattle were stocked and my experience in the field indicates that some class 1 trails were remnants of old class 2 trails.

"Site ID" was included in all models as a random effect to account for replication at some point counts between years. "Year" was also included as a random effect. All other effects were included as fixed effects. The Akaike information criterion (AIC) was used to select the model of best fit (Burnham and Anderson, 2002). Models with a $\Delta i < 2$ were considered equivalent whereas a model with Δi = 3-7 had less support and models with at $\Delta i > 7$ had very little support compared to the best model (Burnham and Anderson, 2002). Akaike weights (w_i) were used to determine the probability of the model with the lowest AIC was the best model. The closer w_i is to 1, the more likely that the best model is the most useful model of the models tested (Burnham and Anderson, 2002).

The strength of the best model was determined by calculating the area under the receiver operator curve (AUC).

Five models were constructed, based on *a priori* hypotheses, to separate natural and human influence, in addition to evaluating the effect of habitat variables, on the pattern occurrence for grassland birds (See Table 2.1 for a list of *a priori* models). The first was (1) a global model that included all variables; two models focused upon the natural site characteristics: (2) the location of the point count, including elevation and steepness, and (3) location including particle size and burns. To determine the extent of human impact, I created a model incorporating (4) all disturbance types as both burns and human activity altered the "typical" vegetation patterns. A final model (5) excluded burns but incorporated all other human disturbances.

Results

Density and distribution patterns: effects of year and well-density

A comparison of presence/absence between years and well-densities showed both sparrows (G^2=3.9, df=1, p=0.048) and longspurs (G^2=8.46, df=1, p<0.01) to be present on more point count sites in 2008 than in 2007, whereas pipits proved similar in occurrence between the two years (G^2=0.48, df=1, p=0.49; Table 2.2). Longspurs were significantly more common in high well-density areas than in low density areas (G^2=26.58, df=1, p<0.0001) whereas sparrows and pipits occurred with frequencies that were not different between low and high well-density sites (SAVS: G^2=0.02, df=1, p=0.89; SPPI: G^2=2.46, df=1, p=0.12, Table 2.2). Longspurs were the only species with a significant two-way interaction between occurrence, well-density and year due to a higher occurrence at high well-densities compared to low well-densities in both years and a greater difference between well-densities in 2007 compared to 2008 (SAVS: G^2=4.88, df=4, p=0.0.30; CCLO: G^2=35.6, df=4, p<0.0001; SPPI: G^2=3.64, df=4, p=0.46).

Chestnut-collared longspur was the most abundant of the study species with an average of 1.38 birds per point in 2007 and 1.24 birds per point in 2008. This was followed by Savannah sparrow (2007: 0.76/point and 2008: 0.67/point); Sprague's pipit was the least abundant species (2007: 0.56/point and 2008: 0.62/point).

There was no trend in abundances between 2007 and 2008 when pooled across well-density for sparrows (Wilcoxon Signed Ranks test Z=-0.38, n=205, p=0.70), longspurs (Z=-1.68, n=205, p=0.093), or pipits (Z=-1.02, n=205, p=0.31; Tables 2.3 and 2.4). In high well-densities, sparrows and pipits displayed similar abundance between years (SAVS: Z=-0.069, n=84, p=0.95; SPPI: Z=-1.48, n=84, p=0.14) whereas longspurs were significantly more abundant in 2007 than 2008 (Z=-3.46, n=84, p=0.001). At low well-density sites none of the species differed in abundance between years (SAVS: Z=-0.52, n=121, p=0.60; CCLO: Z=-0.85, n=121, p=0.40; SPPI: Z=-0.18, n=121, p=0.86; Table 2.3).

In 2007 there was a non-significant trend for more longspurs (Z=-1.87, n=267, p=0.061) on sites with high well-densities and pipits (Z=-1.73, n=267, p=0.083) on sites with low well-densities, but similar numbers for Savannah sparrows between well-densities (Z=-0.96, n=267, p=0.34; Table 2.3). In 2008 there was a non-significant trend toward a higher number of Savannah sparrows at high well-densities (Z=-1.67, n=277, p=0.096). Longspurs (Z=-0.40, n=277, p=0.69) and pipits (Z=-0.39, n=277, p=0.70; Table 2.3) displayed no differences in abundance in relation to well-density in 2008.

Habitat use modeling

The full model (Table 2.1) explained the most variance in the occurrence of each of the three species (SAVS: $w_i = 0.99$; CCLO: $w_i = 1.00$; SPPI: $w_i = 0.99$; Table 2.4). All other models performed poorly in comparison to the full model. The AUC for the best model was greater than 0.5 for Savannah sparrows and Sprague's pipits, indicating that both models have some predictive power although neither are good (SAVS: AUC= 0.55; SPPI: AUC = 0.65). The best model for chestnut-collared longspurs performed poorly and has little predictive power (AUC = 0.42). In the full model for each species, observer differences were important and the direction of these differences varied by species. Observer L recorded more pipits and Savannah sparrows, observer A recorded more longspurs and observer S recorded fewer sparrows than the other two observers. Averages for each model variable are listed in Table 2.5.

Tables 2.6 through 2.8 present the parameter estimates of the coefficient, odds ratio and confidence interval for each variable in the best model. Where the odds ratio (OR) and the lower bound of the confidence interval (CI) are greater than 1, there is a positive effect of the variable on the likelihood of a species' presence. Where the odds ratio and the upper bound of the confidence interval are less than 1, there is a negative effect on the likelihood of a species' presence.

The likelihood of sparrow presence was positively related to topographic index (Odds ratio = 1.32, CI = 1.14 – 1.52) and to the proportion of the point count area that was disturbed by human activity (OR = 1.07, confidence interval = 1.02 – 1.12; Table 2.6). The likelihood of longspur presence was positively related to elevation (OR = 1.03, CI = 1.01 – 1.04) and negatively related to topographic index (OR = 0.57, CI = 0.48 – 0.68) and to proportion of the area disturbed by human activity (OR = 0.94, CI = 0.89 – 0.99; Table 2.7). The likelihood of occurrence for Sprague's pipit was positively associated with topographic index (OR = 1.16, CI = 1.01 – 1.33) and negatively associated with burns (OR = 0.22, CI = 0.084 – 0.57) and percentage of area affected by human disturbance (OR = 0.94, CI = 0.89 – 0.99; Table 2.8).

As proportion of human disturbance was the only landscape variable with odds ratios and confidence intervals that did not include 1 for all species, I graphed species presence and absence in reference to the amount of human disturbance (Figure 2.2). For each species, a Kolmogorov-Smirnoff test determined that the two distributions, presence or absence, did not differ significantly (SAVS: $Z=0.41$, $p=1.00$; CCLO: $Z=1.23$, $p=0.10$; SPPI: $Z=0.41$, $p=1.00$).

Discussion

This chapter assessed occurrence and abundance of Savannah sparrows, chestnut-collared longspurs and Sprague's pipit on the mixed-grass prairie on CFB Suffield. Sparrows and longspurs were present at more point count locations in 2008 compared to 2007 although they were not more abundant in 2008. I found that while there was little significant difference in the abundance at high versus low well-density for any of the species. Longspurs were more likely to be present at point count locations in high well-density areas and Sprague's pipit was consistently more common and more abundant in low well-density areas. I also identified how large-scale habitat features and human disturbance were associated with the occurrence of each of the three species.

Distribution of the study species

Savannah sparrows had similar abundance at high and low well-densities and between years. Occupancy by Savannah sparrows was higher in my study site than previously recorded in CFB Suffield ([3.6%] Dale et al., 1999; [10.7%] Linnen, 2008; [34%] Wiens et al., 2008) although in Saskatchewan the occurrence on 100m fixed-radius point counts were as high as 49% (Davis, 2004).

Chestnut-collared longspurs did not vary significantly in abundance with well-density or year. Longspurs occurred more frequently in areas of high well-densities. Linnen (2008) found a lower rate of occurrence of longspurs (50%) than I did although they used 50m fixed-radius point counts. However, these sites were located on the northern portion of CFB Suffield outside of the NWA in an area with oil wells as opposed to natural gas wells. Throughout southern Saskatchewan, Davis et al. (1999) found longspur occurrence in 100m fixed-radius point counts varied from 0.5% of sites occupied in cropland to 21.4% occupied sites in native pasture. In the more restricted range of the moist mixed grassland ecoregion of Saskatchewan, the occurrence at point counts for longspurs was as high as 74% (Davis, 2004).

Sprague's pipits were common at my study sites and had higher occurrence than recently reported for other portions of CFB Suffield ([24%] Linnen, 2008; [35%] Wiens et al., 2008) but lower occurrence than reported for the NWA during the biophysical inventory ([54%] Dale et al., 1999). Sprague's pipit was the only species that showed no significant trend in either abundance or presence-absence between years but showed non-significant patterns with higher occurrence and abundance in low well-density areas. Wiens et al. (2008) found that frequency of occurrence varied over a 5 year period based on climatic conditions. Davis et al. (1999) found in Saskatchewan that pipit occurrence varied from 0.5% occupancy of sites in cropland to 18.5% site occupancy in native pasture but an occurrence rate as high as 52% was found in the moist mixed grassland ecoregion of Saskatchewan (Davis, 2004).

Linnen (2008) reports similar abundance of Savannah sparrows, longspurs and pipits in Saskatchewan, 2006, and in CFB Suffield, 2007, to those I found on CFB Suffield. It should be noted that Hill and Gould (1997) reported that longspurs tend to form aggregated clumps of breeding birds which can inflate densities reported over a small area. The higher occupancy of some study species at my sites compared to previously recorded values for CFB Suffield likely reflects that my sites were selected based on previous surveys and represented areas that were known to contain the three study species thus purposefully excluding areas where they were likely to be absent. There were some substantial differences in magnitude (up to 20-25%) for occurrence and abundance values in relationship to well-density which may reflect a lack of power to detect existing differences.

Modeling

The predictive ability of models of bird habitat use is dependent upon the variables chosen, the location of the study site and when the model data were collected. My models included only variables that could be obtained on a landscape level and that did not require additional information gathered at the time or exact location of the point counts. I expected that as soil particle size is tied to moisture retention, and thus to vegetation growth (as reviewed by Wiens et al., 2008), that soil particle size would reflect the vegetation type and help explain occurrence of the three species. I initially predicted that soil particle size, along with the other habitat metrics, would be of greater importance than human disturbance in predicting the likelihood of occurrence for the three species based on Wiens et al. (2008) who found that soil particle size was a good predictor of occurrence for several grassland birds, including Sprague's pipit. My models suggested that soil particle size was not related to the likelihood of occurrence of the study species. The effect of other habitat features, such as elevation and topography, varied between species.

Differences among observers in their ability to detect birds were found for each species. This observer bias could be simply due to the spatial distribution of the species or, of more concern, related to inadequacies in training. Diefenbach et al. (2003) found that observer differences during point counts are frequent. Likewise, Diefenbach et al. (2003) found that bias differs among species, regardless of the amount of experience observers had at conducting bird surveys. The observer variable is thus important to maintain in study models due to the potential error created by multiple observers.

<u>Occurrence of Savannah sparrows</u>

The best model, which performed poorly, indicated a positive relationship between the proportion of prairie disturbed by human activities and the likelihood of detecting a Savannah sparrow, similar to the findings of Dale et al. (2009). Based on the best model, with every 1% increase in the area disturbed at the site of the chance of detecting a Savannah sparrow is 1.06 times greater. Thus, if the current level of disturbance in the NWA is estimated at 3% (Table 2.5), then doubling this value makes the likelihood of detecting a Savannah sparrow 1.19 times more likely. Savannah sparrows have previously been associated with disturbed areas, notably near gravel roads (Sutter et al., 2000; Koper and Schmiegelow, 2006), and near oil developments (Linnen, 2008). However, Savannah sparrows have also been found to avoid edge habitat (Davis, 2004; Renfrew et al., 2005), which increases as patch size decreases, but overall, Savannah sparrows are not considered to be area sensitive throughout the Great Plains (Madden et al., 2000; Davis, 2004; Koper and Schmiegelow, 2006). Given the variable response of Savannah sparrows to disturbances, the positive effect of disturbance on the presence of Savannah sparrows indicates that the human-altered habitat has some features that attract the species, such as taller vegetation (see Chapter 3).

"Natural" habitat variables were poor predictors of the presence of Savannah sparrows despite my expectations that habitat would be more important than human impact. Other features that may be better predictors of the presence of Savannah sparrows that were not measured in my study include proportion of shrub cover and vegetation height (see Davis, 2005; Winter et al., 2006). However, vegetation characteristics may not always be accurate predictors of a species as ubiquitous as Savannah sparrows as Madden et al. (2000) found in North Dakota.

Occurrence of chestnut-collared longspurs

The best model found for longspurs had poor predictive power and was unlikely to predict accurately the presence or absence of longspurs on CFB Suffield. Dieni and Jones (2003) found in Montana that longspurs were plastic in their habitat use. Fine scale habitat variables that may be predictors of the presence of longspurs may include low litter cover and depth, and of relatively sparse vegetation (Davis et al., 1999; Davis, 2005).

Linnen (2008) found that longspurs avoided oil-related trails and oil pump sites on CFB Suffield but not natural gas developments in Saskatchewan. Longspurs are tolerant of certain forms of human disturbance including cattle grazing, haying and exotic grasses throughout the Canadian prairies (Dale et al., 1997; Hill and Gould, 1997; Davis et al., 1999; Lloyd and Martin, 2005). They are considered to be sensitive to small patch sizes in Saskatchewan (Davis, 2004) and avoid roads and road margins in both Alberta and Saskatchewan (Sutter et al., 2000; Koper and Schmiegelow, 2006).

Occurrence of Sprague's pipit

Landscape variables played a larger part in describing the likelihood of detecting a pipit than they did for describing the likelihood of detecting either Savannah sparrows or longspurs. Pipits were more likely to be found in hilly locations but avoided burned areas and human disturbance. Contrary to my findings, Wiens et al. (2008) found that flatter locations were more likely to contain pipits than locations with steep hillsides. Wiens et al. noted that their model for pipits performed poorly in one of 5 years and one of 5 areas possibly due to high sensitivity to survey year precipitation which is a poor predictor of litter and residual plant cover. Areas recently burned (4-7 years) in Montana and North Dakota have previously been associated with the presence of Sprague's pipit (Madden et al., 1999; Dieni and Jones, 2003) and areas that have not been burned in more than 8 years in the North Dakota mixed-grass prairie often do not contain pipits (Madden et al., 1999). In Saskatchewan, Pylypec (1991) found an immediate decrease in Sprague's pipit following fire, and pipits in CFB Suffield avoided areas that had been recently or frequently burned (Dale et al., 1999). The burns in my study were very recent (0-1 years) and were likely avoided due to a lack of appropriate nesting vegetation.

In the Alberta and Saskatchewan prairie, Sprague's pipit avoids small patch sizes (Davis 2004, Davis et al. 2006), roads (Sutter et al. 2000; Koper and Schmiegelow, 2006) and is intolerant of non-native grass species like crested wheat grass (*Agropyron cristatum*) (Sutter, 1997; Sutter and Brigham, 1998;

Robbins and Dale, 1999; Davis, 2005 but see Davis et al., 1999). Linnen (2008) found that pipits occurred less often in point counts near oil and gas developments including trails in CFB Suffield. In agreement with previous studies, I documented a decreased likelihood of finding pipits during point counts as the proportion of habitat disturbed by industrial development increased. Based on the best model, for every 1% increase in human disturbance the likelihood of detecting a pipit decreases by 0.96 times. Thus if the NWA were to have twice as much human disturbance, the likelihood of detecting a pipit would decrease by 0.88 times. This likelihood of detecting Sprague's pipit in keeping with findings reported in Dale et al. (2009).

Conclusions

Human disturbance in the mixed-grass prairie of CFB Suffield created habitats that increased the likelihood of use by Savannah sparrows but decreased the likelihood of use by both chestnut-collared longspurs and Sprague's pipits. The majority of disturbances on CFB Suffield, including natural gas well sites, pipelines, junctions and off-road vehicle trails, cover only a small proportion of the total surface area. Even with an average 3% of the area disturbed, the best models predicted an effect of human disturbance upon the occurrence of all the species. Occurrence and abundance, however, were statistically similar between areas with high and low well-density.

An increase in the area of native prairie disturbed by human activity on CFB Suffield may cause a reduction in the abundance of sensitive bird species due to habitat loss or alteration. While large scale studies may determine overarching population trends and habitat preferences, smaller scale investigations can determine how individual birds are responding to small scale habitat changes caused by human disturbance.

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Table 2.1: ***A priori*** **models for generalized linear modeling using binomial log-link functions**

Model name	Model parameters
Full model	Observer + Elevation + Steepness + Particle Size + Human Disturbances + Burn
Habitat without soil	Elevation + Steepness
Habitat	Elevation + Steepness + Particle Size + Burn
All disturbances	Burn + Human Disturbances
Human disturbances	Human Disturbances

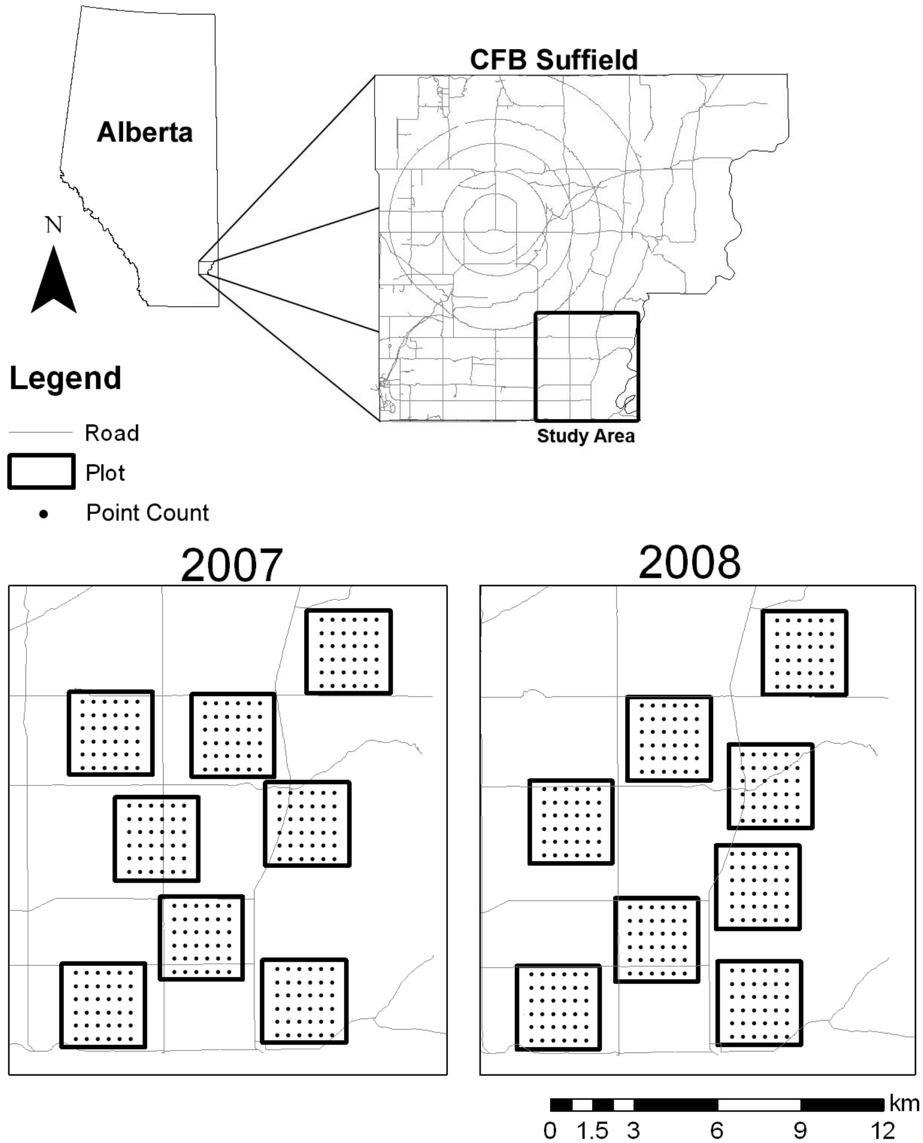

Figure 2.1: Map of the study area in 2007 and 2008 on Canadian Forces Base Suffield in Alberta, Canada. Squares indicate 9 km^2 plots in both years; dots indicate location of point counts.

Table 2.2: Percent occurrence of the three study species at point counts in high and low well-density areas. There were 121 points in low well-density areas and 84 paired points in high well-density areas for a total of 205 paired point counts.

	Low			High			2007 High and Low combined	2008 High and Low combined
	2007	2008	2007 and 2008 combined	2007	2008	2007 and 2008 combined		
Savannah Sparrow	47.9	53.7	50.8	44.0	59.5	51.8	46.3	56.1
Chestnut-collared Longspur	56.2	71.9	64.0	82.1	90.5	86.3	66.8	79.5
Sprague's Pipit	53.7	53.7	53.7	41.7	50.0	45.8	48.8	52.2

Table 2.2: Mean number of birds per point in each level of impact in 2007 and 2008. Data excludes any point with burned areas within 250m. Low well-density plots had 159 and 172 points in 2007 and 2008 respectively; high well-density plots had 108 and 105 points in 2007 and 2008, respectively.

	Low		High		High and Low combined	
	Mean	SE	Mean	SE	Mean	SE
2007						
Savannah sparrow	0.70	0.069	0.85	0.097	0.76	0.057
Chestnut-collared Longspur	1.22	0.10	1.62	0.15	1.38	0.085
Sprague's Pipit	0.62	0.053	0.47	0.055	0.56	0.039
2008						
Savannah sparrow	0.63	0.063	0.73	0.071	0.67	0.047
Chestnut-collared Longspur	1.23	0.069	1.26	0.088	1.24	0.054
Sprague's Pipit	0.64	0.053	0.60	0.064	0.62	0.041

Table 2.4: Generalized linear mixed model logistic regression analysis of hypothesized a priori models based on "K" variables to determine presence-absence of Savannah sparrow (SAVS), chestnut-collared longspur (CCLO) and Sprague's pipit (SPPI) from 468 point counts measured in 2007 and 2008. See Table 1 for model variables.

Model	K	SAVS			CCLO			SPPI		
		AIC	Δ_i	w_i	AIC	Δ_i	w_i	AIC	Δ_i	w_i
Full model	**7**	**782.5**	**0**	**0.99**	**592.3**	**0**	**1.00**	**775.2**	**0**	**1.00**
Habitat without soil	3	792.2	9.7	0.0077	609.5	17.2	1.84E-4	797.5	22.3	1.44E-5
Habitat	5	794.0	11.5	0.0031	611.6	19.3	6.44E-5	792.1	16.9	2.14E-4
All disturbances	2	799.8	17.3	1.73E-4	692.9	100.6	1.43E-22	789.4	14.2	8.24E-4
Human disturbances	1	797.9	15.4	4.48E-4	691.4	99.1	3.02E-22	797.7	22.5	1.30E-5

Table 2.5: Summary of values for environmental variables recorded in CFB Suffield for 360 low well-density point counts and 216 high well-density point counts for 2007 and 2008 combined. Summary is presented as A) mean ± SE and range for continuous variables and B) number of points affected by the listed categorical parameter.

A)

Parameter	Low		High		Overall	
	x ± SE	Range	x ± SE	Range	x ± SE	Range
Steepness	6.83 ± 0.20	2 – 26	7.51 ± 0.27	2 - 26	7.09 ± 0.16	2 - 26
Elevation	113.00 ± 0.66	82 – 161	130.99 ± 1.22	90 – 166	119.75 ± 0.71	82 - 166
Proportion of Human Distur-bances	2.65 ± 0.20	0 – 22.6	3.42 ± 0.24	0 – 20.4	2.94 ± 0.15	0 – 22.6
Particle Size	11.33 ± 0.15	6.4 – 14.1	9.66 ± 0.18	6.4 – 14.1	10.71 ± 0.12	6.4 – 14.1

B)

Parameter	Low	High	Overall
Burned	29	3	32
Observer A	90	54	144
Observer S	90	54	144
Observer L	180	108	288

Table 2.3: Summary of the best mixed model logistic regression for describing presence-absence of Savannah sparrows on 576 points on CFB Suffield from 2007 and 2008. Bolded parameters indicate odds ratios that differ from one.

Parameter		Coefficient	Standard Error	Odds Ratio	95% CI of Odds Ratio	
Intercept		-275.30	74.85			
Burn		-0.17	0.38	1.19	0.56	2.53
Elevation		0.0049	0.0058	1.00	0.99	1.02
Topographic index		**0.27**	**0.075**	**1.32**	**1.14**	**1.52**
Human Disturbances		**0.066**	**0.025**	**1.07**	**1.02**	**1.12**
Particle Size		0.040	0.037	1.04	0.97	1.12
Observer	A	-0.25	0.21	0.78	0.51	1.17
	S	**-0.76**	**0.22**	**0.47**	**0.31**	**0.71**

Table 2.4: Summary of the best mixed model logistic regression for describing presence-absence of chestnut-collared longspurs on 576 points on CFB Suffield from 2007 and 2008. Bolded parameters indicate odds ratios that differ from one.

Parameter		Coefficient	Standard Error	Odds Ratio	95% CI of Odds Ratio	
Intercept		566.40	89.50			
Burn		0.12	0.45	1.13	0.47	2.73
Elevation		**0.026**	**0.0076**	**1.03**	**1.01**	**1.04**
Topographic index		**-0.57**	**0.090**	**0.57**	**0.48**	**0.68**
Human Disturbances		**-0.065**	**0.027**	**0.94**	**0.89**	**0.99**
Particle Size		-0.017	0.043	0.98	0.90	1.07
Observer	**A**	**1.32**	**0.30**	**3.75**	**2.06**	**6.84**
	S	0.11	0.24	1.11	0.70	1.78

Table 2.5: Summary of the best mixed model logistic regression for describing presence-absence of Sprague's pipit on 576 points on CFB Suffield from 2007 and 2008. Bolded parameters indicate odds ratios that differ from one.

Parameter		Coefficient	Standard Error	Odds Ratio	95% CI of Odds Ratio	
Intercept		-145.40	71.46			
Burn		**-1.52**	**0.49**	**0.22**	**0.084**	**0.57**
Elevation		-0.0021	0.0064	1.00	0.99	1.01
Topographic index		**0.15**	**0.071**	**1.16**	**1.01**	**1.33**
Human Disturbances		**-0.061**	**0.027**	**0.94**	**0.89**	**0.99**
Particle Size		0.046	0.040	1.05	0.97	1.13
Observer	**A**	**-0.76**	**0.23**	**0.47**	**0.29**	**0.74**
	S	**-0.71**	**0.23**	**0.49**	**0.31**	**0.78**

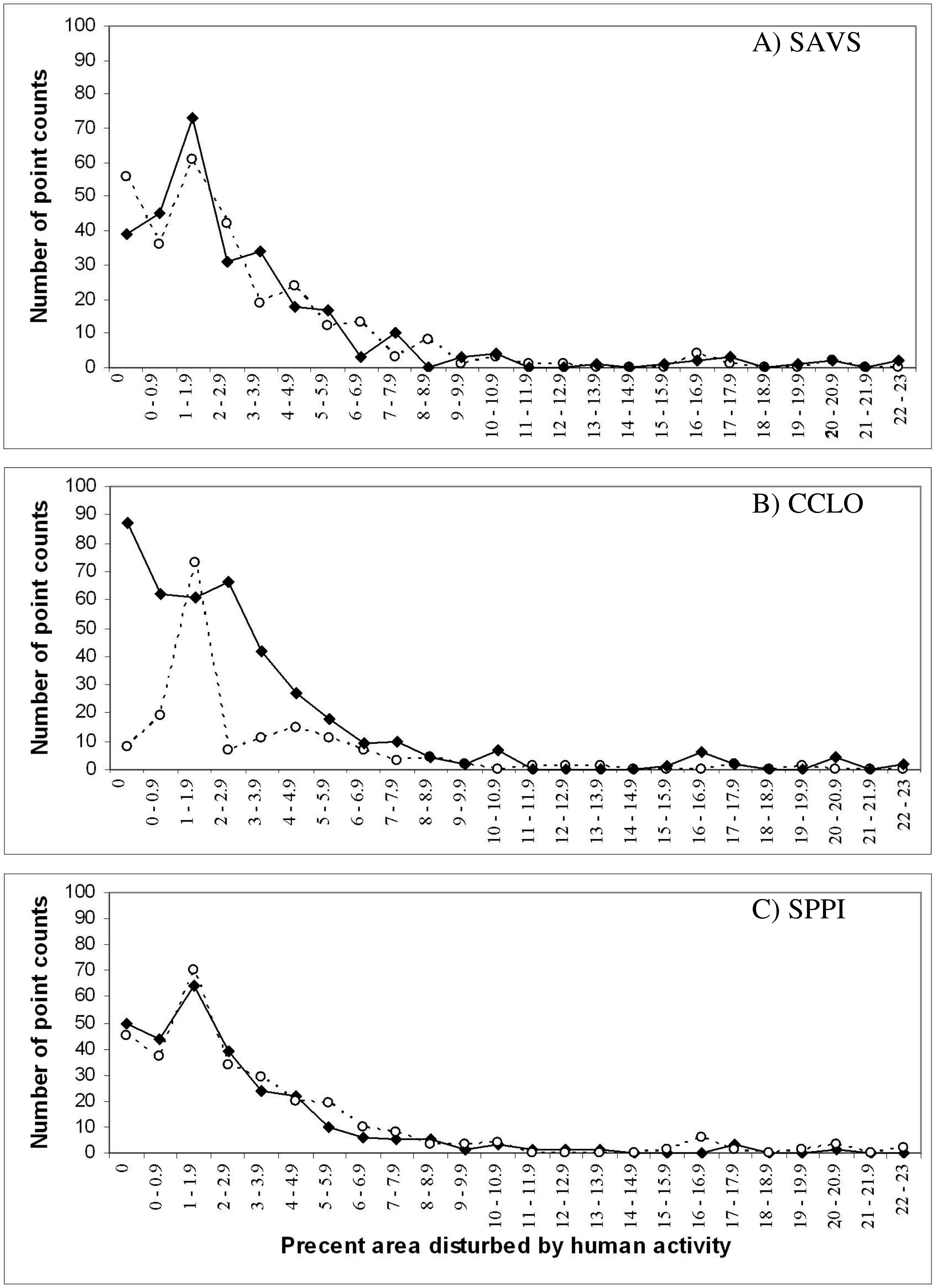

Figure 2.2: Frequency of occurrence of point counts with and without detection of a) Savannah sparrow, b) chestnut-collared longspur, and c) Sprague's pipit relative to the percent area disturbed by human activity in 576 point counts from 2007 and 2008. Solid line indicates number of point counts with the presence of the species; dashed line indicates number of points with that species absent.

Chapter 3
Location of the territories of three grassland birds in relation to habitat structure and human disturbances

Introduction

Human use of native grasslands is harmful to grassland birds due to habitat removal, which mainly occurs through conversion to cropland (Samson et al., 2004; Brennan and Kuvlesky, 2005). Dissection by linear features results in the creation of small patches and edge habitats that are less attractive to area sensitive species (Helzer and Jelinski, 1999; Winter and Faaborg, 1999; Fletcher and Koford, 2002; Fletcher and Koford, 2003; Davis, 2004; Davis et al., 2006; Hamer et al, 2006; Winter et al., 2006). Additionally, habitat degradation of remaining prairies occurs through introduction of invasive plant species (Wilson and Belcher, 1989; Sutter and Brigham, 1998; Lloyd and Martin, 2005; Flanders et al., 2006), inappropriate cattle grazing (Madden et al., 2000; Samson et al. 2004), and haying in the Canadian native mixed-grass prairie (Dale et al., 1997). The direct activities of the energy sector, which are also prominent on the Canadian grasslands, receive minimal attention although the creation of access trails is considered a potential source of habitat edges (Linnen, 2008).

Degradation of breeding habitat through the creation of edges has been linked to increased risk of nest predation (Winter et al., 2000; Herkert et al., 2003; Renfrew et al., 2005; Winter et al., 2006) and higher rates of nest parasitism (Winter et al., 2000; Patten et al., 2006) leading to avoidance of edge habitat. Road edges can introduce exotic vegetation (Gelbard and Harrison, 2003), alter bird behaviour (Bayne and Hobson, 2001; Fletcher and Koford, 2003), and reduce bird species densities and richness (Reijnen et al., 1996; Sutter et al., 2000; Trombulak & Frissell, 2000; Fletcher and Koford, 2003; Ingelfinger and Anderson, 2004; Koper and Schmiegelow, 2006; Coppedge et al., 2008). Energy development for oil and gas involves the creation of access trails, well sites, pipelines and junctions. Areas with off-road vehicle trails support higher abundance of grassland birds than those with gravel or paved roads as they have less frequent traffic and are partially vegetated (Sutter et al., 2000). However, trails still decreased abundance and nesting success of shrub and grassland birds compared to areas further from trails (Miller et al., 1998; Barton and Holmes, 2007).

The initial vegetation removal caused by roads and well-sites may be followed by re-vegetation by non-native grasses causing birds to either avoid or prefer the changed vegetation. Crested-wheatgrass (*Agropyron cristatum*) (henceforth CWG), was reseeded onto agricultural lands to improve cattle forage (Henderson and Naeth, 2005) and it has also been used to remediate areas following disruption by oil and gas disturbances. Crested-wheatgrass decreases native vegetation diversity (Christian and Wilson, 1999; Heidinga and Wilson, 2002; Henderson and Naeth, 2005), has lower arthropod diversity (McIntyre and Thompson, 2003; Flanders et al., 2006), alters grassland bird diversity (Chapman et al., 2004, but see Wilson and Belcher, 1989; Sutter and Brigham, 1998), and lowers nesting success (Lloyd and Martin, 2005). While CWG was used in CFB Suffield to seed after oil and gas disturbances, this practice was halted in the early

1990s and, thereafter, native cultivars were used (B. Smith, pers. comm.). However, CWG has continued to spread on CFB Suffield (Smith, 2007) either through creation of open ground and natural colonization or directly through transport of seeds by vehicles (Trombulak and Frissell, 2000; von der Lippe and Kowarik, 2007). Trails, wells and pipelines that have either been reseeded to CWG, or which have subsequently been invaded by CWG, may act as a habitat edge for grassland birds. Crested-wheatgrass is taller, results in more standing dead vegetation, more bare ground and less litter than native vegetation (Sutter and Brigham, 1998; Christian and Wilson, 1999; but see Lloyd and Martin, 2005), increasing or confounding the possible edge effect created by the presence of trails and other human disturbance. Both predation and brood parasitism are associated with altered vegetation, such as forest or shrubs, present at edges throughout eastern grasslands (Winter et al., 2000; Herkert et al., 2003; Renfrew et al., 2005; Patten et al., 2006; Winter et al., 2006).

Three grassland bird species were selected to investigate the effects of human disturbance related to the energy sector on CFB Suffield. Savannah sparrow (*Passerculus sandwichensis*) is a generalist grassland species that is commonly found in taller vegetation in open habitat (Wheelwright and Rising, 2008), whereas chestnut-collared longspur (*Calcarius ornatus*) and Sprague's pipit (*Anthus spragueii*) are both restricted to the short and mixed grass prairies of North America (Hill and Gould, 1997; Robbins and Dale, 1999). I selected these species as Savannah sparrows are associated with disturbed areas of short or mixed grass prairie that contain taller vegetation (Sutter et al., 2000), chestnut-collared longspurs are somewhat tolerant of human disturbance such as cattle grazing and pastures seeded with exotic grasses (Hill and Gould, 1997; Davis et al., 1999), whereas Sprague's pipit are considered sensitive to disturbance (Robbins and Dale, 1999). Throughout their breeding range in the prairies of Canada and the northern states, Savannah sparrows are relatively insensitive to patch size (Madden et al., 2000; Davis, 2004; Koper and Schmiegelow, 2006 but see Renfrew et al., 2005), use disturbed road margins (Sutter et al., 2000) and have been found at similar abundances in native prairies and in areas reseeded with non-natives, including CWG (Sutter and Brigham, 1998). In the Canadian prairies, chestnut-collared longspurs and Sprague's pipits avoid roads and road margins (Sutter et al., 2000; Koper and Schmiegelow, 2006) and are area sensitive (Davis, 2004). Longspurs have similar densities and occurrence in areas predominantly reseeded to CWG and native prairie in Saskatchewan and Montana (Davis et al., 1999; Lloyd and Martin, 2005), whereas pipits are less common in areas reseeded with CWG or other non-native grasses (Wilson and Belcher, 1989; Sutter & Brigham, 1998; McMaster and Davis, 2001 but see Davis et al., 1999). Studies of CWG use by grassland birds have focused primarily on fields that are typically dominated by CWG rather than small patches occurring within native prairie such as occur at CFB Suffield.

The goal of this chapter is to characterize the habitat defended by breeding, territorial males of the three study species and to determine how human disturbances related to oil and gas development affected territory characteristics. I address the following questions in this chapter: 1) Do human disturbances cause a change in territory size or vegetation used by territorial males? 2) How tolerant are the study species to well sites, pipelines, junctions and off-road vehicle trails? and, 3) Do territories contain the same coverage of CWG as expected based on the occurrence of the exotic grass in adjacent areas?

As habitat suitability is often lower near disturbed areas, especially roads (Reijnen et al., 1996; Sutter et al. 2000; Ingelfinger and Anderson, 2004), I predicted that territories would expand to account for the lower habitat quality from human disturbances and CWG (see Fletcher and Koford, 2003; Ashenhurst and Hannon, 2008). Characteristics of vegetation on territories was expected to match the species general preferences: sparrows in taller, dense vegetation (Wheelwright and Rising, 2008), longspurs in shorter vegetation with more bare ground (Hill and Gould, 1997), and pipits in habitats with more standing dead stems and intermediate (8 to 29 cm) vegetation height (Robbins and Dale, 1999). It was not known if vegetation characteristics varied between areas of low or high well-density (see below) on CFB Suffield; however, I expected more exotic grasses on the landscape in high well-density areas due to an increase in the number of trails and traffic (von der Lippe and Kowarik, 2007). Territories of Savannah sparrows were predicted to be located closer to human disturbances and to contain more CWG due to their preference for taller vegetation in Canadian mixed-grass prairies and the their preference for taller vegetation found next to roads and trails (Sutter et al., 2000; Wheelwright and Rising, 2008; Linnen, 2008). Longspurs were expected to be indifferent to CWG and human disturbance due to their tolerance of both potential disturbances (Lloyd and Martin, 2005; Linnen, 2008). Pipits were predicted to avoid gas disturbances and CWG when establishing territories based on previous reported responses to these forms of disturbance (Sutter et al., 2000; McMaster and Davis, 2001; Linnen, 2008; Dale et al., 2009).

Methods

Study area

The study site was located in the south block of Canadian Forces Base (CFB) Suffield, in southern Alberta, 50 km northwest of Medicine Hat and 250 km southeast of Calgary (T.15 to T.19 and R.3 to R.9 W4M). This area represents one of the large remaining blocks of mixed-grass prairie in Canada. Using ArcGIS 9.2 (ESRI, 2007), eight square 3km x 3km plots were delineated in a federal pasture within the National Wildlife Area (NWA), and in an adjacent area outside of the NWA but within the military base, to facilitate locating bird territories. Each plot was designated as “low impact” with 8 wells/square mile (n=5) or “high impact” with 16 wells/ sq. mile (n=3). Suffield was chosen due to a recent proposal to increase the density of wells on the NWA to 16 wells/ sq. mile (CEAR, 2007). In 2008, four of the 9km^2 plots were shifted to avoid areas burned in 2007; the same number of sites per well-density was maintained (Figure 3.1).

Territory mapping

Territory surveys were started on May 24th and completed on July 28th in 2007. All surveys were conducted between 04:30 and 14:00. To locate birds, I randomly picked locations known to contain the species based on point count information (Chapter 2). I also attempted to maximize distance between territories to be mapped within the eight plots. This avoidance of abutting territories was intended to make territories independent with respect to general vegetation type and proximity to disturbance.

Because methods used in 2007 were biased towards selecting territories near trails, procedures were updated in 2008. Within each of the 9km^2 main plots I designated two random 500 x 500 m subplots in which all three species had been detected (Figure 3.1). I located and mapped all birds within these subplots from May 24th to July 26th. There were a total of 16 subplots surveyed in this manner (6 for high well-density areas, 10 for low well-density areas). This method (as opposed to the 2007 method) was designed to determine how territories were placed based on local landscape characteristics and to document which local features were avoided. My goal was to map at least four territories per species thus all territories of males of the three species were typically mapped within these subplots. However, in one subplot, I found 20 territorial chestnut-collared longspur males and in this subplot I mapped five randomly chosen males, and recorded the approximate location of the remaining males within the subplot. When there were no individuals of a given species in a subplot, I attempted to locate males of that species in areas adjacent to the subplot. If that failed, I attempted to locate males elsewhere on the 9 km^2 plot. Crested wheatgrass was also mapped inside the subplots in 2008 to compare the proportion of the area of active bird territories covered by CWG with CWG coverage in nearby, unused areas. There was no comparable collection of CWG data in 2007.

In both years I used the boundary flush method of Reed (1985) to delineate male territories. Territories, in this study, are conservative estimates of the area defended by males rather than a record of definitive territory boundaries. Territories were visited and mapped only once. After two observers located a singing male, we flagged all points associated with singing, calling, or where conflicts and chases occurred between two or more males. In the case of Sprague's pipit flags were placed under aerial singing locations. After the observers had a minimum of 20 flags associated with the edge of the territory, and the male was not seen defending any new areas, we used a handheld GPS (accuracy of ± 4m) to record the location of flags at the perimeter of the territory. More flags were often located within these boundaries although they were not recorded (range: 40 – 200 flags). Territory mapping took a minimum of 45 minutes to a maximum of 3 hours, with an average mapping time of approximately 2 hours. If there was CWG inside the territory, the patch size and shape was mapped using a GPS unit. Trails and well sites visible from or in the territories were also marked, and trails were roughly classified "on the ground" based on use to compare to aerial photographs and reference files provided by the Department of National Defense (DND). Off-road vehicle trails were assigned into five categories by DND. In my analysis I combined trail categories based on the level of impact into "low class trails" (DND class 2 & 3) and "high class trails" (DND class 4 & 5) due to difficulty in determining the exact DND category for any specific stretch of trail. Class 1 trails, are single track disturbances, often cattle trails or pipelines with minimal soil exposure and rut depth and high vegetation cover and were not used in my analysis due to the difficulty of locating them in the field. Low class trails were two track vehicle trails characterized by ruts with a depth of 2-30cm, a disturbance width of 30-75cm per rut and partial soil exposure. High class trails were two track vehicle trails with a disturbance width of 80-200cm, a rut depth up to 60cm and significant soil exposure. During each territory survey, all bird species seen and heard were also recorded.

Territory edge points were mapped in ArcGIS 9.2 (ESRI, 2007) to yield the territory area based on the maximum convex polygon enclosed by the flagged perimeter. When the territory generated by this method included locations where no territorial defense was observed the territory shape was altered to exclude these locations and reflect the area that was actually defended. This created smaller, more conservative estimates of territory area that more closely resembled observed defense behaviors. One Savannah sparrow in 2008 defended two neighboring locations separated by ~50m of undefended space. This male was assumed to be nesting with two females and the two territories were treated separately for all analyses.

Vegetation characteristics

After territory edges were demarcated, vegetation inside the territory was measured. In 2007 vegetation in all territories was recorded, whereas in 2008 I randomly chose one out of every four territories per species mapped in each subplot for vegetation measurements. I established 12 vegetation 1-m^2 quadrats in each territory, based on a Daubenmire frame, randomly placed a minimum of 15 paces apart. In each quadrat, an assistant and I visually estimated percent cover of living herbaceous vegetation (%LivC), litter (fallen dead) (%LitC), bare ground (%BG), standing dead vegetation (%SD) and shrubs (% shrub). Standing dead vegetation included only non-woody species while shrub cover included both living and dead woody vegetation. The average height of vegetation was estimated with a Robel pole at each corner and at the center of the quadrat. Up to six additional vegetation plots per territory were established in areas with CWG cover and measured as per standard vegetation plots. The maximum of six CWG quadrats was arrived at arbitrarily. I used Pearson's correlation to determine related vegetation characteristics.

I compared the vegetation characteristics, including the presence and coverage of CWG, within territories of males to nearby, unused areas by creating and mapping simulated vegetation territories, hereafter called vegetation territories, from May 24th to July 26th in 2008. To obtain an estimate of size for the vegetation territories that would be reasonable for all three species, I used the average areas of mapped territories for the three species, as determined in 2007 (mean = 0.63±0.04 ha, n=106). I created vegetation territories using an approximately 50m radius circle with an average area of 0.70±0.005 ha (n=40). These vegetation territories were placed within the subplots in locations where at least one of the species was not found. Vegetation measurements were conducted in the same manner as in actual bird territories. Any bird species heard or seen in the area was also recorded. For every vegetation survey in an actual bird territory, I mapped a vegetation territory within that subplot for that species. Vegetation territories were also delineated and their vegetation measured in 2007, using different procedures to locate areas unused by the study species. After preliminary analyses uncovered biases in where vegetation territories were placed in 2007, I only used vegetation territories from 2008 in subsequent analyses although data from real territories in both years were used.

Distance to human disturbances and trail crossing

Distances to human disturbances were measured from the nearest territory edge to each different type of human disturbance. Disturbances included off-road vehicle trails (DND class 2 to 5), roads, pipelines, junctions and well sites based on GIS layers provided by DND. Gravel roads were infrequent and were often over 1 km away from bird territories. Due to the rarity of roads they were not used in analysis.

To determine if birds were willing to establish territories straddling trails or if they treated trails as barriers that then served as territory boundaries, I recorded trail crossings for all bird territories. A territory was considered to cross a trail (DND class 2 – 5) whenever a trail fell within the perimeter of the territory. To determine the expected number of territories that would cross a trail, I placed 84 circular computer simulated territories each with an area of 0.70 ha within each of the 9 km^2 plots and counted the number of simulated territories that crossed any trail (DND class 2 – 5).

Statistical analysis

Analyses in this study were carried out using SPSS 16.0 for Windows (SPSS Inc. Chicago, IL USA) and all values are presented as mean ± standard error unless otherwise noted. Territory size and distance to well, pipeline, junction and trail were compared between years and sites with low versus high well-density using a two-way ANOVA (Analysis of Variance) to determine differences between years while controlling for the effect of well-density. To normalize data prior to analysis, distance to pipeline was square-root transformed while distance to trail was log transformed. I used Pearson' correlations to look for significant correlations between pairs of vegetation variables. I found that living cover was negatively correlated with standing dead vegetation ($r=-0.77$, $df=147$, $p<0.001$) whereas shrub cover was positively correlated with litter cover ($r=0.99$, $df=147$, $p<0.001$) on territories of all species combined. Living cover was also negatively correlated with litter cover and shrub cover for sparrow ($r=-0.58$, $df=46$, $p<0.001$) and pipit territories ($r=-0.54$, $df=64$, $p<0.001$), analyzed separately, but not longspur territories ($r=-0.17$, $df=37$, $p=0.32$). In subsequent analyses, living cover and shrub cover were excluded (values are presented in summary tables). Vegetation height and the percentage of bare ground, standing dead vegetation and litter cover were compared between years and well-densities for each species using a two-way ANOVA. All proportional data were arcsine transformed prior to analysis. I pooled vegetation data for 2007 and 2008 to compare differences between species using a one-way ANOVA and a Tukey's post-hoc test. I compared actual versus vegetation territories with respect to vegetation height, bare ground and litter cover using independent t-tests with unequal variance with the pooled 2007 and 2008 territory data. Standing dead vegetation was only compared between the vegetation territories and actual territories for 2008 as standing dead vegetation was considerably taller in 2007 than 2008. Vegetation quadrats were placed specifically in patches of CWG and metrics were compared between vegetation quadrats placed on actual (2007 and 2008) and vegetation (2008) territories to determine if CWG patches were different from the native vegetation on CFB Suffield in vegetation height, bare ground and litter cover using an independent sample t-test assuming unequal variances. Standing dead vegetation was compared between CWG quadrats and native vegetation quadrats for 2008 only, using an independent sample t-test assuming unequal variance.

For each species, I compared distance to disturbance between randomly located territories simulated using ArcGIS 9.2 and actual territories to determine if birds were influenced by human disturbances when locating territories. I performed six randomizations of simulated territories per species per year. This created a total of 198 and 174 Savannah sparrow simulated territories, 168 and 204 chestnut-collared longspur simulated territories and 276 and 324 Sprague's pipit simulated territories in 2007 and 2008 respectively. Simulated territories were circular with a randomly generated radius based on the range of territory sizes mapped during the study period (range of territory radii SAVS: 26 – 98m; CCLO: 30 – 87m; SPPI: 22 – 61m). I compared, for each species, the distance to disturbance between actual and simulated territories and between high and low well-density for each year using two-way ANOVAs. Distance to pipelines, high impact trails and low impact trails were log transformed to achieve normality prior to analysis.

Trail crossing was analyzed for each species separately using a X^2-goodness of fit test to determine if birds crossed more trails than expected. The expected cross rate of 40.77% was calculated using the cross rate of simulated territories if all available space was occupied.

To calculate the degree to which a bird was willing to incorporate a trail within its territory, I followed Bayne et al. (2005). If a trail bisected a territory, I calculated the proportion of the territory on the largest side of the trail (all percentages are therefore reported as > 50%). I then compared this proportion using a one-sample t-test against a null hypothesis split of 50% to determine if territories were placed randomly with regard to a trail or if trails were located near a territory edge. Trail crossings were pooled between areas of high and low well-density to increase sample size.

I calculated the proportion and total area in each territory that supported CWG for each species. Crested wheatgrass cover was compared between actual and simulated territories and between the two levels of well-density using a two-way ANOVA separately for 2007 and 2008. In 2008, the proportion of CWG in territories was compared to the proportion of CWG available in the corresponding 500 x 500 m^2 subplots using a paired t-test. These two analyses allowed me to determine if territories of each species contained more or less CWG than simulated territories (unused areas), as well as to determine if territories of each species contained more or less CWG than available on the local landscape (regardless of use). Finally, I used a log-linear analysis (G^2) for a 3-way contingency table (VassarStats, R. Lowry) to find any differences between the presence - absence of CWG in actual territories and vegetation territories while controlling for well-density.

Results

Differences between years at low versus high well-density

I mapped 33 sparrow, 28 longspur and 45 pipit territories in 2007, and 28 sparrow, 34 longspurs and 54 pipit territories in 2008. On average, Savannah sparrows and chestnut-collared longspurs had larger territories than Sprague's pipit (0.90±0.073, 0.74±0.050, and 0.46±0.023 ha, respectively). The range of territory size was 0.22-2.42 ha for sparrows, 0.24-2.28 ha for longspurs and 0.16-1.19 ha for pipits. The average territory size of each of the species did not vary significantly between plots with high and low well-density (SAVS, $F_{1,57} = 0.67$, p=0.42; CCLO, $F_{1,58} = 1.68$, p=0.20; SPPI, $F_{1,95} = 0.$, p36=0.55). Longspurs however, had significantly larger territories in 2007 than in 2008, whereas Savannah sparrows and pipits tended to have smaller territories in 2007 (SAVS, $F_{1,57} = 3.79$, p=0.06; CCLO, $F_{1,58} = 7.76$, p=0.007; SPPI, $F_{1,95} = 2.64$, p=0.11). There was no interaction between year and well-density for sparrows or pipits (SAVS, $F_{1,57} = 0.52$, p=0.69; SPPI, $F_{1,95} = 0.44$, p=0.51) although there was significant interaction between well-density and year for longspur territories due to small territory size found at high-well densities in 2008 (CCLO, $F_{1,58} = 6.97$, $p=0.01$; Figures 3.2 and 3.3).

Due to interannual variation in the distance to disturbance for both longspur and pipit territories, I did not pool data for 2007 and 2008 except where noted. High and low well-densities were not pooled, except where noted, due to significant differences between distances to disturbances for both longspur and pipit territories.

For Savannah sparrow territories there was no influence of well-density or year on distance to wells (Well density: $p=0.20$; Year: $p=0.25$), pipelines (Well density: $p=0.06$; Year: $p=0.98$), junctions (Well density: $p=0.09$; Year: $p=0.97$) or trails (Well density: $p=0.87$; Year: $p=0.44$; see Appendix 1, Table A.1). Longspur territories were closer to wells ($p=0.001$) and junctions ($p=0.02$) at high well-density and closer to pipelines ($p=0.009$) in 2007 compared to 2008 (see Appendix 1, Table A.2). Longspur territories were similar in distance to trail (Well-density: $p=0.78$; Year: $p=0.19$) between well-density and year. Pipit territories were closer to well sites in 2008 ($p=0.007$) and were closer to junctions ($p=0.007$) in high well-densities (see Appendix 1, Table A.3).

Neither Savannah sparrow nor pipit territories differed in coverage by CWG between 2007 and 2008 (SAVS: $p = 0.17$; SPPI: $p = 0.16$; Appendix 1, tables A.4 and A.6) or between areas of high and low well-density (SAVS: $p = 0.13$) although pipit territories tended to contain more CWG at high well-densities (SPPI: $p = 0.06$). Longspur territories, however, had greater CWG coverage in

2007 versus 2008 ($p = 0.04$) but not between well-densities ($p = 0.68$; Appendix 1, Table A.5).

Vegetation characteristics

Using a two-way ANOVA, I found no significant differences in height, bare ground or litter cover between years or well-densities for any of the three study species (see Appendix 1, Tables A.1-3). There was more standing dead vegetation for all species territories in 2007 compared to 2008, with no difference between well-densities (see Appendix 1, Tables A.1-3).

Litter cover ($F_{2,144} = 39.35$, $p < 0.001$) and vegetation height ($F_{2,144} = 5.94$, $p=0.003$), from both years combined, differed among the three species and a Tukey's post-hoc test indicated that sparrow territories had significantly taller vegetation and less litter cover than either longspur or pipit territories (Tables A.1-3). There were no differences among the three species in the cover of bare ground ($F_{2,144} = 1.33$, $p=0.27$) or standing dead vegetation ($F_{2,144} = 0.36$, $p=0.70$) in their territories (Tables A.1-3).

Sparrow territories had taller vegetation ($t=-2.19$, $df=40.4$, $p=0.034$) and less litter cover ($t=2.30$, $df=60.6$, $p=0.025$) than vegetation territories, but did not differ in amount of bare ground ($t=0.97$, $df=37.4$, $p=0.34$; Table 3.1). Longspur territories did not differ in vegetation height ($t=1.39$, $df=11.7$, $p=0.19$), bare ground ($t=-0.68$, $df=35.5$, $p=0.50$), or litter cover ($t=-0.85$, $df=32.2$, $p=0.40$) compared to vegetation territories (Table 3.2). Lastly, pipit territories did not differ from vegetation territories in vegetation height ($t=1.05$, $df=25.97$, $p=0.31$), bare ground (t=0.003, df=34.4, p=0.99), or litter cover (t=0.27, df=28.5, p=0.79; Table 3.3).

Standing dead vegetation was compared between actual and vegetation territories only for 2008 due to the differences between standing dead vegetation in 2007 and 2008. Sparrow and longspur territories did not differ from vegetation territories in the amount of standing dead vegetation (SAVS: t=-0.58, df=23.7, p=0.57; CCLO: t=-0.46, df=18.6, p=0.65), whereas pipit territories had more standing dead vegetation than vegetation territories (t=-4.35, df=33.93, p<0.001).

Distance to nearest well site

Savannah sparrow territories did not differ from simulated territories in distance to well sites in either 2007 at either high or low well-densities (Simulated vs Actual: $F_{1,227}$=0.40, p= 0.53; Well-density: $F_{1,227}$=3.17, p= 0.077; Interaction: $F_{1,227}$=0.59, p= 0.44; Figure 3.4a). In 2008, territories were further from well sites at high well-density compared to areas of low well-density, but otherwise distance to the nearest well site was similar (Simulated vs. Actual: $F_{1,198}$=0.017, p= 0.90; Well-density: $F_{1,198}$=6.28, p=0.013; Interaction: $F_{1,198}$=0.006, p= 0.94). In 2007, longspur territories did not differ significantly from simulated territories in distance to wells ($F_{1,192}$=0.084, p=0.77) but all territories were significantly further from wells at low well-densities compared to high well-densities ($F_{1,192}$=22.53, p<0.001; Interaction: $F_{1,192}$=5.44, p=0.021; Figure 3.4b). In 2008, longspur territories were further than simulated territories from well sites ($F_{1,234}$=4.15, p=0.043) and further from wells at low well-densities compared to high well-densities ($F_{1,234}$=5.78, p=0.017; Interaction: $F_{1,234}$=0.24, p=0.63; Figure 3.4b). In 2007, pipit territories were significantly further than simulated territories from well sites and all territories were further from wells at low well-densities compared to high well-densities (Simulated vs Actual: $F_{1,317}$=5.34; p=0.022; Well-density: $F_{1,317}$=9.29, p=0.002; Interaction: $F_{1,317}$=2.08, p=0.15; Figure 3.4c). In 2008, pipit territories were similar to simulated territories in distance to nearest well although all territories were further from well sites in low-well densities compared to high well-densities (Simulated vs. Actual: $F_{1,374}$=0.18, p=0.68; Well-density: $F_{1,374}$=10.86, p=0.001; Interaction: $F_{1,374}$=0.84, p=0.36; Figure 3.4c).

Distance to nearest pipeline or junction

Savannah sparrow territories did not differ in distance from simulated territories from pipelines in either 2007 or 2008 and did not differ between high and low well-density (2007 Simulated vs. Actual: $F_{1,227}$=0.12, p=0.73; Well-density: $F_{1,227}$=0.065, p=0.80; Interaction: $F_{1,227}$=2.63, p=0.11; 2008 Simulated vs. Actual: $F_{1,198}$=0.47, p=0.49; Well-density: $F_{1,198}$=0.44, p=0.51; Interaction: $F_{1,198}$=1.43, p=0.23; Figure 3.5a). In 2007, longspur territories were closer to pipelines than simulated territories (Simulated vs. Actual: $F_{1,192}$=5.06, p=0.026; Well-density: $F_{1,192}$=0.19, p=0.66; Interaction: $F_{1,192}$=1.79, p=0.18). In 2008, longspur territories did not differ from simulated territories with respect to distance to pipelines at either well-density (Simulated vs. Actual: $F_{1,234}$=2.65, p=0.11; Well-density: $F_{1,234}$=0.061, p=0.81; Interaction: $F_{1,234}$=0.50, p=0.48;

Figure 3.5b). Pipit territories and simulated territories did not differ in distance from pipelines at either well-density in 2007 (Simulated vs. Actual: $F_{1,317}$=0.17, p=0.68; Well-density: $F_{1,317}$=0.91, p=0.34) but pipit territories were further from pipelines at high well-density but are closer to pipelines in low well-densities whereas simulated territories have the opposite trend (Interaction: $F_{1,317}$=10.23, p=0.002; Figure 3.5c). In 2008, distance to pipeline did not differ between pipit territories and simulated territories at either well-density (Simulated vs. Actual: $F_{1,374}$=0.043, p=0.84; Well-density: $F_{1,374}$=3.45, p=0.064; Interaction: $F_{1,374}$=0.10, p=0.75; Figure 3.5c).

Territories of all species were closer to junctions in high well-density areas compared to low well-density areas (2007 SAVS: $F_{1,227}$=7.37, p=0.007; 2008 SAVS: $F_{1,198}$=3.05, p=0.082; 2007 CCLO: $F_{1,192}$=13.65, p<0.001; 2008 CCLO: $F_{1,234}$=3.58, p=0.060; 2007 SPPI: $F_{1,317}$=7.59, p=0.006; 2008 SPPI: $F_{1,374}$=61.19, p<0.001). There was no difference in the distance to junction between actual and simulated territories for any of the species (2007 SAVS: $F_{1,227}$=0.48, p=0.49; 2008 SAVS: $F_{1,198}$=0.33, p=0.57; 2007 CCLO: $F_{1,192}$=0.002, p=0.97; 2008 CCLO: $F_{1,234}$=0.009, p=0.92; 2007 SPPI: $F_{1,317}$=0.093, p=0.76; 2008 SPPI: $F_{1,374}$=0.011, p=0.92), nor were there significant interactions (2007 SAVS: $F_{1,227}$=0.34, p=0.56; 2008 SAVS: $F_{1,198}$=0.12, p=0.73; 2007 CCLO: $F_{1,192}$=0.61, p=0.44; 2008 CCLO: $F_{1,234}$=0.38, p=0.54; 2007 SPPI: $F_{1,317}$=2.52, p=0.11; 2008 SPPI: $F_{1,374}$=0.007, p=0.93).

Distance to nearest trail

In 2007, sparrow territories did not differ from simulated territories in distance from low impact trails at either well-density (Simulated vs. Actual: $F_{1,227}$=0.21, p=0.51; Well-density: $F_{1,227}$=0.56, p=0.46; Interaction: $F_{1,227}$=2.08, p=0.15). The same trend was found in 2008 (Simulated vs. Actual: $F_{1,198}$=0.50, p=0.48; Well-density: $F_{1,198}$=2.72, p=0.10; Interaction: $F_{1,198}$=0.16, p=0.69; Figure 3.6a). In 2007, longspurs territories were closer than simulated territories to low impact trails but distances did not vary between well-density (Simulated vs. Actual: $F_{1,192}$=6.03, p=0.015; Well-density: $F_{1,192}$=0.041, p=0.84; Interaction: $F_{1,192}$=0.11, p=0.74). In 2008 distances did not differ between longspur territories and simulated territories at either well-density (Simulated vs. Actual: $F_{1,234}$=0.063, p=0.80; Well-density: $F_{1,234}$=0.45, p=0.83; Interaction: $F_{1,234}$=0.009, p=0.93; Figure 3.6b). Distance to low impact trails did not differ between pipit territories and simulated territories at either well-density in either year (2007 Simulated vs. Actual: $F_{1,317}$=0.65, p=0.42; Well-density: $F_{1,317}$=0.42, p=0.52; Interaction: $F_{1,317}$=1.32, p=0.25; 2008 Simulated vs. Actual: $F_{1,374}$=0.27, p=0.60; Well-density: $F_{1,374}$=1.81, p=0.18; Interaction: $F_{1,374}$<0.001, p=0.99; Figure 3.6c).

The average distance from both simulated territories and actual territories to high impact trails, DND class 4 or 5, was over 100m except for sparrows in high well-density plots (Figure 3.7). In 2007, all territories were further from high impact trails at high well-densities compared to low well-densities (SAVS: $F_{1,227}$=5.44, p=0.021; CCLO: $F_{1,192}$=12.41, p=0.001; SPPI: $F_{1,317}$=10.42, p=0.001) but there were no significant differences between well-densities in 2008 (SAVS:

$F_{1,198}$=1.25, p=0.26; CCLO: $F_{1,234}$=0.19, p=0.66; SPPI: $F_{1,374}$=0.035, p=0.85; Figure 3.7). Savannah sparrow territories did not differ from simulated territories in distance to high impact trails in either year (2007: $F_{1,227}$=0.26, p=0.61; 2008: $F_{1,198}$=0.040, p=0.84). Longspur territories were significantly closer to high impact trails than were simulated territories in 2007 ($F_{1,192}$=4.42, p=0.037) but tended to be further in 2008 ($F_{1,234}$=3.60, p=0.059). Pipit territories were did not differ from simulated territories in either year (2007: $F_{1,317}$=0.093, p=0.76; 2008: $F_{1,374}$=0.47, p=0.49).

Territory crossing of off-road vehicle trails

Birds crossed trails during territory defense in both years. The frequency with which Savannah sparrow territories crossed trails did not differ significantly from the expected rate of trail crossing, 40.77%, in either year (2007: X^2 = 1.71, df = 1, p>0.05; 2008: X^2 = 1.17, df = 1, p>0.05). Longspur territories crossed trails more frequently than expected in 2007 (X^2 = 3.97, df = 1, p<0.05) but less frequently than expected in 2008 (X^2 = 6.62, df = 1, p<0.05). Pipit territories crossed trails less frequently than expected in both years (2007: X^2 = 20.68, df = 1, p<0.05 2008: X^2 = 9.61, df = 1, p<0.05; Table 3.4).

All species territories differed significantly from the prediction of the null model that trails would bisect territories into equal (50/50%) halves (Table 3.5). Pipit territories in 2007 were the least biased to one side of the trail with a mean territory split not significantly different from 58/42% although pipit territories in 2008 were more biased to one side of the trail with a null model of 73/27%.

Longspur territories were biased to one side of the trail with mean territory splits not significantly different from null models of 71/29% in 2007 and 74/26% in 2008. Savannah sparrow territories fell between the range of longspur and pipit territories (Table 3.5).

Distribution of crested wheatgrass

Quadrats designed to measure CWG contained significantly taller vegetation (Standard: 10.83±0.26; CWG: 16.40±0.78; $t=8.91$, $df=91.1$, $p<0.001$), more bare ground (Standard: 5.47±0.41; CWG: 10.81±1.73; $t=2.27$, $df=89.85$, $p=0.026$) and more litter cover (Standard: 16.09±0.55; CWG: 22.66±1.69; $t=3.11$, $df=95.68$, $p=0.002$) than vegetation quadrats taken on actual territories. There was no difference in the amount of standing dead vegetation between the two types of quadrats (Standard: 12.90±0.67; CWG: 15.54±1.41; $t=1.70$, $df=48.75$, $p=0.10$).

Savannah sparrows had the largest proportion of territories with CWG present (29 out of 61) followed by longspurs (25 out of 62) and pipits (24 out of 99; Table 3.6). A significantly higher number of Savannah sparrow territories had CWG in plots with high well-density than with low well-densities ($G^2 = 4.86$, $df = 1$, $p = 0.03$) but no difference in frequency of occurrence of CWG between actual and vegetation territories for both well-densities combined ($G^2 = 2.84$, $df = 1$, $p = 0.09$). A significantly larger proportion of longspur territories contained CWG at high well-densities than in low well-densities ($G^2 = 9.92$, $df = 1$, $p = 0.002$), but no overall difference existed between actual and vegetation territories ($G^2 = 0.00$, df = 1, p = 1.00). A significantly lower proportion of pipit territories contained CWG compared to vegetation territories (G^2 = 5.66, df = 1, p = 0.02) and there was a non-significant trend for higher frequency of occurrence of CWG in high well-densities compared to low well-densities (G^2 = 3.48, df = 1, p = 0.06).

The percentage of the area covered by CWG within territories was highest for Savannah sparrows (8.66±2.90), followed by pipits (1.03±0.40) and longspurs (0.40±0.10). For all species, CWG coverage was greater at high well-densities than at low well-densities. Savannah sparrow territories contained similar CWG coverage as vegetation territories ($F_{1,90}$ = 0.53, p=0.47; Figure 3.8a). Longspur territories contained significantly less CWG than vegetation territories ($F_{1,78}$ = 6.12, p=0.016; Figure 3.8b) and pipit territories contained significantly less CWG compared to vegetation territories when one outlier pipit territory was removed from analysis (Grubb's test: Z=3.38, n=99, p<0.05; $F_{1,120}$ = 3.83, p = 0.053; Figure 3.8c). This atypical pipit had 81% coverage of CWG on his territory. Territories of all three species had significantly less CWG in plots with low well-density compared to plots with high well-density (SAVS: $F_{1,78}$= 5.11, p=0.026; CCLO: $F_{1,78}$= 8.02, p=0.006; SPPI: $F_{1,120}$= 5.01, p=0.027).

Savannah sparrow territories had less CWG cover compared to the 500 x 500m subplots in high well-density plots (t = -2.41, df = 7, p = 0.05), but did not differ in the percent area of a territory covered by CWG in low well-density plots (t = -1.33, df = 19, p = 0.20; Figure 3.9). Regardless of well-density, both longspur and pipit territories contained lower percent cover of CWG than neighboring subplots (CCLO high: t = -4.45, df = 8, p=0.002; CCLO low: t = -

4.95, df = 24, p<0.001; SPPI high: t = -2.57, df = 23, p = 0.02; SPPI low: t = -3.21, df = 29, p=0.003; Figure 3.9).

Discussion

In this chapter, I determined how territory size and placement were affected by disturbances related to oil and gas development and assessed habitat selection of Savannah sparrows, chestnut-collared longspurs, and Sprague's pipit in the National Wildlife Area of CFB Suffield.

Differences in precipitation between 2007 and 2008 likely accounted for the majority of between year differences. Precipitation levels are linked to above ground primary productivity (Lane et al., 2000) and standing dead vegetation and litter results from the death and decay of the living cover. Thus, as the proportion of standing dead vegetation was low in 2008, this was likely caused by low precipitation in 2007 (84.4mm precipitation from May to July; Environment Canada National Climate Data and Information Archive) whereas, in 2006, precipitation was slightly wetter than the normal (148.9mm from May to July; Environment Canada National Climate Data and Information Archive). The heavy rains early in the field season of 2008 may have affected bird settlement patterns (197.2mm from May to July; Environment Canada National Climate Data and Information Archive). The 30 years average for CFB Suffield is 134.5mm of precipitation from May to July (Environment Canada National Climate Data and Information Archive).

Despite the yearly difference in precipitation, vegetation use in my study was similar between years. As per my original predictions, vegetation characteristics within territories were similar to those reported previously within the breeding ranges of the study species (Hill and Gould, 1997; Robbins and Dale, 1999; Wheelwright and Rising, 2008). Counter to my predictions, bird territory size did not vary between well-densities. As predicted, each species demonstrated a different tolerance to human disturbances associated with natural gas development. Additionally, species responded differently to crested wheatgrass.

Savannah sparrows

Savannah sparrow territories did not vary in size between plots with low and high well-densities, nor did size vary between years. The average territory size found in my study falls within the range of previous records for sparrow territories (range: 0.03 – 1.25; as reviewed by Wheelwright and Rising, 2008). On CFB Suffield, sparrows preferred taller vegetation with less litter cover compared to vegetation territories but did not differentiate between more or less bare ground or standing dead vegetation. Dale (1983) and Davis (2005) found, in Saskatchewan mixed-grass prairies, that vegetation height is a good predictor of the presence of Savannah sparrows while Winter et al. (2006), in the northern tall-grass prairie of the United States, found the species avoided shrubs. However, Madden et al. (2000) found that Savannah sparrows were too ubiquitous in North Dakota mixed-grass prairies, to determine corresponding vegetation attributes.

For both well densities, I found that Savannah sparrow territories were not closer or further to well sites, pipelines or junctions than simulated territories. Well sites in the area were marked by a tall, narrow post; I observed that male sparrows often perched and sang from these posts when wells were incorporated into territories. Use of human structure as perches may explain the proximity of Savannah sparrows to well sites. Pipelines and junctions were reseeded with CWG if they were installed prior to the early 1990s. Studies by the Department of National Defense have found significant differences in vegetation structure on pipelines that have been in place for over 30 years, mainly due to increased soil compaction and the presence of non-native grass species (Rowland, 2008). As CWG is taller than native grasses and forbs, and sparrow territories tended to contain tall vegetation, sparrows might be attracted to pipelines and junctions because of CWG. I did not find this pattern, which may be due to low coverage of CWG around these disturbances or due to surrounding landscape features associated with the presence of CWG, neither of which I investigated. Linnen (2008) also found some evidence, using point counts, that Savannah sparrows may be associated with the denser vegetation found near oil development on CFB Suffield although this relationship was not significant in their study.

I found that sparrow territories were not further from low impact trails compared to simulated territories and sparrow territories frequently crossed trails, thus trails did not appear to act as a barrier to territory establishment. High impact trails were over 100m from both Savannah sparrow territories and simulated territories and this may reflect the rarity of high impact trails in my study area. Sutter et al., (2000) found in Saskatchewan that Savannah sparrows may favor roads due to a preference for associated taller vegetation. Overall, the response of Savannah sparrows to trail or road edges is ambiguous. Some studies have found the species avoids small patch sizes Wisconsin (Renfrew et al., 2005) whereas, in Alberta and Saskatchewan, other studies have not (Davis, 2004; Koper and Schmiegleow, 2006). Responses seem to depend on the dominant vegetation and type of edge.

In Savannah sparrow territories that crossed trails, two thirds of the defended area was on one side of the trail, indicating that trails were not barriers to territory establishment but territories still tended to occur on one side of the trail. Bayne et al., (2005) found that seismic lines in the boreal forest were perceived as habitat edges by ovenbirds (*Seiurus aurocapilla*) as males with territories next to seismic lines placed their territories predominantly (92% of area) on one side of the seismic lines. Seismic lines in the boreal forest represent a sudden change in structure even if this gap in the forest is relatively narrow (2-3m). Vehicle trails may present a sudden change in habitat as they offer higher bare ground and often taller, non-native vegetation (see Sutter et al., 2000). This taller vegetation on or near trails may be attractive to Savannah sparrows causing this species to place territories near or across trails. Most sparrow territories contained large, continuous patches ($\geq 100m^2$) of CWG and three sparrow territories were entirely contained within a patch of CWG in 2007.

Many studies have reported that Savannah sparrows are found in both non-native and native vegetation (Sutter and Brigham, 1998; Wilson and Belcher, 1989). Thus I expected the species to use patches of CWG due to their preference for taller vegetation (Wheelwright and Rising, 2008). In fact, I found that sparrow territories had more CWG coverage than was typical of the landscape in low well-density plots, but had less CWG coverage than available in high well-density plots while occurrence of CWG was greater. Patterns on both high and low well-density plots indicate that Savannah sparrows are not avoiding CWG and are willing to incorporate patches of CWG within their territories. The use of more CWG in low well-density sites agrees with Fletcher and Koford (2002) who found that, in Iowa, Savannah sparrows will select non-native grassland over native if that vegetation matches the species' general vegetation preferences.

Overall, Savannah sparrows on CFB Suffield primarily select habitat for breeding that supports taller vegetation. Proximity to human caused disturbances and the presence and proportion of non-native vegetation within territories displayed variable patterns. It is possible that certain kinds of disturbances, like traffic associated with trails, may cause avoidance whereas other disturbances, such as well sites, are attractive. As a whole, I found that human disturbance had a minimal effect on Savannah sparrow territory placement, although Dale et al. (in press) reported that increasing well-density from 1997 to 2003 on CFB Suffield was associated with increasing Savannah sparrow abundance.

Chestnut-collared longspurs

For unknown reasons, longspurs had smaller territories in 2008 compared to 2007, but there was no difference in territory size in response to well-density despite similar abundances between years (see Chapter 2). In both years, average territory sizes fell within the range previously recorded in southern Alberta and Saskatchewan, i.e., an average size of 0.4 to 0.8 ha (range: 0.25 – 4 ha; as reviewed by Hill and Gould, 1997). There were no differences in vegetation between longspur territories and vegetation territories. Other research in the Canadian mixed-grass prairies has shown that longspurs are associated with sparse vegetation and low litter depth (Dale, 1983; Davis et al., 1999). In Saskatchewan, Davis (2005) found that longspurs preferred shorter vegetation, less standing dead vegetation, less litter cover and more bare ground near their nest sites. However, Dieni and Jones (2003), in northern Montana mixed-grass prairies, reported that longspurs used taller and denser vegetation than available on the landscape and nest site vegetation was often similar to the landscape vegetation.

Longspur territories were further from wells than simulated territories in 2008 but not in 2007. Actual territories were closer to pipelines and low impact trails in 2007 compared to simulated territories although this pattern was absent in 2008. Linnen (2008) found that on other areas of CFB Suffield and in southern Saskatchewan that longspurs reached their highest abundances at 50m and 150m from oil and gas development, respectively (based on a range of 50 – 450m from oil and gas disturbances). My results do not offer any direct support for Linnen’s findings due to sampling bias in 2007 that favored longspur territories closer to trails (2007: 25.6m; 2008: 44.8m).

As a result of sampling bias, in 2007 I found that longspurs held territories that crossed trails with a higher frequency than expected if trails were not a barrier to territory establishment. In 2008, when samples were independent of trails, longspurs held territories that crossed trails less frequently than expected. This suggests that the 2008 data are more representative of longspur behaviour. Previous research in the Canadian prairies has found longspurs breeding in areas that have been disturbed through cattle grazing (Davis et al., 1999), haying (Dale et al., 1997), and non-native vegetation (Lloyd and Martin, 2005). However, studies in the Canadian prairies have found that longspurs avoid both roads (Sutter et al., 2000; Koper and Schmiegelow, 2006) and off-road vehicle trails (Linnen, 2008). Therefore, longspurs may find placing territories across trails undesirable but can tolerate the presence of trails and will hold territories that cross trails.

When territories straddled trails, longspurs had on approximately 70% of their territory located on one side. Trails do not appear to present a barrier to territory establishment but longspur territories crossed trails less frequently than Savannah sparrow territories. As previously discussed, vehicle trails offer a higher proportion of bare ground (see Sutter et al., 2000) which may be attractive to longspurs that regularly incorporates areas of bare ground into their territories (Hill and Gould, 1997).

Lloyd and Martin (2005) found, in Montana, that densities of chestnut-collared longspurs did not vary between fields of CWG and native prairie, but the nesting success of longspurs in CWG was significantly lower and smaller young were fledged. Sutter and Brigham (1998), in Saskatchewan, also found longspurs occurred at similar densities between sites dominated by CWG and sites that contained only native grassland. I found that longspurs had significantly less CWG coverage in their territories than available on the landscape or in vegetation territories which suggests that longspurs preferred native vegetation or shorter vegetation. Whereas longspurs appeared to tolerate the presence of small clumps of CWG, coverage never exceeded 15% of their territories and CWG was more commonly found in territories located at high well-densities than territories at low well-densities. Most longspur territories contained small patches ($\leq 20m^2$) of CWG rather than continuous blocks with all but two patches smaller than $800m^2$ (max. $1705m^2$).

Overall, chestnut-collared longspurs in my study avoided human disturbance in the form of non-native CWG. Davis (2004) found that longspurs are sensitive to small patch sizes and therefore edge, while Linnen (2008) found the species at reduced abundance near access trails. It does appear that natural gas disturbance results in some fragmentation and degradation of the available habitat for longspurs on CFB Suffield. I recorded up to 20 - 25 male longspurs performing territorial behavior and this high density of longspurs was found in other portions of the study area. The lack of consistent avoidance of disturbances, other than CWG, may reflect the fact that longspurs establish territories to be close to conspecific birds (Hill and Gould, 1997) and this semi-colonial nesting pattern may lead some birds in an aggregation to nest near human disturbances.

Sprague's pipit

The size of pipit territories in CFB Suffield was similar at both well-densities in both years. Territory size was within the range of previous estimates of between 0.1 and 2 ha (as reviewed Robbins and Dale, 1999). These prior estimates were largely based on density and aerial display observations rather than direct territory mapping. Vegetation was consistent on pipit territories between plots with high and low well-density and between years. Vegetation characteristics in my study were comparable with those found by Dale (1983), Sutter (1997) and Davis (2005), in Saskatchewan mixed-grass prairie. Here, pipits preferred more standing dead vegetation, less bare ground, and increased litter depth in territories and near nesting sites compared to surrounding prairie.

Pipit territories were further from well sites than were simulated territories in 2007 but not 2008. As the average distance to the nearest well was over 100m, it is in keeping with prior research that found fewer pipits within 350m of tradition oil wells on CFB Suffield (from a range of 50 to 450m; Linnen, 2008). Similarly, pipit territories had weak and variable responses to distance to nearest pipeline or junction when compared to simulated territories. The different vegetation structure found near pipelines and junctions (Rowland, 2008) may not cover a sufficient surface area to cause territory displacement. Given my findings, it is unlikely that pipelines and junctions cause territory displacement.

As was documented for wells, junctions and pipelines, pipit territories and simulated territories were similar distances to the nearest low impact trail, however, territories crossed trails less frequently than expected. Of the 27 pipits that did cross trails, most territories were not clearly located on one side of the trail. The low number of territories crossing trails is more telling than the preference for a single side of the trail. Sutter et al. (2000) found that pipits in southern Saskatchewan avoided roads and associated drainage ditches compared to off road vehicle trails and simply assumed that trails had little to no effect on the presence of pipits without testing the assumption. In Alberta, Koper and Schmiegelow (2006) also found that pipits had lowered abundances near roads. This avoidance of trails and roads by pipits is similar to that found in other birds that are grassland specialists. For example, bobolinks (*Dolichonyx oryzivorus*) show territory displacement of approximately 50m from roads (Fletcher and Koford, 2003). Sagebrush obligates, such as Brewer's Sparrow (*Spizella breweri*) and Sage Sparrow (*Amphispiza belli*), also have lower abundance within 100m of low traffic roads (10 – 700 vehicles per day; Ingelfinger and Anderson, 2004). Pipits defend their territories during long aerial displays (Robbins and Dale, 1999), and vehicle ruts and changes in vegetation structure may be clearly visible to displaying males.

Pipit territories had less CWG coverage than occurred across the landscape, than was found on simulated territories, and had fewer occurrences of CWG in their territories compared to simulated territories. Of the five pipit territories found with more than 10% CWG coverage, all were located in association with at least two contiguous singing male pipits. All five territories were also located in high well-density plots and four of these were located in the same 9km^2 plot. Two of the five territories contained several small scattered clumps of CWG rather than continuous blocks. A third territory crossed a road and CWG was located in roadside ditches. While these birds were atypcial in the study area, they indicate that some pipits will tolerate the presence of CWG. Pipits are more common in native prairie than in prairie reseeded with CWG and this pattern is believed to be caused by the general avoidance of pipits of taller, denser vegetation (Wilson and Belcher, 1989; Sutter, 1997; Sutter and Brigham, 1998; Robbins and Dale, 1999; Davis, 2005).

Overall, Sprague's pipit avoided crossing off-road vehicle trails and used fewer areas with CWG than available. The effect of wells, pipelines and junctions on the location of pipit territories was minimal in this study. Other studies have found that Sprague's pipit avoids edge habitat, specifically roads (Sutter et al., 2000) and is area, and therefore edge, sensitive (Davis, 2004; Davis et al., 2006). Sprague's pipit is listed as threatened on Schedule 1 of the *Species at Risk Act* (COSEWIC, 2000) and there is relatively little information available regarding the effects of human disturbance on this species. Increasing human disturbance may not cause an obvious decrease in the abundance of pipits (see Chapter 2) but if pipits continue to place territories to avoid crossing off-road vehicle trails and CWG as these features increase on prairie landscapes, less suitable breeding habitat will be available and populations will continue to decline.

General conclusions

Of the three species studied on CFB Suffield, Savannah sparrows were least affected by oil and gas related disturbances and by non-native vegetation. Chestnut-collared longspurs had no clear pattern in the placement of territories with relation to distance to disturbances but did avoid CWG in areas with both high and low well-densities. Sprague's pipit avoided both crossing off-road vehicle trails and CWG presence in their territories. For all species, territory size was unaffected by well-density, as were vegetation characteristics found within territories.

Overall, high well-density plots and low well-density plots had similar vegetation despite more coverage of CWG and higher levels of human disturbance at high-well densities (see Chapter 2). The lack of obvious displacement of territories near wells, pipelines and junctions at either well-density may be caused by the relatively small area impacted by disturbances, both in terms of total surface area affected and in terms of the vegetation changes associated with these disturbances. However, an increase in the number of well sites on CFB Suffield between 1997 and 2003 has been linked to increased abundance of Savannah sparrows and decreased abundance of Sprague's pipit (Dale et al., 2009). How much these changes in bird abundance are due to the presence of the well sites themselves or due to associated infrastructure, such as trails, had not been assessed prior to my study.

Trails appear to act as habitat edges for pipits, but trails are only partially avoided by longspurs and sparrows. Some grassland songbirds, such as vesper sparrows (*Pooecete gramineus*), Brewer's sparrows (*Spizella breweri*) and grasshopper sparrows (*Ammodramu savannarum*), avoid off-road vehicle trails although other songbirds, such as horned lark (*Eremophila alpestris*), are relatively more common near roads and trails (Miller et al., 1998; Ingelfinger and Anderson, 2004; Barton and Holmes, 2007). Linnen (2008) found lower abundances based on point count data, for chestnut-collared longspurs within 50m and Sprague's pipit within 250m of trails associated with oil wells on CFB

Suffield, whereas Savannah sparrows had slightly higher abundance within 50m of trails. Because the presence of exotic grass species is frequently associated with roads (Gelbard and Harrison, 2003), and traffic is a known factor in the spread of exotic plants (von der Lippe and Kowarik, 2007), trails are likely vectors in the transport and spread of CWG into native prairie.

Crested wheatgrass was most often found alongside off-road vehicle trails or in patches around well sites and pipelines during my study in the NWA. Compared to areas of low well-density, areas of high well-density were associated with greater coverage of CWG on CFB Suffield (see Figure 9). Patches of crested wheatgrass are structurally different from native mixed-grass vegetation in CFB Suffield with taller stems, more bare ground and more litter cover. These characteristics do not match previously recorded vegetation preferences for chestnut-collared longspurs and Sprague's pipits (Hill and Gould, 1997; Robbins and Dale, 1999). My study did not document if patches of CWG were used differently than native vegetation by birds foraging for themselves or for young, but observational studies could further explore the affects of this introduced plant on breeding bird behaviour.

It is not the presence of wells and pipelines placed by oil and gas development that is affecting territory placement by the study species, but the associated creation of access trails and introduction of non-native vegetation that is changing the vegetation structure in the NWA. Without data on breeding success, however, territory data alone cannot predict possible changes to grassland bird populations or whether sites with higher levels of human disturbances represent sources or sink habitats or locations that are avoided entirely by nesting songbirds.

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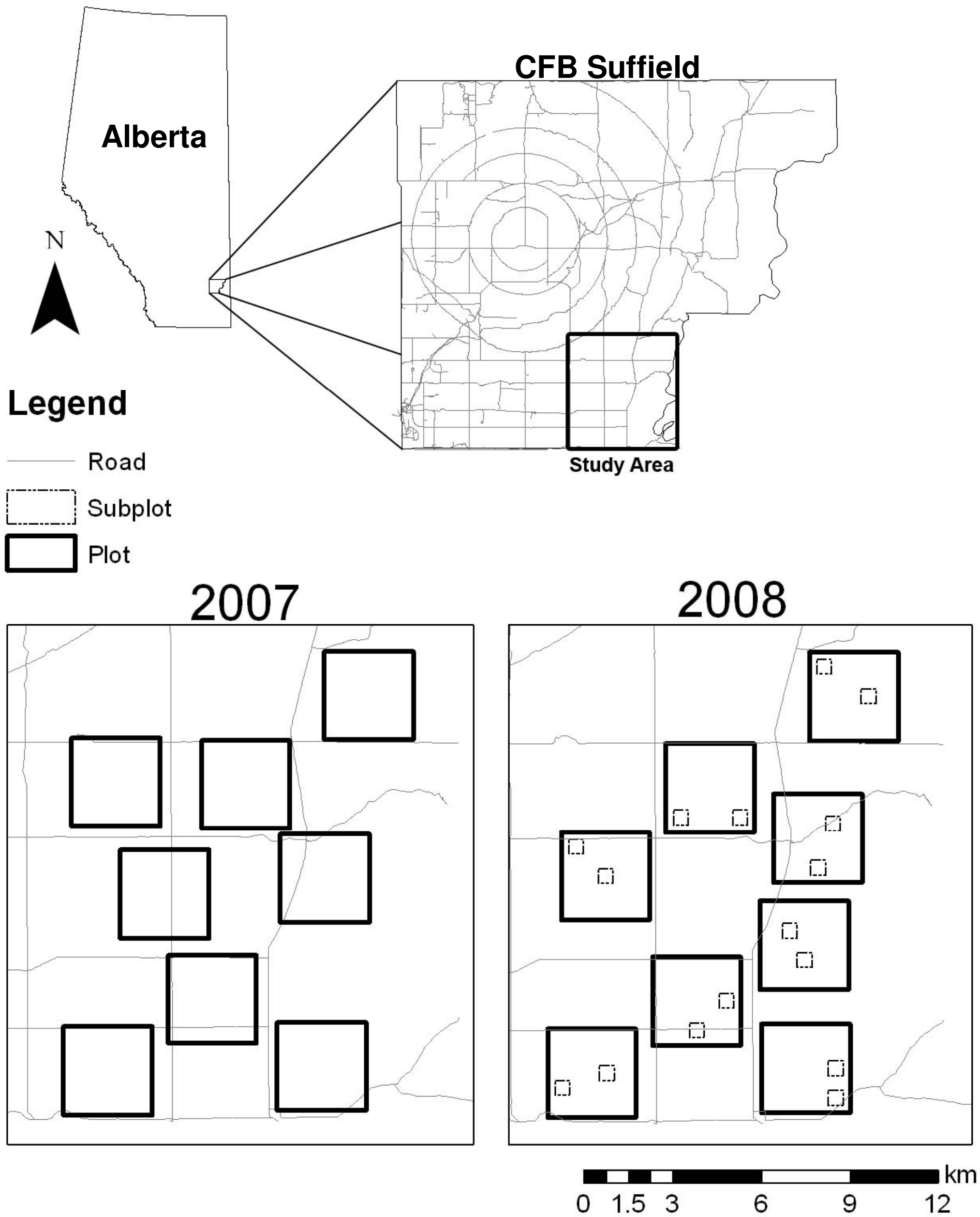

Figure 3.1: Map of the study area in 2007 and 2008 on Canadian Forces Base Suffield in Alberta, Canada. Heavy squares indicate 9 km^2 plots in both years while the small dashed boxes represent the 500x500m subplots used in 2008.

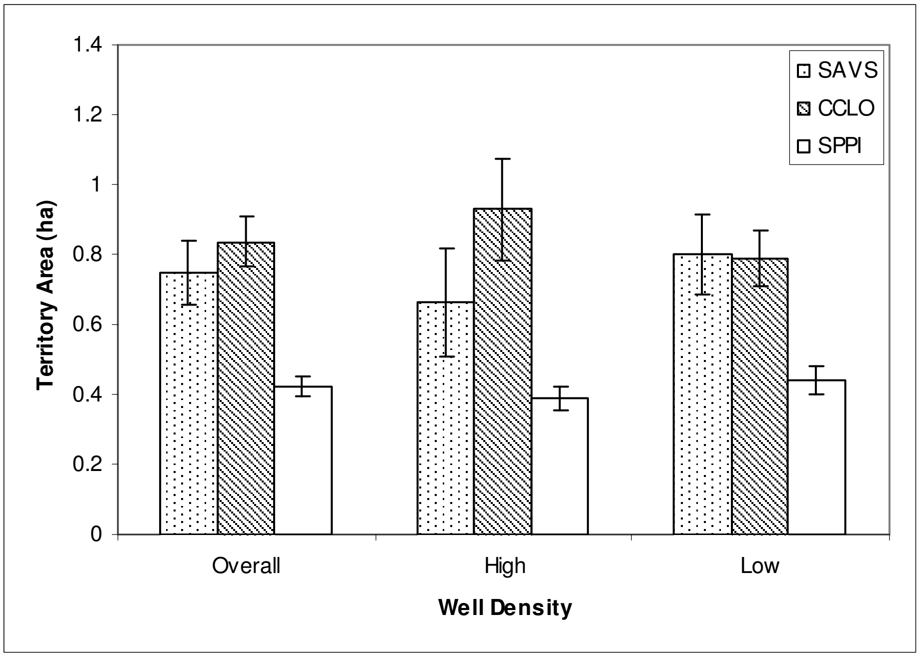

Figure 3.2: Average territory size in hectares (±SE) of Savannah sparrows (SAVS) (low: n=21, high: n=12), chestnut-collared longspurs (CCLO) (low: n=19, high: n=9), and Sprague's pipit (SPPI) (low: n=18, high: n=27) at low (8 wells/ sq. mile) or high (16 wells/sq. mile) well-density in 2007.

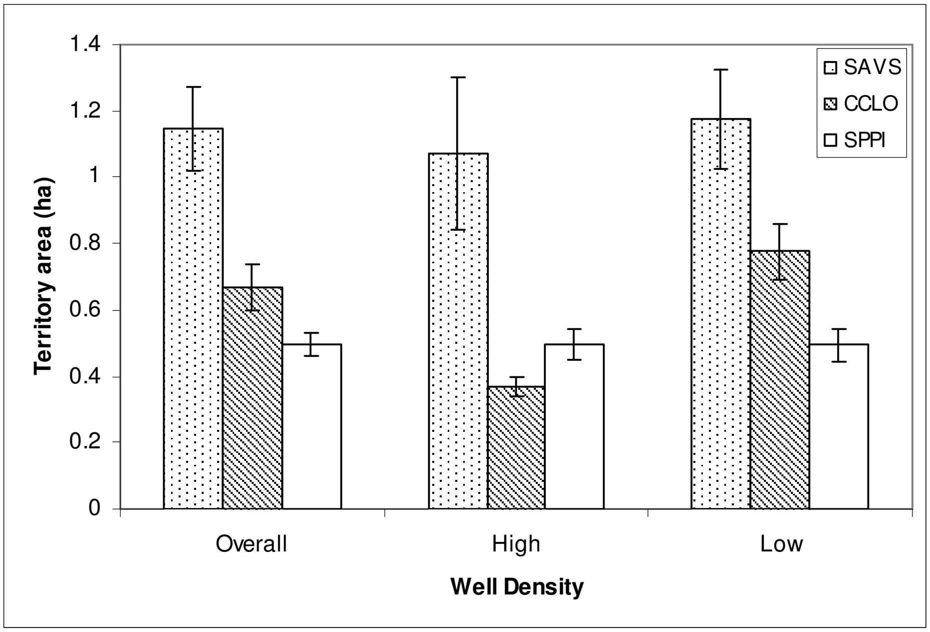

Figure 3.3: Average territory size in hectares (±SE) of Savannah sparrows (SAVS) (low: n=20, high: n=8), chestnut-collared longspurs (CCLO) (low: n=25, high: n=9), and Sprague's pipit (SPPI) (low: n=30, high: n=24) at low (8 wells/ sq. mile) or high (16 wells/sq. mile) well-density in 2008.

Table 3.1: Savannah sparrow vegetation data from 33 territories in 2007 and 13 territories in 2008 compared against vegetation data from 25 vegetation territories in low and high well-densities. Each territory contained 12 vegetation plots. Averages are for all vegetation plots in all territories per disturbance category. Bare ground (BG); standing dead vegetation (SD); living cover (LivC); litter cover (LitC). Years are pooled due to low variation between years except for standing dead vegetation which is only from 2008.

		Savannah Sparrow Territories							Vegetation Territories						
		Height (cm)	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*	*Height (cm)*	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*
Low Well-density	Mean	13.07	4.42	20.36	56.73	18.44	0.18	30	10.23	7.55	5.50	71.03	16.03	1.71	18
	Standard Error	0.73	0.73	1.88	2.25	1.35	0.014		0.74	1.71	1.14	2.07	1.19	0.55	
	Range	6.25 – 26.75	0.42 - 15	6.25 – 43.33	37.92 – 77.08	8.75 – 39.17	0.39 – 5.53		5.92 – 17.75	0 – 27.92	0 – 16.25	51.67 – 85.42	9.17 – 27.5	0 – 7.5	
High Well-density	Mean	14.32	6.09	21.33	60.61	11.88	0.12	16	13.43	3.63	4.82	74.35	17.38	1.25	7
	Standard Error	0.77	1.45	3.86	3.99	1.05	0.010		2.73	0.68	1.61	3.57	1.92	0.34	
	Range	9.17 – 20.92	0 - 23.75	0 - 55.83	32.08 – 86.67	3.75 - 19.17	0.038 – 0.19		8.58 – 29.42	1.25 – 6.67	0 - 10.42	59.58 - 85	10.42 – 23.33	0 -2.5	
Overall	Mean	13.51	5	20.70	58.08	16.16	0.16	46	11.12	6.46	5.31	71.96	16.41	1.58	25
	Standard Error	0.55	0.69	1.80	2.01	1.05	0.011		0.94	1.28	0.92	1.78	1.00	0.41	
	Range	6.25 – 26.75	0 – 23.75	0 – 55.83	32.08 – 86.67	3.75 – 39.17	0.038 – 0.39		5.92 – 29.42	0 – 27.92	0 - 16.25	51.67 – 85.42	9.17 – 27.5	0 -7.5	

Table 3.2: Chestnut-collared longspur vegetation data from 28 territories in 2007 and 9 territories in 2008 compared against vegetation data from 12 vegetation territories in low and high well-densities. Each territory contained 12 vegetation plots. Averages are for all vegetation plots in all territories per disturbance category. Bare ground (BG); standing dead vegetation (SD); living cover (LivC); litter cover (LitC). Years are pooled due to low variation between years except for standing dead vegetation which is only from 2008.

		Chestnut-collared Longspur Territories							Vegetation Territories						
		Height (cm)	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*	*Height (cm)*	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*
Low Well-density	Mean	9.11	4.85	16.30	59.55	16.91	0.17	26	10.09	5.96	5.40	71.16	16.80	1.96	8
	Standard Error	0.41	0.72	1.36	2.70	1.26	0.013		0.76	1.09	1.57	1.56	1.65	0.68	
	Range	5.67 – 13.67	0.91 – 16.25	5.42 – 30.42	14.58 – 81.25	0.83 – 31.25	0.0083-0.31		6.25 – 12.92	2.5 – 12.08	0 – 11.67	62.08 – 75.42	12.92 - 25	0 – 5.83	
High Well-density	Mean	8.99	6.97	22.40	48.79	21.93	0.22	11	14.27	3.33	5.94	74.69	15.52	0.63	4
	Standard Error	0.29	1.82	3.92	4.63	2.83	0.028		5.06	0.54	2.10	5.54	2.65	0.50	
	Range	7.25 – 10.42	2.08 – 22.08	4.17 - 45	25.83 - 70	8.75 – 43.33	0.088 – 0.43		8.58 – 29.42	2.08 – 4.58	0.83 – 9.58	63.33 - 85	10.42 – 21.25	0 – 2.08	
Over-all	Mean	9.08	5.48	18.11	56.35	18.40	0.18	37	11.48	5.08	5.58	72.34	16.37	1.52	12
	Standard Error	0.30	0.74	1.54	2.45	1.26	0.013		1.71	0.82	1.21	2.02	1.35	0.51	
	Range	5.67 – 13.67	0.91 – 22.08	4.17 - 45	14.58 – 81.25	0.83 – 43.33	0.0083 – 0.43		6.25 - 29.42	2.08 – 12.08	0 – 11.67	62.08 - 85	10.42 - 25	0 -5.83	

Table 3.3: Sprague's pipit vegetation data from 45 territories in 2007 and 19 territories in 2008 compared against vegetation data from 22 vegetation territories in low and high well-densities. Each territory contained 12 vegetation plots. Averages are for all vegetation plots in all territories per disturbance category. Bare ground (BG); standing dead vegetation (SD); living cover (LivC); litter cover LitC). Years are pooled due to low variation between years except for standing dead vegetation which is only from 2008.

		Sprague's Pipit Territories							Vegetation Territories						
		Height (cm)	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*	*Height (cm)*	*% BG*	*% SD*	*% LivC*	*% LitC*	*% shrub*	*n=*
Low Well-density	Mean	10.04	5.82	7.30	72.26	14.61	0.15	38	10.02	6.37	3.88	71.68	17.00	1.34	12
	Standard Error	0.28	1.03	0.70	1.39	1.00	0.01		0.82	1.61	1.11	2.93	2.79	0.42	
	Range	6.58 – 14.08	0.42 – 37.5	1.25 – 18.33	47.5 – 89.17	3.75 – 35.83	0.038 – 0.36		6.92 – 17.75	14.58 – 76.40	11.25 – 46.56	51.67 – 82.5	5.83 – 40.83	0 -5	
High Well-density	Mean	9.76	5.77	13.80	65.18	14.84	0.15	26	11.31	4.42	3.54	74.08	17.79	1.5	10
	Standard Error	0.30	0.75	1.84	2.13	0.75	0.0075		0.91	0.47	1.27	3.28	2.16	0.43	
	Range	7 – 13.25	0.83 – 18.75	2.08 – 46.67	35.83 – 87.08	8.75 – 27.5	0.088 – 0.28		8.5 – 17.92	2.08 – 6.67	0 - 10.42	59.58 – 89.17	7.08 – 29.17	0 – 4.17	
Overall	Mean	9.93	5.80	9.94	69.38	14.70	0.15	64	10.61	5.48	3.73	72.77	17.36	1.41	22
	Standard Error	0.21	0.68	0.94	1.26	0.66	0.00066		0.61	0.91	0.81	2.15	1.77	0.29	
	Range	6.58 – 14.08	0.42 – 37.5	1.25 – 46.67	35.83 – 89.17	3.75 – 35.83	0.038 – 0.36		6.92 – 17.92	0 – 14.58	0 – 11.25	51.67 – 89.17	5.83 – 40.83	0 -5	

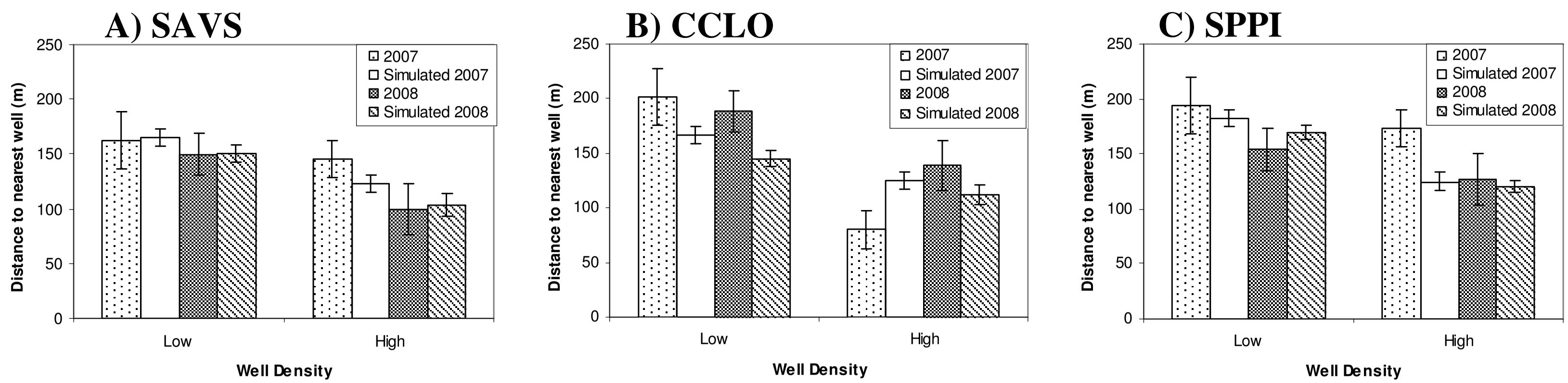

Figure 3.4: Average distance (±SE) to nearest well site taken from the edge of actual and simulated territories. Actual territories were pooled for 2007 and 2008. A) Savannah sparrows (SAVS) (2007 low: n=21, 2007 high: n=12; 2008 low: n=20, 2008 high: n=8) and simulated territories (2007 High: n=126; 2007 Low: n=72; 2008 High: n=126; 2008 Low n=48), B) Chestnut-collared longspur (CCLO) (Total: n=62; High: n=18; Low: n=44) and simulated territories (2007 High: n=113; 2007 Low: n=55; 2008 High: n=150; 2008 Low n=54), C) Sprague's pipit (SPPI) (Total: n=99; High: n=42; Low: n=57) and simulated territories (2007 High: n=170; 2007 Low: n=106; 2008 High: n=180; 2008 Low n=144).

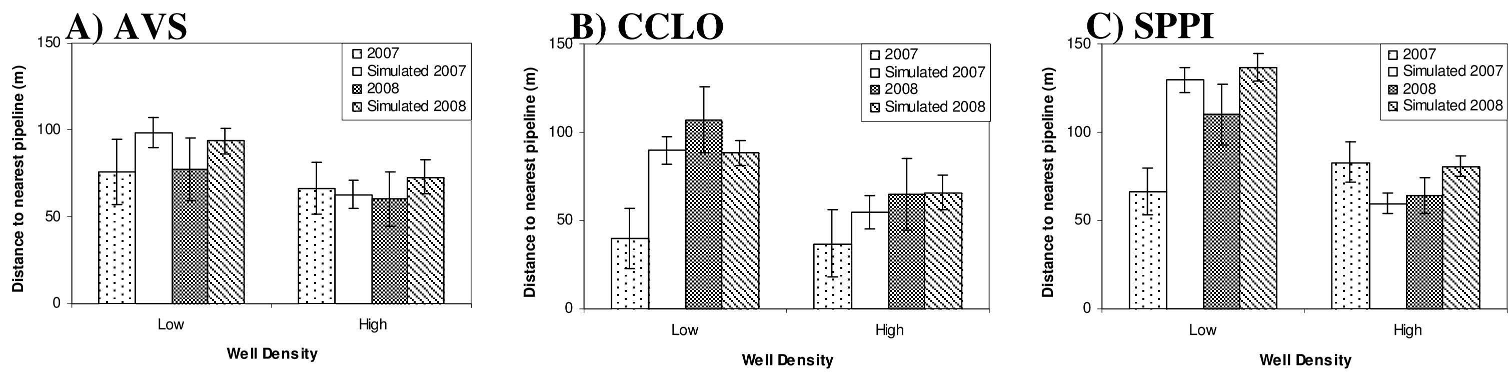

Figure 3.5: Average distance (±SE) to nearest pipeline taken from the edge of actual and simulated territories. Actual territories were pooled for 2007 and 2008. A) Savannah sparrows (SAVS) (2007 low: n=21, 2007 high: n=12; 2008 low: n=20, 2008 high: n=8) and simulated territories (2007 High: n=126; 2007 Low: n=72; 2008 High: n=126; 2008 Low n=48), B) Chestnut-collared longspur (CCLO) (2007 low: n=19, 2007 high: n=9; 2008 low: n=25, 2008 high: n=9) and simulated territories (2007 High: n=113; 2007 Low: n=55; 2008 High: n=150; 2008 Low n=54), C) Sprague's pipit (SPPI) (2007 low: n=18, 2007 high: n=27; 2008 low: n=30, 2008 high: n=24) and simulated territories (2007 High: n=170; 2007 Low: n=106; 2008 High: n=180; 2008 Low n=144).

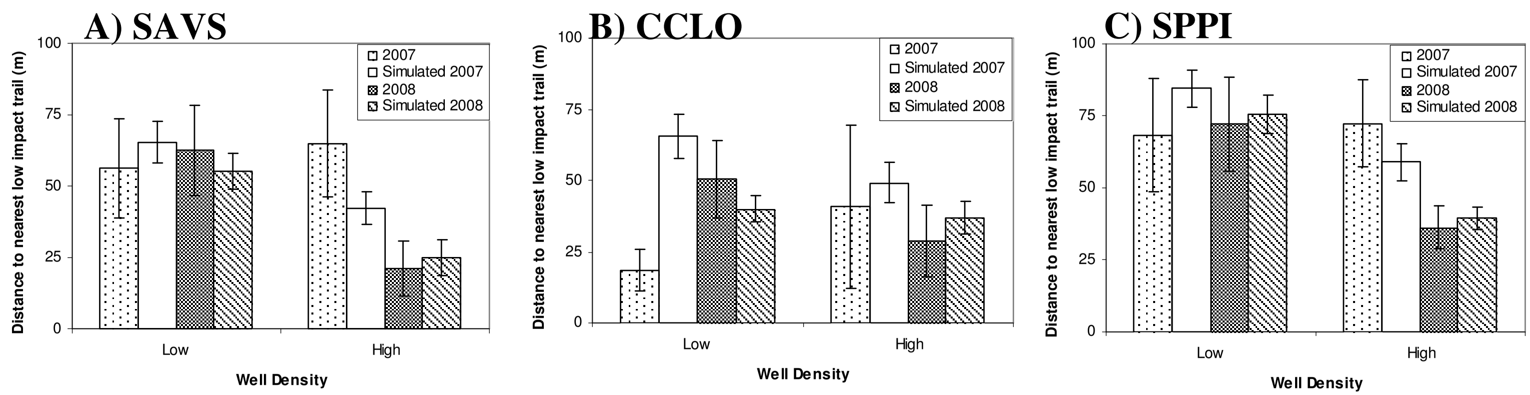

Figure 3.6: Average distance (±SE) to nearest low impact trail (DND class 2 or 3) taken from the edge of actual and simulated territories. Actual territories were pooled for 2007 and 2008. A) Savannah sparrows (SAVS) (2007 low: n=21, 2007 high: n=12; 2008 low: n=20, 2008 high: n=8) and simulated territories (2007 High: n=126; 2007 Low: n=72; 2008 High: n=126; 2008 Low n=48), B) Chestnut-collared longspur (CCLO) (2007 low: n=19, 2007 high: n=9; 2008 low: n=25, 2008 high: n=9) and simulated territories (2007 High: n=113; 2007 Low: n=55; 2008 High: n=150; 2008 Low n=54), C) Sprague's pipit (SPPI) (2007 low: n=18, 2007 high: n=27; 2008 low: n=30, 2008 high: n=24) and simulated territories (2007 High: n=170; 2007 Low: n=106; 2008 High: n=180; 2008 Low n=144).

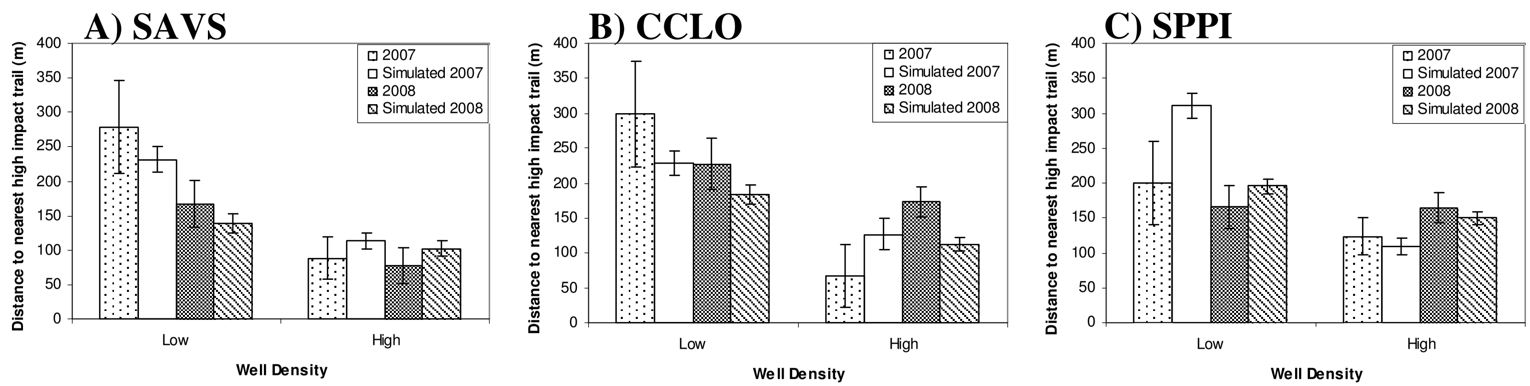

Figure 3.7: Average distance (±SE) to nearest high impact trail (DND class 4 or 5) taken from the edge of actual and simulated territories. Actual territories were pooled for 2007 and 2008. A) Savannah sparrows (SAVS) (2007 low: n=21, 2007 high: n=12; 2008 low: n=20, 2008 high: n=8) and simulated territories (2007 High: n=126; 2007 Low: n=72; 2008 High: n=126; 2008 Low n=48), B) Chestnut-collared longspur (CCLO) (2007 low: n=19, 2007 high: n=9; 2008 low: n=25, 2008 high: n=9) and simulated territories (2007 High: n=113; 2007 Low: n=55; 2008 High: n=150; 2008 Low n=54), C) Sprague's pipit (SPPI) (2007 low: n=18, 2007 high: n=27; 2008 low: n=30, 2008 high: n=24) and simulated territories (2007 High: n=170; 2007 Low: n=106; 2008 High: n=180; 2008 Low n=144).

Table 3.4: Number of territories crossing trails in 2007 and 2008. All trail data is from observations during the territory surveys. Savannah sparrows: SAVS; chestnut-collared longspur: CCLO; Sprague's pipit: SPPI. Expected rate was 40.77% of territories should cross trails.

	Year	Territories crossing trails	Total territories mapped	Percent territories crossing trails (%)
SAVS	2007	15	33	45.45
	2008	14	28	50.00
CCLO	2007	18	28	64.29
	2008	11	34	32.35
SPPI	2007	9	44	20.45
	2008	18	54	33.33

Table 3.5: The average proportion of area of territories on one side of a vehicle trail based on the side with a proportion over 50%. All species held territories that were significantly different from a mean territory split of 50/50% and one-sample t-tests determined what split was no longer significantly different. Savannah sparrows: SAVS; chestnut-collared longspur: CCLO; Sprague's pipit: SPPI.

	Year	Average Proportion of largest side	Range	Standard deviation	Observed territory split was not different from a mean split of:
SAVS	2007	78.2	57.7 - 96.2	12.7	71/29
	2008	74.7	50.7 - 99.9	13.5	64/36
CCLO	2007	80.3	50.9 - 98.4	18.3	71/29
	2008	84.1	59.2 - 99.4	14.0	74/26
SPPI	2007	71.8	55.0 - 95.5	17.0	58/42
	2008	81.5	54.1 – 99.8	16.2	73/27

Table 3.6: Proportion of territories that contained any CWG in both 2007 and 2008. Simulated territories were surveyed in 2008. Savannah sparrows: SAVS; chestnut-collared longspur: CCLO; Sprague's pipit: SPPI.

Disturbance category	Species	Proportion of territories with CWG	Total territories	Proportion of simulated territories with CWG	Total simulated territories
Low	SAVS	0.39	41	0.22	18
	CCLO	0.27	44	0.38	8
	SPPI	0.16	56	0.50	12
High	SAVS	0.65	20	0.43	7
	CCLO	0.72	18	0.50	4
	SPPI	0.35	43	0.50	10
Total	SAVS	0.48	61	0.28	25
	CCLO	0.40	62	0.42	12
	SPPI	0.24	99	0.50	22

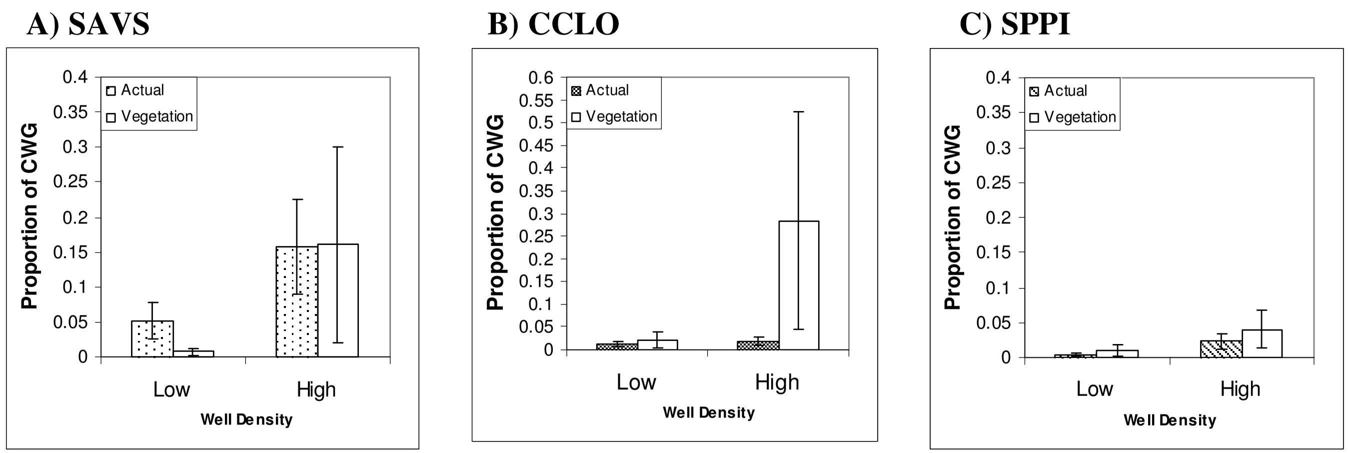

Figure 3.8: Average proportion of territories that was covered by CWG (±SE) for 2007 and 2008 combined, compared to vegetation territories. A) Savannah sparrow (SAVS) (High: n=20; Low: n=41; Simulated High: n=7; Simulated Low: n=18), B) Chestnut-collared longspur (CCLO) (High: n=18; Low: n=44; Simulated High: n=4; Simulated Low: n=8), C) Sprague's pipit (SPPI) (High: n=42; Low: n=57; Simulated High: n=10; Simulated Low: n=12).

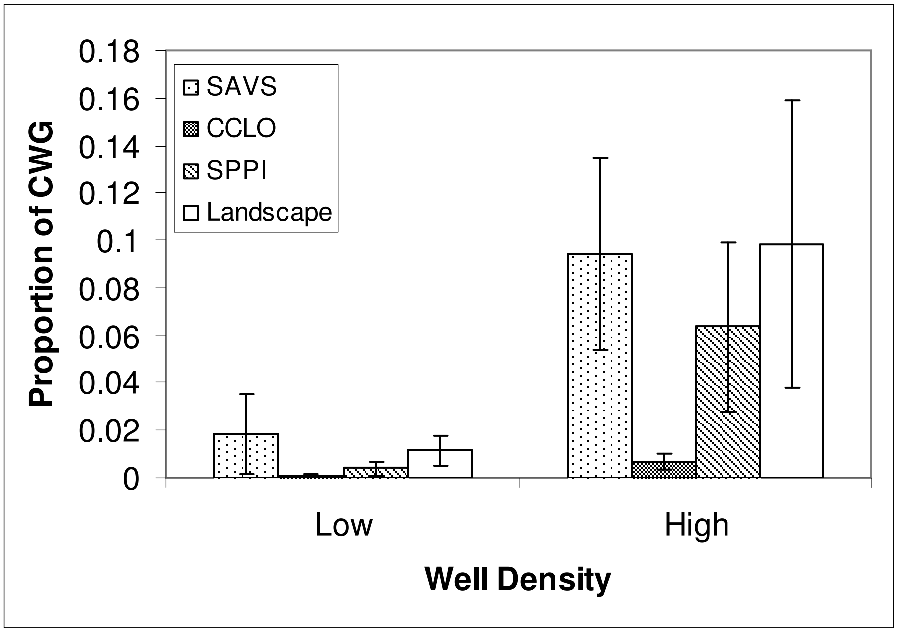

Figure 3.9: Proportion of crested wheatgrass in actual territories in 2008 compared to the proportion of CWG overall in the landscape (based on ten 500 x 500m subplots in low well-densities and 6 subplots in high well-densities). There were 8, 9 and 25 Savannah sparrow (SAVS), chestnut-collared longspur (CCLO) and Sprague's pipit (SPPI) territories in high well-density plots, respectively. There were 20, 25 and 30 SAVS, CCLO and SPPI territories in low well-density plots, respectively.

Chapter 4
Nest success and fledgling size of chestnut-collared longspurs and Sprague's pipit on CFB Suffield

Introduction

Habitat loss alone cannot account for the rapid declines in some endemic grassland bird species in the past 50 years (as reviewed by Samson et al., 2004; Perlut et al. 2006; Askins et al., 2007), although the mixed-grass prairie in North America has declined in extent to approximately 30% of its historical range (Samson et al., 2004). Besides direct loss of habitat, major causes of grassland bird decline include burning, haying, grazing and exotic species plantings (Dale et al., 1997; Herkert et al., 2003; Lloyd and Martin, 2005; Renfrew et al., 2005; Shochat et al., 2005; Sutter and Richison, 2005; Warren and Anderson, 2005; Perlut et al., 2006). Such activities contribute to rangeland degradation and fragmentation of the remaining grasslands (as reviewed by Brennan and Kuvlesky, 2005).

The effects of human disturbance on the nesting success of grassland birds are variable. Habitat edges in grasslands are associated with lower nest success due to increased rates of parasitism (Patten et al., 2006) and increased predation (Winter et al., 2000; Herkert et al., 2003 but see Renfrew et al., 2005). However, nesting success varies among species and can be unaffected by patch size or by the presence of recreational trails (Miller et al., 1998; Davis, et al., 2006; Winter et al, 2006). Similarly, Shochat et al. (2005) found that nesting success increased near burned edges. The effects of energy sector development, such as the creation of wells and access trails, and the associated spread of exotic grasses, on reproductive success of grassland birds has not been reported in the scientific literature.

This chapter focuses on the nesting success of two endemic grassland birds: chestnut-collared longspur (*Calcarius ornatus*), and Sprague's pipit (*Anthus spragueii*) in native mixed-prairie on Canadian Forces Base (CFB) Suffield in southern Alberta. Energy sector development in this study included the creation of well sites, pipelines, pipeline junctions and off-road vehicle access trails. The goals of the research described in this chapter were: 1) to determine the date of nest initiation, nesting success, and size at fledging of chestnut-collared longspur and Sprague's pipit on CFB Suffield (a site where these species had been previously studied but nesting data not collected) and 2) to compare nesting patterns between plots with high versus low well-densities.

Methods

The study took place on CFB Suffield from May to July 2007 and 2008 in a 221 km^2 area on the southern portion of the National Wildlife Area. Eight study blocks, 9 km^2 each, were selected in each year to reflect differences in well and accompanying trail, junction and pipeline densities characteristic of the base. Density of wells was classified as low (<8 wells per sq. mile) or as high (>8 wells per sq. mile). Maximum density in the high well-density area reached 16 wells per sq. mile. Three plots had high well-density and 5 had low well-density.

Nests were found opportunistically, usually by flushing females. Visits in 2007 were spaced out every 6-8 days to determine nest fate. Eggs were not candled in 2007 so lay or hatch date cannot be calculated. In 2008, eggs were candled upon discovery and age was determined through reference photos in Lokemoen and Koford (1996). Nests were revisited a maximum of three times, once within 1-2 days on or after the estimated hatch date and once 8 days after hatching. Lay dates were calculated based on the morphology of the candled eggs and incubation was expected to last 10-12½ days in longspurs and 13-14 days in pipits (Hill and Gould, 1997; Robbins and Dale, 1999). The number of eggs or nestlings was recorded at each visit. In 2008, as per Martin et al. (2000), body weight and tarsus length of the chicks were measured once when the young were estimated to be 8 days of age and the nest was left undisturbed following that time. If a nest was found after hatch, the nest was left undisturbed to prevent early fledging, although number of hatchlings was recorded.

A nest was termed "successful" if at least one young fledged. Nests that could not be relocated or were relocated after the nestlings had potentially fledged were treated as failed to maintain a conservative estimate of nesting success. As there were only 11 pipit nests found throughout the study, 8 in 2008 and 3 in 2007, these data are summarized but not analyzed statistically. Difference in the total proportion of successful longspur nests between 2007 and 2008 was determined with a Chi-Squared test. The number of young fledged from a nest was compared to the clutch size of that nest to determine survivorship from egg to fledging. Longspur chick weight and tarsus length were averaged within a nest and chick weight was corrected for age using growth rates in Lloyd and Martin (2005). I did not statistically compare nest success, number of young fledged, chick weight or tarsus length between plots with different well-densities due to small sample sizes within each year.

Distance to the nearest form of oil and gas disturbance (well site, pipeline, junction or off-road vehicle trail) was determined using ArcGIS 9.2 (ESRI, 2007) as per Chapter 3. Distance to nearest human disturbance was not analyzed statistically due to the non-random nature of nest location.

Results

Clutch initiation

I located 28 longspur and 8 pipit nests between May 19th and July 26th in 2008 for the purpose of determining clutch initiation. Longspur nest lay dates ranged from May 16th to July 7th with an average date of June 7th in 2008 (Figure 4.1). The first eggs in longspur nests were laid, on average, 13 days earlier in high well-density plots than in low well-density plots (Figure 4.1). Pipits clutch initiation ranged from May 16th to July 15th with an average initiation date of June 6 – 7th in 2008 (Figure 4.2). Egg clutches were initiated throughout the season with an increase in initiation between May 21st and 24th for longspurs compared to the rest of the breeding season (Figure 4.1).

Nesting success

In 2007 twenty-three longspur nests and 3 pipit nests were located between May 16th and July 26th. Longspurs had a 69.6% nest success rate with 59.4% of young surviving to fledging (Table 4.1). Nests from low well-density plots had a marginally higher success rate (72.7%) compared to nests in high well-density plots (66.7%). Survival of young from egg to fledging was higher in low well-density compared to high well-density (61.8 and 57.4%, respectively).

Longspurs had an overall 57.1% nest success rate with 46.4% of young surviving to fledging per nest in 2008 (Table 4.2). Nests in low well-density plots had lower success rates (38.5%) compared to nests in high well-density plots (73.3%) and survival of young per nest was lower in low well-densities (28.8%) compared to high well-densities (61.7%).

I found no significant difference in longspur nest success between 2007 (69.6%) and 2008 (57.1%; X^2=1.26, df=1, p>0.10). There was also no significant difference in the survival of young per nest between 2007 and 2008 (59.4 and 46.4%, respectively; X^2=1.63, df=1, p>0.10).

Hatchling size just prior to fledging

At 8 days of age, longspurs tended to have heavier young (average per nest low: 19.25±2.61g, n=2 nests; high: 15.12±0.84g, n=8 nests) with longer tarsi on low well-density plots (low: 20.95±1.08mm; high: 17.84±0.38mm).

The average pipit young, 8 days after hatching, in a nest weighed 12.94±0.54g (n=2 nests) in low well-density plots compared to 15.34±0.61g (n=3 nests) in high well-density plots. The tarsus length for pipits tended to be smaller in low well-density plots (14.75±0.46mm) than in high well-density plots (18.73±0.50mm).

Distance from nests to human disturbance

Nests varied with distance to the nearest human disturbance. Longspur nests were closer to trails (mean= 57.1m, range= 0.1–243m) than wells (mean= 197.9m, range= 49–373m), pipelines (mean= 123.1m, range= 0.3–375m), or junctions (mean= 237.8m, range= 14–736m). Pipit nests were further than longspur nests from oil and gas disturbances being closest to trails (mean= 67.2m, range= 12.1–132.2m) and distant from well sites (mean= 199.9m, range= 114.3–236.2m), pipelines (mean= 126.2, range= 20.9–241.4m) and junctions (mean= 286.3m, range= 132.3–549.2m). As nests were not located randomly, no statistics were performed on the distance from a nest to the nearest human disturbance.

Discussion

I examined whether well-density affects lay date, nest success and the size of young at fledging. While the cause of nest success or failure was not documented by my study, each year had different, although weak, trends in nest success and fledgling size between areas of high and low well-density for Sprague's pipit and chestnut-collared longspur. I did not find an overall effect of well-density upon the survival of longspur young, except in 2008 where there was significantly lower survival at low well-densities, nor upon the size of young fledged, although nests were initiated earlier in high well-density sites than low well-density sites. My sample size was small and all conclusions must be examined cautiously.

Clutch initiation for longspurs in Saskatchewan begins in late April or early May (Davis, 2003) although Maher (1973, in Hill and Gould, 1997) found that late springs could delay nest initiation up to 2 weeks. In 2008, there was a snowfall in late April that may have caused the delay in nesting as we did not find any longspur nests prior to May 19th and the first clutches we found were initiated only a few days prior to discovery despite the fact that point counts started on May 9th. The observation that longspur clutches were laid earlier in high well-densities than in low well-densities was likely a result of when study sites were first searched. High well-density sites were easier to access earlier in the season due to military training preventing access to some of the low well-density study sites until late May.

Nest success for longspurs in this study (69.6%) is somewhat higher than previously reported for the Canadian prairies ([45%] Davis, 1994 in Hill and Gould, 1997; [55.9%] Hill and Gould, 1997). Pipit nest success in CFB Suffield was higher than previously found in the Saskatchewan prairies ([30.7%, n=67] Davis, 2003) although I had a small sample size. Successful longspurs nests in our study produced 3.31 and 3.25 young per successful nest, in 2007 and 2008, respectively, which is somewhat lower than previous reported for Canadian mixed-grass prairies ([3.5 young] Davis, 1994 in Hill and Gould, 1997; [3.4 young] Hill and Gould, 1997). Precipitation in CFB Suffield over the past 30 years averages 134.5mm of precipitation from May to July (Environment Canada National Climate Data and Information Archive). However, 2007 was a drier than average summer (84.4 mm precipitation from May to July; Environment Canada National Climate Data and Information Archive) while 2008 had heavy rains throughout the summer (197.2mm from May to July; Environment Canada National Climate Data and Information Archive). Both clutch sizes and the number of young fledged from all nests at CFB Suffield did not vary significantly between years or between well-densities for longspurs which suggests that the level of human activity and the varied climate conditions between the years did not affect number of young produced. Nesting success in the prairies has been linked to brood parasitism and predation associated with edge habitat (Winter et al., 2000; Herkert et al., 2003; Renfrew et al., 2005; Patten et al., 2006; Winter et al., 2006). Skagen et al. (2005), however, found that nests in very small patches have higher survival which they believed was due to predator avoidance of edges.

Longspur young found in low well-density plots were, on average, heavier and had larger tarsi than young found in high well-density plots. Lloyd and Martin (2005) found that longspur young gained weight more slowly and had a smaller fledging mass in crested wheatgrass (*Agropyron cristatum*) fields than in native grasslands in Alberta. However, they found no difference in length of tarsi between areas with exotic versus native vegetation (Lloyd and Martin, 2005). Our longspur young, 8 days old, were approximately the same weight as those found elsewhere in Alberta, at 7 days old (Martin et al., 2000), and about 1-2 grams heavier than those found in Montana at 8 days old (Lloyd and Martin, 2005). Growth rates of young songbirds likely reflect habitat quality (Quinney et al., 1986; McCarty and Winkler, 1999). Juvenile survival and recruitment of songbirds is highly dependant on growth rate and fledgling size (Magrath, 1991; Both et al., 1999; Naef-Daenzer et al., 2001; Medeiros and Freed, 2009).

Nests success is often related to predation rates and available arthropod biomass for feeding young (Shochat et al., 2005; Skagen et al., 2005; Sutter and Richison, 2005). Nest success can vary with patch size and fragmentation but the mechanism behind these variations is not usually known (Davis, 2004; Davis et al., 2006). Smaller patches are typically associated with lower nest success in grassland birds (Perkins and Vickery, 2007) and nest abandonment is more frequent in areas with off-road vehicle traffic (Barton and Holmes, 2007), possibly a result of associated noise levels (Reijnen et al., 1996) or due to trails acting as edge habitat (Ingelfinger and Anderson, 2004). Off-road vehicle trails are common in my study site but were infrequently used. Higher nest success in both of our study years compared to previous averages may be caused by decreased predator risk later in the nesting season, when we found most of our nests (Roos, 2002), and the low rates of vehicle traffic in my study area.

Fragmentation and primary habitat loss are both potential drivers for lower nest success (Fahrig, 2003). While habitat loss through activities, such as haying, has direct impacts upon nest survival by destroying nests (Dale et al., 1997), the effects of degradation through natural gas development is unclear. Davis et al. (2006) posited that age and date of clutch initiation are more important than either fragmentation or nest site vegetation on nest success.

Natural gas development on CFB Suffield directly affects a relatively small area; thus only nests located within some, as yet undetermined, buffer around these disturbances may experience decreased success. Displacement of adults and territories away from trails will lower the number of nests found near trails and maintain "natural" levels of nesting success (Miller et al., 1998). Despite the small sample size in my study, nest success was comparable to that reported by other studies of longspurs in the Canadian prairies.

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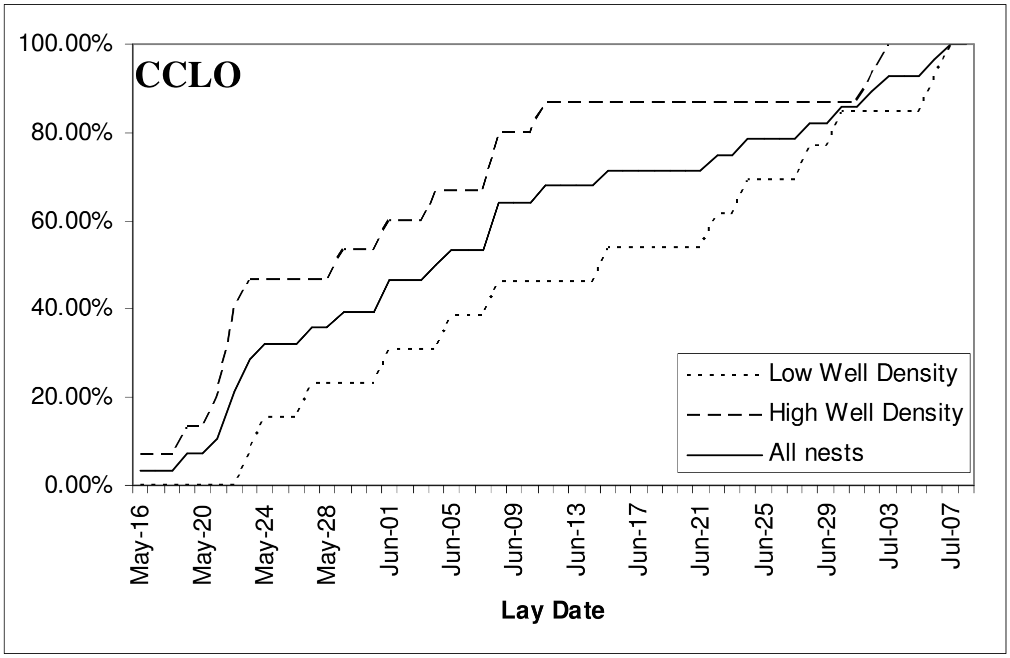

Figure 4.1: Cumulative frequency of chestnut-collared longspur nests laid in 2008 (n=28). There were 15 nests in high well-density areas and 13 nests in the low well-density areas. Nests whose lay date could not be determined were not included.

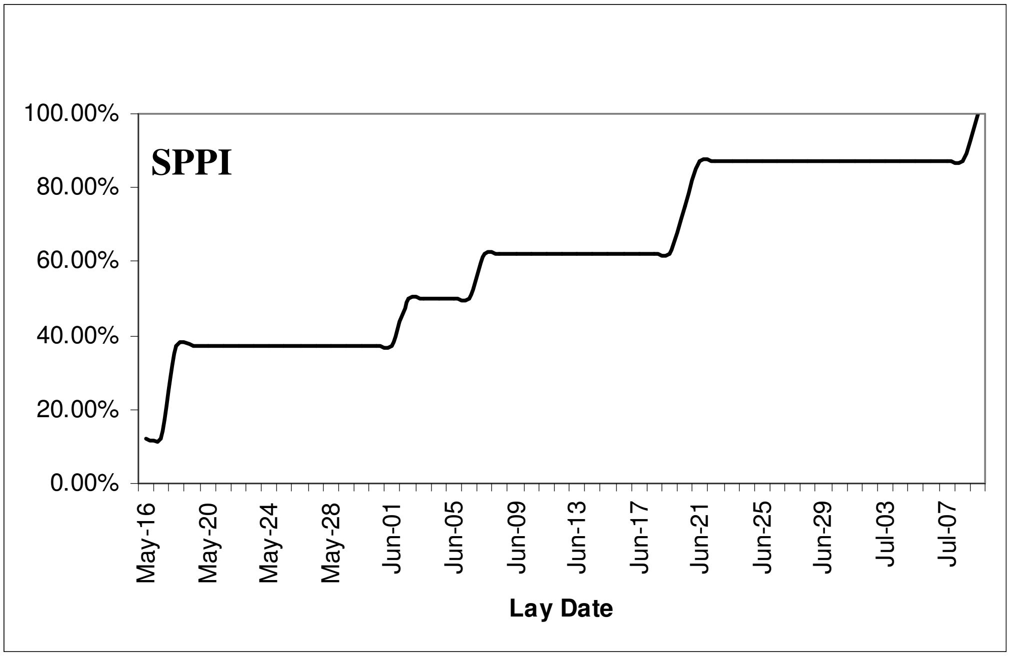

Figure 4.2: Cumulative frequency of Sprague's pipit nests laid nests laid in 2008 (n=8). Nests whose lay date could not be determined were not included.

Table 4.1: Nest success of Sprague's pipit (SPPI) and chestnut-collared longspur (CCLO) in 2007. Mean clutch size reflects the maximum number of eggs or fledglings recorded per nest. Mean young fledged is the average number of young fledged from a successful nest.

Well - Density	Species	Number of nests found	Mean clutch size	Range of clutch size	Number of successful nests	Mean number of fledged young	Range of fledged young	Survival of young to fledging (%)
Low	SPPI	3	4.67	3-6	1	5	n/a	27.8
	CCLO	11	3.82	3-5	8	3.25	2-4	72.7
High	SPPI	0	n/a	n/a	n/a	n/a	n/a	n/a
	CCLO	12	3.92	2-5	8	3.38	3-4	66.7
Total	SPPI	3	4.67	3-6	1	5	n/a	27.8
	CCLO	23	3.87	2-5	16	3.44	2-4	59.4

Table 4.2: Nest success of Sprague's pipit (SPPI) and chestnut-collared longspur (CCLO) in 2008. Mean clutch size reflects the maximum number of eggs or fledglings recorded per nest. Mean young fledged is the average number of young fledged from a successful nest.

Well-Density	Species	Number of nests found	Mean clutch size	Range of clutch size	Number of successful nests	Mean number of fledged young	Range of fledged young	Survival of young to fledging (%)
Low	SPPI	2	5.00	5	2	4.5	4-5	90
	CCLO	13	3.77	2-5	5	3	1-5	28.8
High	SPPI	6	4.67	3-5	3	4.67	4-5	41.7
	CCLO	15	3.93	2-5	11	3.36	1-5	61.7
Total	SPPI	8	4.75	3-5	5	4.6	4-5	57.5
	CCLO	28	3.86	2-5	16	3.25	1-5	46.4

Chapter 5
General conclusions

Summary of main findings

Canadian Forces Base Suffield provides grassland songbirds with breeding habitat while supporting oil and gas development. Savannah sparrow, chestnut-collared longspur and Sprague's pipit occupancy was higher in the southern block of the National Wildlife Area than recorded elsewhere on CFB Suffield regardless of well-density. I found that the likelihood of detecting each of the study species during standard point-count surveys varies primarily with observer and with the proportion of an area impacted by oil and gas disturbance. Savannah sparrows were more likely to be detected at a point count as human disturbance increased while chestnut-collared longspur and Sprague's pipit were more likely to be detected as human disturbances decreased. Savannah sparrow occurrence was higher on hilly areas and on areas exhibiting increased levels of human impact. Site characteristics, such as elevation, topography and the presence of burned areas, affected pipit occurrence. The models I created could not accurately predict the likelihood of detecting a longspur.

When testing the distance from the territory edge to individual disturbances, I found that there was little difference between simulated territories and actual territories for well sites, pipelines, junctions, or trails. Territories spanning trails were uncommon for Sprague's pipits, and common for Savannah sparrows. Longspurs appeared to avoid trails and place territories less frequently across trails in 2008, when the sampling method was less biased towards surveying territories located along trails. Vegetation was similar between areas of high and low well-densities but Savannah sparrow territories had taller vegetation and less litter cover than longspur and pipit territories. Crested wheatgrass (CWG), an introduced plant, had lower occurrence and percent cover in both longspur and pipit territories than the adjacent landscape. Of the three species, Savannah sparrows were the most likely to have any CWG within territories, whereas chestnut-collared longspurs were the least likely.

Nests for longspurs and pipits were found incidentally through both years of the study. Due the small number of nests found, I was unable to determine if or how disturbance affects the nesting success of these species. However, my nest data provides information for CFB Suffield which had previously been totally lacking.

Management implications

Fragmentation and degradation remain the focus of grassland bird research (as reviewed by Samson et al., 2004; Askins et al., 2007). Based on my findings, longspurs and pipits avoid some forms of disturbances related to natural gas extraction whereas Savannah sparrows associate with trails and CWG for both longspurs and pipits. There is apparent displacement of territories around off-road vehicle trails and near patches of crested wheatgrass. Fragmentation of the mixed-grass prairie through the creation of new trails and the spread of CWG may reduce the area in which pipits and longspurs will establish territories. Alternatively, increased human disturbance could force species to establish territories in areas with more CWG which may lead to lower nesting success, as was found in Montana for chestnut-collared longspurs (Lloyd and Martin, 2005).

Some individual birds demonstrated tolerance of low impact trails when establishing territories as individual longspurs and pipits held territories that spanned trails. If the quality of grasslands adjacent to trails is high, birds may tolerate this form of disturbance. Savannah sparrows placed territories with no regard to the presence of trails in my study which is consistent with previous research that indicates Savannah sparrows to be tolerant to a variety of human disturbances (Sutter et al., 2000; Wheelwright and Rising, 2008; Linnen, 2008). Species that are sensitive to trails, like the longspur and pipit, would likely benefit from a reduction in the total number of vehicle trails, minimal creation of new trails, and restoration of existing, non-essential trails to native mixed-grass prairie. Numbers of other species, such as the Savannah sparrow, would remain the same or even decrease with trail remediation.

Crested wheatgrass was most often found alongside off-road vehicle trails or in patches around well sites and pipelines during my study in the NWA. As the number of well sites and associated human disturbance increased in the area, so too did the coverage of CWG. Habitat edge in the prairies is often characterized by a distinct change in vegetation, such as caused by shrubs or forested edges rather than shifts between more structurally similar vegetation types, such as native prairie and agricultural land. I found that CWG has taller stems, results in more bare ground and more litter cover compared to native prairie and this creates a zone of potentially undesirable or unusable vegetation for species that prefer shorter vegetation such as chestnut-collared longspurs and Sprague's pipits. Savannah sparrows, on the other hand, prefer tall, lush vegetation similar to CWG and will use non-native vegetation throughout the mixed and tall-grass prairie (Sutter and Brigham, 1998; McMaster and Davis, 2001; Fletcher and Koford, 2002; McMaster et al., 2005). Further spread of CWG on CFB Suffield may benefit Savannah sparrows while decreasing suitability of potential breeding habitat for longspurs and pipits.

Based on my data, I could not determine how human disturbance affected territory placement. Dale et al. (2009) found that when new wells were put in to increase well-density from 4 wells/sq. mile to 8 wells/sq. mile there was a decrease in Sprague's pipit abundance and an increase in Savannah sparrow abundance. I believe that further increases in well-density may continue to alter the abundance and occurrence of grassland songbirds on CFB Suffield mainly through fragmentation and degradation associated with the creation of more off-road vehicle trails and the spread of CWG.

In my study, the density of wells on the landscape was rarely related to: abundance or occurrence of the study species, placement of territories, or occurrence of CWG on territories. This lack of pattern does not support the findings of Dale et al. (2009), who found that doubling well density affected abundance of Savannah sparrows and Sprague's pipits. Looking at human impacts as a categorical variable based on one factor, however, glosses over the potential individual effects of disturbances. Classifying areas as high or low well-density may function for management purposes, but the effects of human disturbance were better described in my study as a continuous variable based on the cumulative area affected instead of categories of effect.

Disturbances related to natural gas extraction affect the occurrence and territory placement of songbirds on CFB Suffield mainly through off-road vehicle trails and crested wheatgrass. Some species, like Savannah sparrows, will not be affected by these changes while other species, like chestnut-collared longspur or Sprague's pipit, will be negatively affected. By minimizing the length, rut-depth and soil exposure of off-road trails as well as working towards reduction in both the spread and current coverage of crested wheatgrass, the mixed-grass prairie on CFB Suffield can continue to provide high-quality habitat for grassland songbirds.

I was unable to determine what characteristics of areas disturbed by humans (eg., presence of bare ground, increased noise due to vehicle traffic, or altered vegetation due to soil compaction) caused avoidance of these locations by the three study species. Documentation of how birds use areas within their territories may explain if they use patches of CWG or features created by natural gas development in the same ways as native, undisturbed vegetation. Additionally, future research on CFB Suffield should include collection of detailed nesting information, such as daily survival of nests and nestlings, to determine if birds holding territories close to natural gas developments experienced decreased reproductive success. The patterns described in my thesis are useful in documenting the need to preserve grassland habitat, but there remains a need to understand the underlying behavioural mechanisms that give rise to these patterns.

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Appendix 1

Table A.1: Distance (m) to nearest example of four types of human disturbance for Savannah sparrows compared across areas with high and low well density and across years. Significant differences between years, determined using a two-way ANOVA, are indicated with "1" at a p-value of less than 0.05. Significant differences between well-densities are indicated with "2" while interaction between year and well-density is indicated with "3".

	2007				2008			
Source of Disturbance	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Wells	145.8±17.0	12	162.5±26.3	21	99.2±23.2	8	149.5±18.9	20
Trails	64.9±18.9		56.1±17.2		21.1±9.7		62.3±15.8	
Pipelines	66.5±14.8		75.8±19.1		60.4±15.6		77.1±18.0	
Junctions	162.5±27.5		257.7±38.1		183.1±52.3		233.3±34.1	

Table A.2: Distance (m) to nearest example of four types of human disturbance for chestnut-collared longspurs compared across areas with high and low well density and across years. Significant differences between years, determined using a two-way ANOVA, are indicated with "1" at a p-value of less than 0.05. Significant differences between well-densities are indicated with "2" while interaction between year and well-density is indicated with "3".

	2007				2008			
Source of Disturbance	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Wells[2]	80.1±22.0	9	201.6±23.7	19	138.7±19.9	9	188.6±17.0	25
Trails	40.7±28.9		18.5±7.4		28.5±12.7		50.6±13.7	
Pipelines[1]	37.0±19.1		39.8±17.0		64.9±20.1		107.1±18.7	
Junctions[2]	130.3±44.5		288.4±54.2		185.9±49.6		276.1±34.9	

Table A.3: Distance (m) to nearest example of four types of human disturbance for Sprague's pipit compared across areas with high and low well density and across years. Significant differences between years, determined using a two-way ANOVA, are indicated with "1" at a p-value of less than 0.05. Significant differences between well-densities are indicated with "2" while interaction between year and well-density is indicated with "3".

	2007				2008			
Source of Disturbance	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Wells[1]	173.4±21.3	18	194.2±16.8	27	126.6±9.8	24	154.0±13.9	30
Trails	72.3±18.4		68.1±16.1		36.2±7.5		72.0±16.3	
Pipelines[3]	83.2±13.7		66.3±10.7		64.3±10.1		110.3±17.0	
Junctions[2,3]	217.8±43.5		246.4±34.8		195.7±24.3		370.9±39.4	

Table A.4: Vegetation characteristics for Savannah sparrow territories compared between years. Significant differences, determined using a two-way ANOVA, are indicated with "1" for differences between years at a p-value of less than 0.05. Significant differences between well-densities are indicated "2" while interaction between year and well-density is indicated with "3".

Vegetation Characteristic	2007				2008			
	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Height (cm)	13.5±0.8	12	13.3±0.9	21	16.6±1.8	4	12.6±1.3	9
Bare ground (%)	10.0±1.5		12.8±1.2		12.3±3.3		10.8±0.8	
Litter cover (%)	20.9±1.3		22.5±1.1		22.5±2.8		18.2±1.5	
Standing dead (%)[1]	22.3±1.6		25.4±2.5		12.5±2.5		13.5±2.5	
Crested wheatgrass coverage (%)	19.9±11.1	12	8.4±4.9	21	9.4±4.0	8	1.9±1.7	20

Table A.5: Vegetation characteristics for Sprague's pipit territories compared between years. Significant differences, determined using a two-way ANOVA, are indicated with an "1" for differences between years at a p-value of less than 0.05. Significant differences between well-densities are indicated "2" while interaction between year and well-density is indicated with "3".

Vegetation Characteristic	2007				2008			
	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Height (cm)	9.1±0.3	9	9.4±0.4	19	8.4±1.2	2	8.4±1.1	7
Bare ground (%)	12.3±1.3		13.5±1.3		8.5±2.1		17.1±3.7	
Litter cover (%)	28.1±2.0		24.5±1.5		20.9±3.2		23.1±1.2	
Standing dead (%)[1]	30.2±2.5		23.7±1.4		13.0±4.7		13.5±1.4	
Crested wheatgrass coverage (%)[1]	2.9±1.7	9	2.5±1.5	19	0.7±0.3	9	0.08±0.06	25

Table A.6: Vegetation characteristics for Sprague's pipit territories compared between years. Significant differences, determined using a two-way ANOVA, are indicated with an "1" for differences between years at a p-value of less than 0.05. Significant differences between well-densities are indicated "2" while interaction between year and well-density is indicated with "3".

Vegetation Characteristic	2007				2008			
	High well-density		Low well-density		High well-density		Low well-density	
	mean±SE	n	mean±SE	n	mean±SE	n	mean±SE	n
Height (cm)	9.7±0.3	18	9.9±0.3	27	10.0±0.6	8	10.4±0.6	11
Bare ground (%)	10.3±1.1		14.2±1.0		12.0±2.3		12.5±1.3	
Litter cover (%)	24.7±1.2		23.2±0.7		23.2±1.0		23.5±1.8	
Standing dead (%)[1]	26.6±2.0		22.4±1.3		17.2±1.1		15.8±1.3	
Crested wheatgrass coverage (%)	1.2±1.1	18	0.4±0.24	27	6.4±3.6	24	0.4±0.3	30