HETEROGENEITY OF AVIAN BREEDING HABITAT ON GRAZING LANDS OF THE NORTHERN GREAT PLAINS

by

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Native rangelands in the Great Plains are largely privately owned and used for beef production. Vegetation heterogeneity is important for maintaining biodiversity, but private land may be more homogenous than desired. My research had two components: 1) to examine whether a variety of grazing strategies created vegetation heterogeneity in a large, intact rangeland, and 2) to understand beef producers' attitudes about vegetation heterogeneity.

First, I sampled vegetation structure, composition, and bird abundance at multiple plots on eleven management units in Cherry County, Nebraska. Units were managed with commonly used grazing strategies (e.g., short-duration grazing and season-long continuous grazing). I examined the relationship of vegetation heterogeneity, bird abundance, and bird communities to grazing management variables using various analytical techniques. Grazing strategy had few relationships to vegetation structure or bird abundance and communities, but structure and birds were most often predicted by pasture-level grazing management variables, like stocking rate and season of use. Therefore, multiple grazing strategies on a landscape did not contribute to vegetation heterogeneity, and vegetation structure and bird communities were more homogenous than expected. The goal of ranchers to efficiently use their vegetation resource likely

overwhelmed any effect of grazing strategy. Public land could be used to ensure that heterogeneity exists on the landscape for species that cannot find suitable habitat on private land.

Second, I interviewed 12 beef producers to explore their opinions of heterogeneity, and conducted a mail survey of producers in Nebraska, South Dakota, and North Dakota. Both indicated that beef producers' main concern is sustainable beef production, and this likely contributes to homogenizing the rangeland landscape. My data confirm that producers appreciated wildlife and have positive views toward landscape management. Although fire and prairie dogs might enhance heterogeneity of vegetation, these were negatively viewed because they increased risk to the producer. Producers' responses provided insights on how conservationists should engage them in biodiversity conservation. Importantly, "seeing is believing". If conservationists can use existing resources, like university ranches, to show the benefits of managing for heterogeneity, they may be more likely to adopt those practices. I recommend engaging producers through Extension and field days.

DEDICATION

I would like to dedicate this work to my husband, Bryn Tetreau. He's been supportive and flexible throughout this arduous process. Thank you for your unending support and love.

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CHAPTER 1: Introduction

Rangelands are in decline worldwide, both in area and in quality, for a variety of reasons including conversion to cropland, invasive species encroachment, suppression of fires, and the use of unnatural grazing regimes (Temple et al. 1999, Ditomaso 2000, Fuhlendorf et al. 2012, Wright and Wimberly 2013). Not surprisingly, grassland birds are also declining, and populations are decreasing more than other avian guilds in North America (Vickery et al. 1999, Sauer et al. 2014). Despite these facts, rangelands of the Great Plains are underrepresented in protected areas, such as refuges and national parks (Samson and Knopf 1994, Hazen and Anthamatten 2004). Rather, rangelands in the Great Plains are largely privately owned and managed, and when they are owned publicly they often are leased to landowners for beef production, which is the main industry in native rangelands that have not undergone conversion (Freese et al. 2010).

Declining rangelands have spawned two major thrusts for rangeland conservation: 1) protect remaining rangelands from conversion to crop agriculture (e.g., Lipsey et al. 2015), and 2) conserve and restore heterogeneity and natural disturbance regimes of native rangelands across large landscapes (e.g., Fuhlendorf and Engle 2001). Although both of these activities are important to prevent extinctions of grassland birds, there is evidence that even large and intact grasslands are not capable of maintaining grassland bird populations: a study in the Flint Hills in Kansas and Oklahoma showed that grassland bird populations were declining, even though the region is large (2 million ha) and relatively intact. The authors of the study attributed continued avian declines to intensive beef production in the region and homogenization of the landscape (With et al.

2008). Therefore, the focus of this research was on understanding heterogeneity in a large, intact rangeland landscape from both ecological and social perspectives.

Habitat heterogeneity is theorized to be the basis for biodiversity (MacArthur and MacArthur 1961, Tews et al. 2004), and many rangeland ecologists have promoted different ways of increasing rangeland heterogeneity for biodiversity conservation (e.g., Fuhlendorf and Engle 2001, Toombs et al. 2010). In landscape ecology, heterogeneity has been defined as "the existence of two or more qualitatively different patch types that may or may not differ in suitability;" a patch was defined as an area with differing environmental qualities from the surrounding areas (pg. 341 in Addicott et al. 1987). Because of the relatively simple structure of rangeland habitats (Rotenberry and Wiens 1980), the relationship between vertical and horizontal habitat structure and cover, which can provide patchiness or heterogeneity, is important to understand. In defining what environments are patchy or heterogeneous, we also must take care to ensure that we are considering patchiness and heterogeneity from the point of view of the organisms of interest (Wiens 1976).

Any efforts to increase heterogeneity in large, intact rangelands are complicated by the fact that most remaining native rangeland available for wildlife conservation is on private land. Thus, the use of typical strategies for wildlife and habitat conservation, such as the creation of refuges or parks, or invoking the Endangered Species Act, are politically challenging (Krannich and Smith 1998). For example, there was an outcry among the western ranching population when discussions began on listing greater sage-grouse (*Centrocercus urophasianus*) as threatened or endangered, because it was assumed that a federal listing would be catastrophic for private land managers due to restrictions on production (Knapp et al. 2015). From this resistance, however, unique strategies have been implemented and appear to be successful, such as the Sage Grouse Initiative in the Great Basin, which is in some ways an effort to avoid federal listing of the species (Belton 2008, Baruch-Mordo et al. 2013). Other species, like the black-tailed prairie dog (*Cynomys ludovicianus*) are more challenging to protect because they are often listed as pests at the state level, and producer groups lobby strongly for their control or eradication (Lybecker et al. 2002, Lamb and Cline 2003, Schumacher 2016). These challenges highlight why a focus on private land and private producers is crucial at this point in time. Without an understanding of the ways private land is managed and the opinions of private producers about conservation topics, it is not possible to develop strategies and policies for rangeland conservation at large and meaningful scales.

Thus, my research took a holistic perspective: I conducted an ecological study, where I looked at grazing strategies across a landscape managed by private producers (Chapters 2 and 3), and a human dimensions study, where I used qualitative interviews (Chapter 4) and a quantitative survey (Chapter 5) to better understand the social dimensions of rangeland management. In a privately owned landscape like the Nebraska Sandhills and other relatively intact regions of the Northern Great Plains, it is crucial to understand what is happening across the landscape and what the landowners' opinions and attitudes are about topics that are important to conservation.

CHAPTER 2: Managing for the middle: variation in bird habitat is not explained by grazing strategies on a Sandhills landscape[1]

ABSTRACT

Grassland birds are declining at a greater rate than any other guild of birds in North America, and one reason for their decline is the degradation of habitat. In conservation circles, there is growing emphasis on managing native rangelands for heterogeneity to promote biodiversity, and an associated assumption that beef production on privately owned rangelands causes homogenization of the landscape, otherwise known as "managing to the middle". However, little research has been done to examine the relationships of grazing management and birds on private land, and some managers assume that using multiple grazing strategies across a landscape will increase heterogeneity and provide benefits for biodiversity. Thus, the goal of this research was to examine structural heterogeneity and songbird abundance in relation to grazing strategies used by private producers in a large, intact rangeland region. I completed a mensurative study in the Nebraska Sandhills on eleven management units, six of which were owned and managed by different private producers, and five of which were owned by the U.S. Forest Service and leased to private producers. There were five different grazing strategies, including season-long continuous, deferred rotation, management intensive, dormant season only, and a fixed rotation. I measured vegetation structure on each management unit and used mixed models to assess the relationship between vegetation structure and management variables (e.g., grazing strategy and stocking rate); I also

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[1]This chapter will be formatted for submission to Rangeland Ecology and Management. Co-authors will include Larkin A. Powell, Walter H. Schacht.

conducted songbird counts and used N-mixture models to assess the relationship of songbird abundance to both vegetation structure and management variables. The management variables most commonly related to vegetation structure and songbirds were season of use and stocking rate, and grazing strategies were not related to most songbirds or vegetation characteristics. Thus, rangeland managers should not assume that a variety of grazing strategies used across a landscape will inevitably result in heterogeneity of vegetation structure; rather, managers should focus on creating contrasting vegetation structure in large areas, such as pastures, thus increasing large-scale heterogeneity and providing habitat for a wider variety of grassland bird species.

INTRODUCTION

Livestock grazing has implications for biodiversity management in rangelands (Fleischner 1994, Fuhlendorf and Engle 2001, Krausman et al. 2009), because grazing by livestock impacts structural heterogeneity of vegetation (hereafter structural heterogeneity) and is the primary use of rangelands across North America (Adler et al. 2001, Derner et al. 2009). Structural heterogeneity increases the number of habitat niches available, and thus affects potential animal diversity (MacArthur and MacArthur 1961), particularly that of grassland birds. Structural heterogeneity on rangelands is influenced by livestock selection for favored plants and plant communities, topographic positions, soil types, and climatic conditions; therefore, grazing management can be used to manipulate structural heterogeneity.

Grazing management is typically based on four principles: 1) optimize stocking rate, 2) optimize frequency and season of use, 3) optimize type of herbivore, and 4) optimize grazing distribution (Vallentine 2001). These principles serve to moderate plant selection by herbivores in an attempt to maintain the forage resource indefinitely (Barnes and Hild 2013). On private land, the principles are typically applied within the framework of a grazing strategy with the aim of increasing livestock production and profitability (Briske et al. 2008). The most common grazing strategies include season-long continuous grazing, rest-rotation grazing, deferred-rotation grazing, and management-intensive grazing (Schacht et al. 2011), with the latter two being promoted by private ranching groups (e.g., grazing coalitions) as well as state and federal government agencies (Briske et al. 2008, Toombs and Roberts 2009) because some believe they are better for beef production and wildlife. These heavily promoted grazing strategies typically have grazing bouts that are timed to favor the growth of preferred forage species and/or use cross-fencing to reduce pasture size and distance to watering points, thus increasing grazing efficiency, but grazing pressure is often maintained at locally recommended levels (Coughenour 1991, Jacobo et al. 2006, Briske et al. 2008).

Grazing strategies with differing intensities and frequencies of grazing, different seasons of use, and variable grazing distributions are expected to have varying effects on structural heterogeneity and botanical composition within a management unit. Management intensive strategies, with smaller pastures and shorter grazing periods, are characterized by reduction of selective grazing and relatively even use of pasture vegetation. High-performance strategies (e.g., season-long continuous grazing) allow greater forage selectivity by livestock, which presumably increases the nutritional quality of forage consumed (Vallentine 2001, Vermeire et al. 2008). Deferred-rotation strategies defer grazing on one pasture in the management unit until the end of the growing season; whereas, one pasture in rest-rotation strategies is not grazed for an entire year (Schacht et al. 2011). A number of studies have found evidence of differences in vegetation and/or birds among strategies (Hart et al. 1993, Adler et al. 2001, Davis et al. 2014); these studies suggest that landscape bird diversity would improve by simply using a variety of grazing strategies across a landscape (e.g., Vavra 2005, Kempema 2007, Ranellucci et al. 2012). However, other studies did not support the expectation that grazing strategies would result in different vegetation structure and composition (Vermeire et al. 2008, Briske et al. 2011, Barnes and Hild 2013).

One problem with these previous studies is that most of them were conducted on non-private property, such as property owned by non-governmental organizations, universities, and/or state and federal governments (Briske et al. 2011, Augustine et al. 2012, Sliwinski and Koper 2015, Ahlering and Merkord 2016). In the Northern Great Plains, 75% of the land is in private ownership (Freese et al. 2010), and in Nebraska, at least 94% of grazing land is privately owned (Reece et al. 2008). There has been a call for research that examines the relationships of grazing strategies and wildlife at relatively large spatial scales and in a "less controlled approach", which is more similar to what is found on private land where management decisions can be changed daily (Vavra 2005, Krausman et al. 2009, Barnes and Hild 2013). Therefore, the goal of this research was to examine how habitat characteristics vary across a rangeland landscape that was managed using a variety of grazing strategies, and how grassland birds responded to both vegetation structure measures and management. Specifically, I compared vegetation structure among the selected grazing strategies, and determined if abundance of songbird species varied among the different grazing strategies.

METHODS

Field methods

This study took place in Cherry County, Nebraska, in the Nebraska Sandhills, a region with large, contiguous tracts of native private and public rangeland. The Nebraska Sandhills cover 50,000 km^2 of rolling, grass-covered sand dunes with intermittent subirrigated meadows and wetlands. Over 90% of the Sandhills is intact native rangeland that is used primarily for beef production (Bleed and Flowerday 1998). The species present are a mix of short- and tall-grass prairie species, sand tolerant species, and species associated with permanent and ephemeral wetlands and lakes (Potvin and Harrison 1984). Plant communities in the rangelands include the bunchgrass community, which include little bluestem (*Schizachyrium scoparium*), Junegrass (*Koeleria macrantha*), and needle-and-thread grass (*Hesperostipa comata*); the sand muhly (*Muhlenbergia pungens*) community, which commonly inhabits recently disturbed areas; and the blowout community, with blowout grass (*Redfieldia flexuosa*), prairie sandreed (*Calamovilfa longifolia*), and blowout penstemon (*Penstemon haydenii*; Bleed and Flowerday 1998). Meadow communities are variable depending on proximity of the water table to the soil surface, and contain bromegrasses (*Bromus* spp.), timothy grass (*Phleum pretense*), and switchgrass (*Panicum virgatum*). The most noteworthy non-native species are Russian thistle (*Salsola iberica*), kochia (*Kochia scoparia*), and downy brome (*Bromus tectorum*). Although grasses make up the dominant cover type in the Sandhills, there are numerous species of forbs and some shrubby species, which make for a diverse plant community (Bragg and Steuter 1996). Cherry County is approximately 87% rangeland (U.S. Department of Agriculture 2015).

I sampled eleven management units to include a variety of grazing strategies, where a management unit was one or multiple pastures grazed by a single herd of cattle in a given year. The number of pastures in a management unit ranged from 1 to 20, and pasture size ranged from 94 to 934 ha (mean = 345, SD = 234). Six management units were on private ranches, and five management units were on the Samuel R. McKelvie National Forest. To increase consistency among management units, I sampled only from upland habitats in an area with relatively low amount of lakes and wetlands and similar ecological site descriptions (Table 1). Ecological sites in the Sandhills that I sampled included sandy (level areas between dunes with higher plant density), sands (grass-covered, rolling dunes), choppy sands (steep slopes and lower plant density), and blowouts (areas of moving sand and limited vegetation). I sampled multiple pastures from within each management unit (except for the season-long, continuous strategy, which by definition consists of a single pasture). In each management unit I sampled 24 plots (Figure 1). Each sample plot was separated by at least 250 m and was at least 250 m from perimeter fences and non-rangeland habitats (e.g., wetlands, roads). Because this research was completed on private land and public land leased to private producers, it was not possible to experimentally manipulate any of the management variables used.

In May, vegetation structure was measured using 100 × 50 cm frames that were located at 8 stratified locations within each plot; four frames were located at 50 m and four frames were located at 100 m from the center of the plot in each cardinal direction (Figure 2). By sampling multiple frames per plot, I was able to assess heterogeneity at the local scale of 100 m^2, in addition to pasture (~67 ha) and management unit scales (~134 ha).

I measured litter depth to the nearest centimeter at the center of each frame; litter included dead vegetation that was lying at or below a 45° angle to the ground. Visual obstruction readings (VOR) were measured at each frame using a modified Robel pole (increments of 2.5 cm) from four directions at a distance of 4 m and height of 1 m (Robel et al. 1970). The increment at which the pole was completely obscured by vegetation was recorded. Cover of litter, bare ground, live grass, standing dead vegetation, and shrubs were visually estimated within each frame using the following increments: 0%, > 0 to < 1%, 1 to 5%, 6 to 25%, 26 to 50%, 51 to 75%, 76 to 95%, > 95%. Midpoints of the cover classes were used for analysis purposes (Daubenmire 1959, Coulloudon 1999, Towne et al. 2005). At each frame location, I recorded the ecological site (blowout, choppy sands, sands, or sandy). See Appendix A for vegetation structure datasheet and instructions.

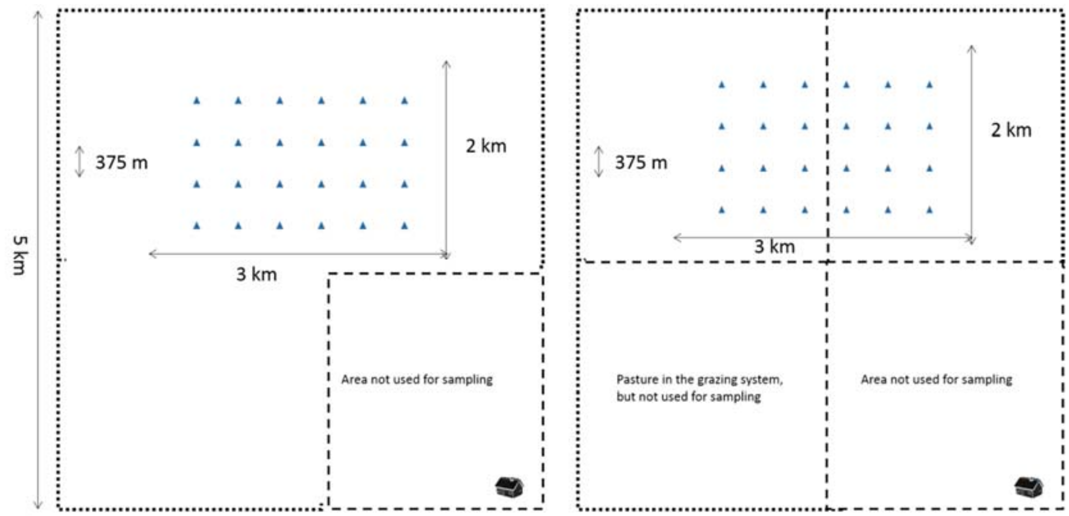

Figure 1. Two conceptual management units, showing layout of sampling plots (blue triangles) within summer upland grazing pastures using a 6 km^2 sampling area. In this example, the summer grazing area is 1950 ha (4800 ac). For grazing strategies with multiple pastures, more than one pasture was sampled across the fence line (on right).

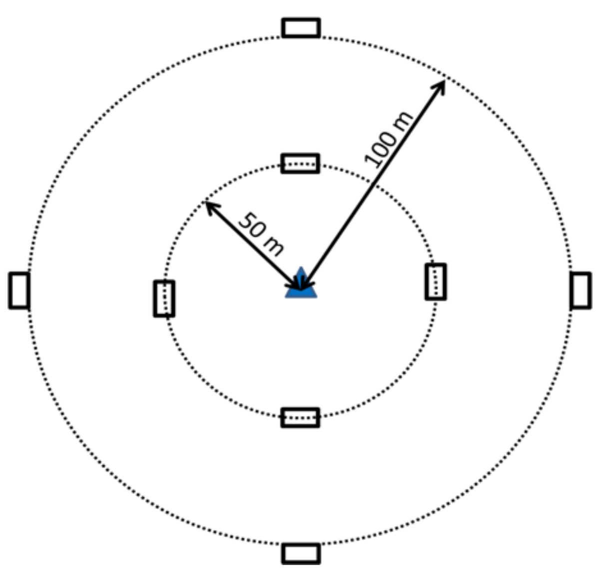

Figure 2. Stratified sampling design for vegetation structure measurements. The blue triangle is the center of the plot. Four frames were located at 50 m and four frames were located at 100 m from the center of the plot in the four cardinal directions.

I conducted point counts three times at each plot in each year for a total of six visits to each plot. Point counts were completed from 4 June through 3 July 2014 and 29 May through 30 June 2015. All plots were visited by at least 4 different observers over the course of the study to limit observer bias. Counts were restricted to days with no rain, limited fog, and winds below 16 $km \cdot h^{-1}$ and were conducted from 10 minutes before sunrise until about 10:00 am (Hutto et al. 1986). I recorded all birds that were seen or heard during six minutes, and for each bird I recorded the species, sex, the behavior of the bird (observed singing, observed calling, heard singing, heard calling, observed only), the distance to the bird from the observer, and the interval during which the bird was observed (first two minutes, second two minutes, fifth minute, sixth minute). For each point count, I recorded the date, time, observer, cloud cover, wind speed (approximated if observer did not have a Kestrel anemometer), and noise level (no noise, low noise, medium noise, high noise).

For each management unit, I collected information about the grazing strategy that was used on that unit in the previous year (e.g., short-duration, deferred rotation, season-long continuous, dormant season, fixed rotation), the age class of the cattle that grazed the unit, the number of cattle in the unit, and the dates that the different pastures were grazed in a management unit. Although there are clearly defined categories of grazing strategies, landowners deviate from them in a multitude of ways to ensure they meet their goals. For example, a management intensive grazing strategy might not allow dormant-season grazing by definition, but many landowners need to over-winter their cattle, and often a pasture included in the growing season rotation will also be used in the dormant season. Landowners also must be flexible concerning the weather, the markets, and their own lifestyles, all of which can cause a landowner to deviate from a pre-defined grazing strategy. Thus, we also examined the relationship of other relevant factors, such as stocking rates and periods of use, to vegetation structure and bird abundance. From the information I collected from landowners, I was able to calculate a stocking rate (AUM/ha) for each pasture sampled within the management unit, as well as determine seasons of use (e.g., warm season, cool season, and dormant season). Warm season was June 1–October 15 (average killing frost date), cool season was April 15–May 31, and dormant season was October 15–April 15.

Vegetation structure analysis

For exploratory analyses, I calculated the means and standard deviations of seven vegetation structure variables across management units (n = 192 frames per unit) and across the entire study area (n = 2112 frames total). I calculated standard deviations within each plot (n = 8) and then used these to calculate mean standard deviation across the study area (n = 264) as an estimate of the variability in the vegetation structure variables of interest across the eleven management units. The vegetation structure variables of interest were VOR, litter depth, litter cover, standing dead vegetation cover, grass cover (live), bare ground, and shrub cover. Forb cover was also of interest, but forb cover was generally very low at the time of sampling (mid-May).

The subsamples within each grazing management unit in my study design made it necessary to use mixed effects models to analyze the vegetation structure data. The fixed effects of interest included grazing strategy, four continuous stocking rate variables (stocking rate for the previous year, previous cool season, previous warm season, and previous dormant season; previous year used because sampling took place in May, prior to the majority of current year grazing), a categorical stocking rate variable (high > 0.35 AUM/ha, low < 0.35 AUM/ha), a categorical management intensity variable (low < 3 pastures in the strategy, moderate 3−6 pastures in the strategy, high > 6 pastures in the strategy), a disturbance intensity variable (Stocking Rate|Management Intensity: High|High, High|Low, etc.), season of use, ecological site, and ownership (public or private). The random effects of interest included Year (n = 2), Management Unit (n = 11), Pasture (n = 26), and Plot (n = 264). Plot was included as a random effect because I took each of the measurements at eight frames within each plot. In preliminary analyses, ecological site was found to be an important predictor of vegetation structure; however, I omitted ecological site from the model set because it is not manageable and because it could not be used in an interaction with any other variables since there was unbalanced representation among ecological sites (Table 1). Although I was interested in the interaction between stocking rates and grazing strategies, stocking rates did not vary enough within each grazing strategy to make such an interaction valuable or interpretable. Secondarily, a preliminary analysis showed that models including an interaction between the grazing strategy and seasonal stocking rates were rank-deficient and did not converge properly.

The final model set that I used to assess all of the vegetation structure variables included fourteen models, and each model included four nested random effects (Year, Management Unit, Pasture, and Plot). The models included the following fixed effects: 1) null model (no fixed effects); 2) grazing strategy; 3) season of use; 4) seasonal stocking rates (cool + warm + dormant); 5) cool-season stocking rate only; 6) warm-season stocking rate only; 7) dormant-season stocking rate only; 8) previous year's stocking rate; 9) previous year's stocking rate + grazing strategy; 10) previous year's stocking rate + season of use; 11) a categorical variable for previous year's stocking rate; 12) a categorical variable for management intensity; 13) a categorical variable for disturbance intensity; and 14) a categorical variable of ownership. I used the *lmer* function from package lme4 in R (Bates et al. 2015) to use mixed modeling and used Akaike's Information Criterion to assess the relative support for each competing model. For the top-ranking model, I examined the 85% confidence intervals of each fixed effect to determine if that variable had a significant relationship with the dependent variable of interest and to determine when the values of any categorical variables were significantly different from one another.

Heterogeneity of vegetation structure variables, which were the standard deviations of the measurements taken at the eight frames within each plot, were analyzed in a similar manner except that Plot was not available as a random effect because there was only a single value for heterogeneity at each plot. Additionally, I added models to assess if any of the relationships to stocking rates (both overall and seasonal) were quadratic; this resulted in an additional five models in the model set, for a total of 19 models.

Avian abundance analyses

I collected avian data over repeated visits within a season so that I could use *N*-mixture modeling to estimate both detectability and abundance of six songbird species in relation to vegetation structure measures and management (Royle 2004). Instead of conducting an open-metapopulation *N*-mixture analysis, which models immigration/emigration from the population, I combined the two years of data and assumed that each point-year combination was an independent sampling location (Ahlering and Merkord 2016). Assuming independence of the same point in different years is appropriate in this case because grassland birds tend to have low site fidelity (Winter et al. 2005), and each site had slightly different management (e.g., stocking rates, season of use) each year. I truncated bird survey data at 150 m to reduce overlapping counts; point count plots thus covered 7 ha.

The six avian species of interest that also had sufficient data (at least 300 detections) to analyze abundance were grasshopper sparrow, western meadowlark, lark sparrow, horned lark, dickcissel, and field sparrow. Four of these species are included in the Breeding Bird Survey's list of grassland birds, and two (lark sparrow, field sparrow) are considered scrub-dependent species. The vegetation structure variables of interest included visual obstruction reading, grass height, litter depth, shrub height, litter cover, standing dead vegetation cover, grass cover, bare ground, and shrub cover at three scales (plot, pasture, and management unit). All of these measures were included in each of six models as either the means or standard deviations at the three scales. I also included a model for ecological site description and a null model for a total of eight models. For the detection side of the *N*-mixture model, I included the following covariates for all species: minutes after sunrise, observer, Julian day, and percent cloud cover. We assessed these relationships using *N*-mixture models with the *pcount* function in package *unmarked* in program R (Royle 2004, Fiske and Chandler 2011).

To assess the relationship of bird abundance to management, I included the same management variables that were used in the vegetation structure models: 1) grazing strategy; 2) season of use; 3) the three seasonal stocking rates; 4-6) each individual seasonal stocking rate; 7) previous year's total stocking rate; 8) previous year's total stocking rate + season of use; 9) previous year's total stocking rate + grazing strategy; 10) a categorical previous year's stocking rate; and 11) a categorical management intensity; 12) disturbance intensity; 13) ecological site; 14) ownership; 15) null abundance; 16) null abundance + null detection. None of these variables were collinear. I excluded wind speed as a detection covariate because it was moderately collinear with minutes after sunrise ($r = 0.51$) and had to be interpolated for some points because there was only a single anemometer available during data collection, while observers could be more than 20 km apart; additionally, I only conducted surveys when wind speeds were < 16 $km \cdot hr^{-1}$.

For analyses of both vegetation structure variables and management variables, I used a Poisson distribution to model counts for the grasshopper sparrow, lark sparrow, and western meadowlark, the Zero-Inflated Poisson for the horned lark and field sparrow, and the negative binomial for the dickcissel. The appropriate distribution was chosen by comparing the model fit (AIC) of the null abundance/global detection model among the three different distributions for each species. At this time, *N*-mixture models do not allow for the incorporation of random effects; in a preliminary analysis I included "site" as a fixed abundance covariate in each model, but these models did not converge properly. I used 85% confidence intervals of the variables to determine if they were strong predictors of bird abundance. I assessed the goodness-of-fit of each of the species' top models with a parametric bootstrap procedure using the *Nmix.gof.test* function in package AICcmodavg; $p > 0.05$ indicated adequate fit.

RESULTS

Descriptive

Managers used five different grazing strategies on the eleven management units selected for this study: season-long continuous grazing, deferred rotation grazing, management intensive grazing, dormant-season grazing, and a fixed rotation strategy. Movement of cattle through the fixed rotation strategy was based on forage growth, and the pastures included in the strategy were used in the same order each year. Each grazing strategy was represented on both public and private land, except dormant-season grazing and fixed rotation were on private land only. The stocking rate was typically lower on public land than on private land. In 2014, mean stocking rate across the five public management units was 0.52 AUM·ha^{-1}, whereas mean stocking rate across the six private management units was 0.98 AUM·ha^{-1} (Table 2).

Across the study area, vegetation characteristics did not change appreciably between 2014 and 2015 although VOR and mean litter depth were 20% and 30% less in 2015 than in 2014, respectively; and mean bare ground was 46% greater in 2015 than

2014 (Table 3). Vegetation heterogeneity (i.e., standard deviation calculated for each plot using eight sampled frames and then averaged across 264 plots) was similar for all measures in 2014 and 2015 except for litter depth, which had higher heterogeneity in 2014 than 2015 (Table 4).

I detected 51 bird species in 2014 and 64 in 2015; 12 of these species in 2014 and 14 in 2015 were considered grassland birds on the Breeding Bird Survey's (BBS) grassland species list. Of these grassland birds, only dickcissel, grasshopper sparrow, horned lark, and western meadowlark had enough detections to model their abundance in response to the variables of interest in this study (e.g., grazing strategy). I also had sufficient data to model the lark sparrow and the field sparrow, which are considered "successional or scrub breeding" species according to BBS (Sauer et al. 2014).

Vegetation structure

I selected a top ranking model for each of the six vegetation structure variables and their variability in relation to vegetation structure management. Only three measures, shrub cover, variability in litter cover, and variability in grass cover were best explained by grazing strategy. Most measures were best explained by a combination of stocking rates and seasons of use. The best ranking model for VOR included the previous year's total stocking rate and the season of use (w = 0.68, Table B-1). VOR decreased by approximately 1 cm with each 1 AUM·ha^{-1} increase in stocking rate (Table 5, Figure 3). VOR was greatest in pastures that were grazed in the cool and warm seasons, and lowest in pastures that were grazed only in the cool season (Figure 3), but evidence that season of use caused variation in VOR was very weak, because the 85% confidence intervals overlapped 0. VOR heterogeneity at the plot level was best explained by the previous warm-season stocking rate (*w* = 0.86, Table B-2). The relationship between VOR heterogeneity and warm-season stocking rate was quadratic (Table 7), and VOR heterogeneity was greatest at approximately 0.6 AUM·ha^{-1} (moderate stocking rate in my study) in the warm season (Table 4).

The top model for mean litter depth included only the season of use (*w* = 0.73, Table B-3). Litter depth was greatest at about 6 cm in pastures that were grazed in the cool and dormant seasons, lowest at about 1 cm in pastures that were grazed in the cool, warm, and dormant seasons (Table 5, Figure 5); however, there was no obvious pattern in the relationship of litter depth to season of use. Heterogeneity of litter depth at the plot level was best explained by ownership (*w* = 0.47; Table B-4); very little of the heterogeneity was explained by any of the random effects (Table 8). Litter depth heterogeneity was lowest on privately owned land and highest on publicly owned land, but the difference was only 0.5 cm (Table 8, Figure 6).

Litter cover was best explained by stocking rate and season of use (*w* = 0.81, Table B-5). Litter cover decreased by 4.4% (SD = 1.95) with each 1 AUM·ha^{-1} increase (Table 5, Figure 7). Pastures that were grazed in the cool, warm, and dormant seasons had the lowest litter cover at 10%, while the rest of the pastures had between 30% and 40% litter cover regardless of the season of use (Table 5, Figure 7). Heterogeneity in litter cover at the plot level was best explained by stocking rate and grazing strategy (w = 0.96, Table B-6). Litter cover heterogeneity was lowest at moderate stocking rates in my study (~1.7 AUM·ha^{-1}, ~15% litter cover heterogeneity) and highest at low stocking rates

(0.2 AUM·ha^{-1}, ~25%, Figure 8). Heterogeneity in litter cover was at its lowest on season-long, continuously grazed systems (heterogeneity = 15%, Table 7), and highest on dormant-season and fixed-rotation grazed pastures (Figure 8).

The top model for bare ground included stocking rate and season of use (Table B-7). Bare ground decreased by about 4.5% (SD = 2.04) with each 1 AUM·ha^{-1} increase in stocking rate (Table 5, Figure 9). Bare ground was greatest in pastures that were grazed only in the dormant season (about 60% bare ground), and lowest in pastures that were grazed in the cool and dormant seasons (about 30% bare ground; Figure 9). Heterogeneity in bare ground at the plot level was also best explained by the season of use (w = 0.22, Table B-7), but the dormant-season stocking rate, seasonal stocking rates, and categorical stocking rate (high/low) had substantial relative weights (w = 0.19, 0.11, 0.10, respectively) indicating a lack of certainty in the model set. Only pastures grazed in the warm and dormant seasons had higher heterogeneity in bare ground than other pastures, and this was only by about 6% (SE = 2.32; Figure 10).

The top model for standing dead vegetation cover included only the categorical classifications of stocking rate and management intensity (w = 0.60, Table B-9). Standing dead vegetation cover was greatest (14-17%) in pastures that were managed with a low stocking rate and a high management intensity or in pastures with a high stocking rate using a moderate management intensity; the remaining types of pastures had similar standing dead vegetation cover at 10-12% (Table 6, Figure 11). Heterogeneity of standing dead vegetation at the plot level was explained best by ownership; this model had w =

0.50 (Table B-10). Standing dead vegetation cover heterogeneity was highest on publicly owned land and lowest on privately owned land (Table 8, Figure 12).

The top model for live grass cover included stocking rate and season of use (*w* = 0.81, Table B-11). Grass cover increased by 3.6% (SD = 1.42) with each 1 AUM·ha^{-1} increase in stocking rate (Table 5, Figure 13). Grass cover was lowest in pastures that were grazed in the warm and dormant season (12% cover), and highest in pastures that were grazed in the cool and dormant seasons (25%), cool and warm seasons (25%), and warm season only (24%). Heterogeneity in grass cover was best explained by the grazing strategy (*w* = 0.82, Table B-12). A fixed rotation strategy had the highest heterogeneity in grass cover (21%, SE = 2.12), whereas a deferred rotation strategy had the lowest heterogeneity in grass cover (12.5%, SE = 1.49; Table 7, Figure 14).

Both shrub cover and the heterogeneity of shrub cover at the plot level responded to stocking rate and grazing strategy (Table B-13, Table B-14). Shrub cover (Table 6, Figure 15) and shrub cover heterogeneity (Table 7, Figure 16) were highest in the management intensive and fixed-rotation grazing strategies, and lowest in the other three grazing strategies, and both decreased by about 2% with every 1 AUM·ha^{-1} increase in stocking rate.

The random effect of pasture explained more variance in VOR and heterogeneity of VOR than plot and management unit random effects (Table 5, Table 7). None of the random effects explained much of the variance in litter depth means or heterogeneity; variance in litter cover was explained by pasture, management unit, and plot (Table 5). Variance in litter cover heterogeneity was explained by the random effects of pasture and year (Table 7). Much of the random variation in bare ground and heterogeneity of bare ground was explained by the plot and year random effects (Table 5, Table 7). For standing dead vegetation, the plot and pasture random effects explained more random variance than management unit or year. The pasture random effect explained a larger amount of the random variance of heterogeneity of standing dead vegetation than did the management unit random effect (Table 8).

Avian abundance, vegetation structure

Five of the six species of interest responded to some vegetation structure characteristics, whereas western meadowlarks did not respond to any of the vegetation characteristics (null model was top model, $w = 0.37$; Table C-2). Best-ranking models for each of the species had adequate fit, as indicated by the goodness-of-fit tests ($p > 0.05$; 0.75 > c-hat > 1.11).

Grasshopper sparrow abundance was best explained by vegetation characteristics at the scale of the management unit ($w = 1.0$, Table C-1), and there was strong evidence that VOR, grass height, litter depth, standing dead vegetation cover, grass cover, and bare ground were related to variation in grasshopper sparrow abundance (Table 9). Grasshopper sparrow abundance decreased with increasing VOR, and increased with bare ground, grass cover, standing dead vegetation, and grass height, and litter depth (Figure 17).

Lark sparrow abundance also was explained best by vegetation characteristics at the management unit scale ($w = 0.48$, Table C-3). Lark sparrow abundance decreased with litter depth, standing dead vegetation cover, and grass cover, and increased with

VOR (Table 9, Figure 18). Lark sparrow abundance was highest with 4 birds per plot when litter depth, grass cover, and standing dead vegetation cover were at their lowest, and abundance decreased to less than two birds per plot when these vegetation characteristics were at their greatest.

Horned larks were the only species for which heterogeneity of vegetation structure was the strongest predictor of abundance (*w* = 0.7, Table C-4). Horned lark abundance decreased with increased heterogeneity of grass height, shrub height, and litter cover, and increased in abundance with increased heterogeneity in VOR and standing dead vegetation cover (Table 9, Figure 19). Horned lark response was strongest for heterogeneity in grass height and shrub height, with abundance decreasing from greater than four birds per plot to about 1 bird per plot from the minimum to maximum plot heterogeneity detected at my study site.

The only species that was best explained by vegetation structure at the plot level was the dickcissel (*w* = 0.61, Table C-5). Dickcissel abundance decreased with increasing VOR, litter depth, litter cover, and bare ground, but increased with standing dead vegetation cover, live grass cover, shrub height, and shrub cover (Table 9, Figure 20). Abundance was commonly below 2 birds per plot, and the 85% confidence intervals were wide, indicating a large amount of uncertainty in these estimates.

The field sparrow responded to mean vegetation structure measures at the management unit scale (*w* = 0.93, Table C-6). Field sparrow abundance decreased with increasing grass height, bare ground, and grass cover, and increased with shrub height, VOR, litter depth, and shrub cover (Table 9, Figure 21). There was uncertainty in the response of field sparrows to low grass height and high shrub height indicated by wide confidence intervals in those regions. Abundance was typically 2 birds or fewer per plot.

Avian abundance, management

Variation in grasshopper sparrow abundance was best explained by the ownership category (public/private) (w = 1.00, Table D-1); grasshopper sparrow abundance was high on publicly owned land (about 3.5 birds per plot) and low on privately owned land (about 2 birds per plot; Table 10, Figure 22). Detection probability for grasshopper sparrows was 0.85, and increased very slightly with minutes after sunrise, and decreased slightly as the season progressed. Different observers were also responsible for some of the variation in detection probability of grasshopper sparrows.

Western meadowlark abundance had a positive relationship with warm-season stocking rates (Table D-2, Table 10, Figure 23); abundance increased by less than 0.5 bird with warm-season stocking rates from 0 to 1 $AUM \cdot ha^{-1}$. Detection probability of western meadowlarks was 0.99 and was significantly related to all the covariates except for cloud cover.

Lark sparrow abundance was most strongly related to ecological sites (Table D-3, Table 10, Figure 24), with abundance being highest at 5 birds per plot in choppy sands ecological sites, 3 birds in complex sites, less than 2.5 birds in sands ecological sites, and less than 2 birds in sandy ecological sites. Lark sparrow detection probability was 0.05, and increased slightly as the season progressed and with cloud cover. Different observers also caused variation in lark sparrow detection probability.

Horned lark abundance was best explained by the disturbance intensity variable (Table D-4, Table 10); abundance was lowest (1 bird per plot) in pastures that were managed with a high stocking rate and a moderate management intensity, and highest (~2.5 birds per plot) in pastures managed with a low stocking rate and high or moderate management intensity (Figure 25). Horned lark detection probability was 0.90 and decreased as the season progressed.

Dickcissel abundance was also best explained by the disturbance intensity variable (Table D-5, Table 10, Figure 26). Dickcissel abundance was highest on pastures managed with a high stocking rate and high or low management intensity, and a low stocking rate and high management intensity, but estimates had wide confidence intervals. Dickcissel detection probability was very low (< 0.01), and increased as the field season progressed. Detection probability may be so low because I combined data from 2014 and 2015, when in 2014 dickcissels were abundant and in 2015 they arrived much later in the season and in lower numbers.

Finally, field sparrow abundance was best explained by stocking rate and grazing strategy (Table D-6). Field sparrow abundance decreased by about 1 bird per plot with an increase in 1 $AUM \cdot ha^{-1}$. Field sparrow abundance was highest at 2 birds per plot on management intensive grazing units, and no field sparrows were detected on dormant-season only units (Table 10, Figure 27). Detection probability of field sparrows was 0.93 and decreased slightly as the season progressed, and varied among observers.

The goodness-of-fit tests for the N-Mixture models indicated adequate fit for all top models for species responses to vegetation structure management strategies ($p > 0.05$, $0.65 <$ c-hat < 1.14).

DISCUSSION

My analyses show that structural heterogeneity of vegetation does exist in the Nebraska Sandhills, but there was little evidence that grazing strategy affected heterogeneity among management units; most of the heterogeneity was found among the individual pastures in my study used to manage grazing. Thus, my results do not support the idea that a variety of grazing strategies contribute to large-scale structural heterogeneity across a landscape. Grazing strategies are used within a framework of beef production, and thus do not operate past thresholds that may create vegetation heterogeneity. Of the fourteen vegetation structure variables that I assessed, only four responded to grazing strategy. These responses were weak or inconsistent. The abundance of only one of the six songbird species I assessed, field sparrows, responded to the grazing strategy.

Use principles of grazing management to create heterogeneity

Even though it is possible to categorize different management techniques into grazing strategies, my results suggest that the management principles underlying these strategies are more effective at managing pastures for birds (Vallentine 2001). Much of the variability in vegetation characteristics was contained among plots or among pastures instead of at the scale of the management unit. Season of use, stocking rate, and/or management intensity were good descriptors of variation in vegetation structure and songbird abundances, but their classification into a grazing strategy was not a good descriptor. Further, the fact that much of the variance was among pastures probably indicates that the rotation of grazing was an important contributor to heterogeneity of vegetation structure at a given point in time, rather than the grazing strategy itself (e.g., all grazing strategies except season-long, continuous allow for the comparison of vegetation in a pasture that was just grazed to the adjacent pasture that has not yet been grazed). These results provide some support for the recommendation that a rest-rotation grazing strategy will provide a variety of habitats, but primarily because of the variability in grazing intensity experienced across a group of pastures at a given point in time (Toombs et al. 2010).

The lack of response of heterogeneity to grazing strategies is not completely surprising. When grazing management is implemented on private land, the goal is optimizing beef production over the long term, rather than mimicking historical disturbance patterns like the fire-grazing interaction. Grazing in the Nebraska Sandhills, and across most of the Great Plains, is done by beef cattle at the recommended stocking rates, and fires, when they are used, are often conservative in scale and intensity (Freese et al. 2014, Twidwell et al. 2016). The common principles that are used to manage beef production (Vallentine 2001) appear to create similar outcomes for vegetation structure and birds across grazing strategies. Additionally, land managers modify the grazing strategies to fit their operations, which may also make their results more similar to each other. The extremes in vegetation structure, which would occur naturally though a fire-grazing interaction are not created through grazing for beef production (Augustine and

Derner 2012). But if the goal was to create contrast among pastures, variable stocking rates in a group of pastures could be applied to work towards that goal (Gillen et al. 2000, Lwiwski et al. 2015, Sliwinski and Koper 2015). However, recent research suggests that, especially in wet years, even very heavy grazing is not capable of providing the types of habitat needed by certain bird species (Augustine and Derner 2012).

Individual vegetation structure and songbird responses

The individual vegetation structure variables, such as VOR, heterogeneity of VOR, and litter cover responded as expected to stocking rates. However, bare ground decreased and grass cover increased with increasing stocking rates. Although I did not collect information on species composition, this could be due to a change in species to more shortgrass species, like hairy and blue grama (*Bouteloua hirsute* and *B. gracilis*, respectively), which have greater canopy cover. Additionally, variability of litter depth and variability of litter cover decreased at moderate stocking rates but were highest at low stocking rates. Although these patterns were statistically significant, the strength of the responses was weak. That variability in litter cover was lowest on season-long, continuous systems may seem counter-intuitive at first, because this strategy is typically thought to create the most heterogeneity, because it allows for uneven grazing distribution (Bailey et al. 1996). However, there was contrast among pastures, and thus higher heterogeneity, within a management unit because some pastures were grazed and some were not yet grazed at the time of sampling in May.

The response of shrub cover to grazing strategies in my study agrees with some studies, but disagrees with others: a study in Oregon showed increased shrub density in a management intensive grazing strategy compared to continuous grazing (Angell 1997), but other studies showed no response to grazing strategy (Hart et al. 1988, Towne et al. 2005, Vermeire et al. 2008, Stephenson 2010). The fact that higher shrub cover was found in both a fixed rotation strategy, in which pastures were grazed at the same time each year at a fairly low stocking rate, and a management intensive strategy with rotating seasons of use and higher stocking rate, leads me to conclude that pre-existing conditions are more likely to explain higher shrub cover than the grazing strategies. The response of field sparrows to grazing strategies was most likely driven by the higher shrub cover in both management intensive and fixed-rotation grazing strategies, a habitat feature preferred by field sparrows (Best 1979).

Although many vegetation structure variables responded to season of use, there were no clear patterns in this response. Controlling season of use has important impacts on vegetation composition and structure and is often a reason that grazing strategies have been implemented (Reece et al. 1999, Vermeire et al. 2008). Season of use may also create contrast between two pastures where one is grazed and another is not grazed (Krausman et al. 2009). Although many of the vegetation structure variables responded to season of use, none of the birds did, which likely indicates that the vegetation structure responses to season of use are not strong enough to impact bird abundance. Koper and Schmiegelow (2006) concluded that season of use was unimportant in management for birds in northern mixed-grass prairie, and Vermiere et al. (2008) reported that vegetation variables were most responsive to precipitation, with stocking rate and season of use being of less importance.

Songbirds responded as expected to various habitat features. Although many previous studies assessed the relationship of birds to vegetation structure variables only at the level of the sampling plot (e.g., Davis et al. 2014, Sliwinski and Koper 2015), four of six focal songbirds in my study responded to vegetation structure measures primarily at the management unit scale, which covered approximately 170 ha (24 plots × 7 ha per plot). This result concurs with the recent recommendations for managing grassland bird habitat at larger scales (Walk and Warner 2000, Lipsey 2015, Greer et al. 2016). Further, although heterogeneity was the focus of this study, my results support the suggestion that songbirds do not necessarily respond to heterogeneity itself, but rather other habitat features (Wiens 1974). Western meadowlarks did not respond to any vegetation structure variables, a result that is consistent with at least one study (Henderson and Davis 2014), and is likely a result of their generalist habitat preferences (Davis and Lanyon 2008).

There was a mixture of management variables that songbirds responded to: some songbird species responded to stocking rates, some to the disturbance intensity, and some to neither, indicating that no single management characteristic can explain the abundance of many different songbird species. Ownership type (public or private) was a relatively unimportant explanatory variable, although this variable did best explain the heterogeneity of standing dead vegetation cover, litter depth, and grasshopper sparrow abundance. The difference in management between public management units and private management units is mainly one of flexibility and stocking rates. Public land stocking rates in my study area tended to be much lower than on privately managed land. Because of the lower stocking rates, cattle may be more selective even in small pastures on public land than on private land, which may explain the greater variability in standing dead vegetation and litter depth. Higher abundance of grasshopper sparrows may also be a reflection of lower stocking rates assuming more residual vegetation is available on public land.

Regional heterogeneity

The mean VOR I measured was similar to two other studies conducted in the Nebraska Sandhills (Kempema 2007, Anderson et al. 2015), where mean VOR across sites was 4 cm and 5 cm, respectively. These means were all much lower than the VOR from one other study done in the Nebraska Sandhills at Valentine National Wildlife Refuge (USGS 2013; mean VOR = 16 cm). Litter depth measurements varied across these studies, but mine was the highest by three times; these differences could be due to different sampling procedures. These differences highlight the need for region-specific recommendations related to vegetation structure management for bird species. For example, in tallgrass prairie, grasshopper sparrows tend to prefer heavily grazed areas (Ahlering and Merkord 2016), whereas in mixed- and short-grass prairie, they tend to prefer lightly grazed areas (Kantrud and Kologiski 1983), making management recommendations region specific, even if the resulting vegetation structure is similar.

Limitations

My study was designed to examine a wide variety of grazing strategies across a landscape in the Nebraska Sandhills, and whether they contributed to increased heterogeneity of vegetation structure across the landscape. In ecological studies it is desirable to have replication or before-after-control-impact designs to ensure that the results are not spurious (Underwood 1994). In controlled experiments it is possible to do this, but typically only on a small scale. In assessing grazing strategies on private land, replication of treatments or measuring effects before and after treatments are nearly impossible because each landowner does things differently and manages adaptively each year (Briske et al. 2011). For this reason, I could not separate the effects of season of use, stocking rates, and grazing strategies; however, my vegetation analyses suggested that season of use was the variable of most consequence in influencing heterogeneity of vegetation structure. Although grazing strategies interacted with season of use, it seems clear that grazing strategies used in this study were not a strong influence on vegetation structure or bird abundance. These management strategies could be related to bird communities and heterogeneity of vegetation structure (Chapter 3).

Grazing strategies do not create heterogeneity automatically

The level of compositional and structural heterogeneity of rangelands may be dependent on the type of grazing strategy used by the land manager (Kempema 2007, Toombs et al. 2010, Ranellucci et al. 2012, Norton et al. 2013). However, my results agree with Briske et al. (2008), Vermeire et al. (2008), Stephenson et al. (2013), and Davis et al. (2014), who found few differences among grazing strategies in terms of vegetation composition and structure, or bird abundance. Adler et al. (2001), Toombs et al. (2010), and Fuhlendorf et al. (2012) have even suggested that grazing strategies used by private landowners results in habitat homogeneity. Grazing strategies used by private producers commonly have a goal of optimizing livestock production (Vallentine 2001, Sliwinski 2017 Chapter 4) and this is done by ensuring that the forage resource is used efficiently through even grazing distribution (Norton et al. 2013), thus resulting in fairly consistent vegetation structure and composition through time and space (With et al. 2008). It is possible that the concept of management strategies creating heterogeneity has been transplanted from the forest management field in which various management strategies create vastly different types of vegetation structure (e.g., a clear cut versus a selective cutting program; Lindenmayer et al. 2008), and there is some cross-over of management professionals dealing with forests and rangelands. In rangelands, however, there is a limited range of disturbance (i.e., stocking rates maintained within a narrow range) that is employed by land managers, which restricts the resulting changes in vegetation structure and composition to a narrow range.

Although rangeland ecologists posit heterogeneity as the goal of management for conservation, the concept is scale-dependent and recommendations for increasing heterogeneity are not always sufficient. For example, Toombs et al. (2010) recommended decreasing stocking rates on ranches with high stocking rates as a first step in increasing heterogeneity. However, this action should only be undertaken when a full evaluation of landscape context is complete, since high stocking rates may be beneficial to some species (Sliwinski and Koper 2015, Ahlering and Merkord 2016). I suggest that individual pastures that are relatively small (<320 ha) should not typically be managed for the spectrum of habitats possible in a rangeland landscape. Rather, pastures should be placed in the context of a landscape and managed to create contrast among pastures. Larger pastures (thousands of acres) could be managed for the spectrum of habitats by using patch-burn grazing to facilitate cattle movement (Scasta et al. 2015). Such a strategy considers the evidence provided in my study that traditional strategies used by managers do not provide enough variation in disturbance to affect breeding avian species.

MANAGEMENT IMPLICATIONS

Stocking rate, season of use, and the disturbance intensity variable (combination of management intensity and stocking rate) were the pasture-level variables most often related to vegetation structure and songbird abundance. Grazing strategy, which is a multi-pasture management framework, was unimportant to most vegetation structure variables and songbirds in the Nebraska Sandhills. This conclusion highlights the need for state and federal agencies and NGOs to question the assumption that a variety of grazing strategies on a landscape will inevitably result in a variety of habitats (G. Wright, Forest Service, personal communication; Audubon's Bird Friendly Beef program (Audubon Society 2016)). All grazing strategies maintain a narrow range of disturbance and by definition do not aim to pass thresholds. Even when the timing and duration of the grazing disturbance may vary, the potential for a variety of habitats to be created is limited. My results further highlight the need to consider private-lands management as a coordinated effort among many pastures, because the pasture is the unit that is most effectively manipulated for habitat through grazing management. Vegetation structure within a pasture can be modified by varying stocking rates, season of use, and grazing distribution (Krausman et al. 2009, Sliwinski and Koper 2015). Although pasture is the appropriate unit for grazing manipulation to create habitat for a variety of wildlife habitats, any management within a pasture should be placed within the context of the surrounding landscape, to ensure that the habitat requirements of many different bird species are met across a landscape, rather than inadvertently creating similar habitat across pastures (Samson et al. 2004, Krausman et al. 2009, Toombs et al. 2010, Freese et al. 2014). Further, grazing alone can only achieve a limited level of heterogeneity. If heterogeneity is the goal, then different management strategies, such as patch-burn grazing, may be required to provide disturbance beyond that provided by traditional grazing strategies used by managers and beef producers.

Table 1. Number of ecological sites on each management unit sampled in the Nebraska Sandhills, averaged across sampling occasions in May of 2014 and 2015.

Management Unit	Blowouts	Choppy Sands	Sands	Sandy
1	0.0	12.0	166.5	13.0
2	4.5	8.0	117.0	61.5
3	7.5	56.0	127.0	1.5
4	2.0	38.5	142.5	5.0
5	0.0	19.5	162.5	10.0
6	2.0	10.0	165.0	15.0
7	0.0	8.5	166.0	14.5
8	1.5	24.5	162.0	2.0
9	0.0	16.0	175.5	0.0
10	0.0	9.0	169.0	14.0
11	1.0	53.5	129.0	8.5

Table 2. Ownership, grazing strategy, pastures and area sampled (ha), and mean stocking rates (AUM·ha^{-1}) across all pastures sampled for each management unit during three seasons (cool, warm, dormant), and average total stocking rate for each prior year, Nebraska Sandhills, 2014-2015.

Unit	Owner	Strategy	Pastures in strategy	Pastures sampled	Area of pastures	2013 Cool	2013 Warm	2013-14 Dormant	2014 Cool	2014 Warm	2014-15 Dormant	2013 Total	2014 Total
1	Private	Dormant	3	2	393	0.61	0.00	0.45	0.80	0.00	0.60	1.06	1.40
2	Private	C	3	2	671	0.05	0.72	0.00	0.03	0.59	0.00	0.76	0.62
3	Private	DR	3	2	467	0.00	0.78	0.36	0.00	0.71	0.00	1.14	0.71
4	Private	MIG	20	4	633	0.32	0.75	0.68	0.36	0.80	0.68	1.74	1.84
5	Private	Rotation	10	2	448	0.00	0.86	0.00	0.00	1.22	0.00	0.86	1.22
6	Public	C	1	1	656	0.00	0.31	0.00	0.00	0.43	0.00	0.31	0.43
7	Public	DR	5	2	1556	0.00	0.65	0.00	0.00	0.52	0.03	0.65	0.56
8	Public	DR	5	2	1296	0.16	0.26	0.38	0.16	0.27	0.30	0.81	0.73
9	Public	MIG	8	3	1150	0.06	0.12	0.00	0.02	0.30	0.00	0.18	0.32
10	Public	DR	8	3	1019	0.03	0.30	0.00	0.04	0.32	0.12	0.33	0.48
11	Private	DR	5	3	369	0.00	0.73	0.68	0.40	0.78	0.00	1.41	1.17

Table 3. Vegetation structure measures across eleven sites in the Nebraska Sandhills, 2014-2015. Values represent means and standard deviations across 2112 sample frames.

	2014		2015	
	Mean	SD	Mean	SD
Mean visual obstruction reading (cm)	4.87	5.60	3.87	5.42
Litter depth (cm)	3.31	3.53	2.26	2.42
Litter cover (%)	25.91	20.40	34.58	28.36
Standing dead vegetation cover (%)	11.94	11.60	13.12	14.48
Grass cover (%)	22.76	19.60	22.60	19.42
Bare ground (%)	38.81	27.45	56.80	27.90
Shrub cover (%)	6.46	12.83	3.74	9.34

Table 4. Heterogeneity of vegetation structure measures across eleven sites in the Nebraska Sandhills, 2014-2015. Values shown are the standard deviations averaged across 264 plots plus their standard deviations.

	2014		2015	
	Mean	SD	Mean	SD
Mean visual obstruction reading (cm)	3.68	3.45	3.50	3.79
Litter depth (cm)	2.75	1.72	1.90	1.14
Litter cover (%)	16.40	7.32	19.91	7.80
Standing dead vegetation cover (%)	8.59	5.44	11.06	6.25
Grass cover (%)	14.09	7.77	16.12	6.71
Bare ground (%)	19.83	7.77	24.46	6.78

Table 5. Parameter estimates of fixed effects (β) and distribution of variance (σ^2) for random effects for the top models for five vegetation structure variables that responded to stocking rates and season of use in the Nebraska Sandhills, 2014-2015. An asterisk (*) indicates that the 85% confidence intervals do not overlap zero.

	Visual obstruction reading		**Litter depth**		**Litter cover**		**Bare ground**		**Live grass cover**	
Random effects	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**
Plot	1.00	1.00	0.35	0.59	60.53	7.78	105.43	10.27	36.07	6.01
Pasture	2.11	1.45	0.45	0.67	68.21	8.26	50.26	7.09	16.07	4.01
Management unit	0.78	0.89	0.59	0.76	65.45	8.09	22.41	4.73	18.48	4.30
Year	0.38	0.62	0.38	0.61	23.51	4.85	92.94	9.64	0.17	0.41
Residual	26.66	5.16	8.17	2.86	478.70	21.88	593.47	24.36	302.87	17.40
Fixed effects	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**
Intercept	3.68*	0.95	3.25*	0.63	42.43*	5.62	47.25*	7.98	19.59*	2.97
Stocking rate (AUM·ha^{-1})	-0.84*	0.42			-4.44*	1.95	-4.47*	2.04	3.66*	1.42
Season: Cool + Dorm	2.53*	1.02	2.29*	0.57	-1.69	4.64	-13.98*	4.90	4.06	3.46
Season: Cool + Warm	2.84*	0.90	0.41	0.49	-2.16	4.07	-5.10	4.35	3.72	3.01
Season: Cool + Warm + Dormant	1.98*	0.97	-1.77*	0.53	-28.89*	4.39	9.38*	4.68	-5.24*	3.30
Season: Dormant	0.17	0.88	-1.16*	0.48	-2.41	3.79	18.12*	4.16	-4.75*	2.94
Season: Warm	1.14*	0.67	-0.80*	0.37	-7.14*	2.88	6.85*	3.17	1.20	2.24
Season: Warm + Dormant	0.12	0.79	-1.28*	0.42	-9.08*	3.44	12.29*	3.78	-9.11*	2.66

Table 6. Parameter estimates of fixed effects (β) and distribution of variance (σ^2) for random effects for the top models for two vegetation structure variables measured in the Nebraska Sandhills, 2014-2015. An asterisk (*) indicates that the 85% confidence intervals do not overlap zero.

	Standing dead vegetation cover		**Shrub cover**	
Random effects	**σ^2**	**SD**	**σ^2**	**SD**
Plot	12.52	3.54	6.77	2.60
Pasture	11.35	3.37	3.13	1.77
Management unit	0.00	0.00	0.00	0.00
Year	0.31	0.56	1.88	1.37
Residual	144.35	12.01	6.77	2.60
Fixed effects	**β**	**SE**	**β**	**SE**
Intercept	10.08*	1.98	5.22*	1.55
Stocking rate (AUM·ha^{-1})			-2.18*	0.59
High SR, Low MI	1.16	2.62		
High SR, Moderate MI	4.40*	2.30		
Low SR, High MI	7.09*	2.47		
Low SR, Low MI	-0.18	2.56		
Low SR, Moderate MI	0.52	2.26		
Strategy: dormant-season only			-0.90	1.91
Strategy: Deferred rotation			0.66	1.32
Strategy: Management-intensive			5.73*	1.48
Strategy: Fixed rotation			4.95*	1.89

Table 7. Parameter estimates of fixed effects (β) and distribution of variance (σ^2) for random effects for the top models for heterogeneity (SD) in five vegetation structure variables measure in the Nebraska Sandhills, 2014-2015. *Stocking rate in these models is for the previous warm season. An asterisk (*) indicates that the 85% confidence intervals do not overlap zero.

	SD VOR*		**SD Litter cover**		**SD Bare ground**		**SD Live grass cover**		**SD Shrub cover**	
Random effects	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**
Pasture	1.78	1.33	2.01	1.42	1.25	1.12	3.76	1.94	2.73	1.65
Management unit	0.29	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Year	0.00	0.00	3.76	1.94	5.67	2.38	0.99	1.00	2.09	1.44
Residual	11.00	3.32	49.96	7.07	50.50	7.11	41.77	6.46	41.32	6.43
Fixed effects	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**
Intercept	3.66*	0.34	14.76*	1.78	20.06*	2.64	17.08*	1.49	5.97*	1.57
Stocking rate ($AUM \cdot ha^{-1}$)	-0.56	5.65	-39.95*	9.32					-27.16*	9.23
(quadratic) Stocking rate	-20.29*	5.45	37.87*	9.81					-8.44	9.53
Strategy: Dormant			7.92*	1.94			-0.08	2.13	-2.60	2.02
Strategy: Deferred rotation			3.28*	1.29			-4.61*	1.49	0.23	1.35
Strategy: Management intensity			2.74*	1.49			-0.84	1.64	6.15*	1.54
Strategy: Fixed rotation			7.47*	1.91			3.55*	2.12	6.84*	1.98
Season: Cool + Dormant					2.52	2.36				
Season: Cool + Warm					1.63	2.30				
Season: Cool + Warm + Dormant					1.22	2.33				
Season: Dormant					1.40	2.64				
Season: Warm					1.77	2.09				
Season: Warm + Dormant					6.06*	2.32				

Table 8. Parameter estimates of fixed effects (β) and distribution of variance (σ^2) for random effects for the top models for variability (SD) in litter depth and standing dead vegetation cover in the Nebraska Sandhills, 2014-2015. An asterisk (*) indicates that the 85% confidence intervals do not overlap zero.

	SD Litter depth		**SD Standing dead cover**	
Random effects	**σ^2**	**SD**	**σ^2**	**SD**
Pasture	0.06	0.25	1.87	1.37
Management unit	0.00	0.00	0.00	0.00
Year	0.17	0.42	1.48	1.22
Residual	2.01	1.42	31.58	5.62
Fixed effects	**β**	**SE**	**β**	**SE**
Intercept	2.13*	0.31	8.85*	0.99
Ownership: Public	0.43*	0.16	2.20*	0.74

Table 9. Parameter estimates (β) and standard errors (SE) for the response of five songbird species' abundance to vegetation structure measures. Abundance covariates are on the log-scale, and detection covariates are on the logit scale. Grasshopper sparrow, lark sparrow, and field sparrow responded to vegetation structure measures averaged across a given management unit, horned larks responded to the variability of vegetation structure measures across a management unit, and dickcissels responded to vegetation structure means within a single plot. Western meadowlarks did not respond to any vegetation structure variables. Bold text indicates that the 85% confidence intervals did not overlap zero.

	Grasshopper sparrow: unit means		Lark sparrow: unit means		Horned lark: unit variability		Dickcissel: plot means		Field sparrow: unit means	
Abundance covariates	β	SE	β	SE	β	SE	β	SE	β	SE
Intercept	**-3.99**	0.69	**3.90**	0.79	**3.25**	0.97	0.35	0.69	**2.34**	1.42
VOR	**-0.13**	0.05	**0.12**	0.07	**0.07**	0.05	**-0.08**	0.03	**0.14**	0.10
Grass height	**0.05**	0.01	-0.01	0.01	**-0.05**	0.02	0.01	0.01	**-0.05**	0.02
Litter depth	**0.11**	0.07	**-0.22**	0.11	0.09	0.11	**-0.07**	0.05	**0.30**	0.19
Shrub height	0.01	0.01	-0.01	0.02	**-0.10**	0.02	**0.02**	0.01	**0.12**	0.03
Litter cover	-0.01	0.01	-0.01	0.01	**-0.03**	0.01	**-0.01**	0.01	0.00	0.02
Standing dead vegetation	**0.08**	0.02	**-0.05**	0.02	**0.09**	0.02	**0.05**	0.01	-0.03	0.04
Grass cover	**0.03**	0.01	**-0.03**	0.01	0.00	0.01	**0.03**	0.01	**-0.07**	0.02
Bare ground	**0.02**	0.01	-0.01	0.01	-0.04	0.03	**-0.02**	0.01	**-0.03**	0.02
Shrub cover	0.03	0.03	-0.05	0.04	0.03	0.03	**0.06**	0.02	**0.01**	0.04
Detection covariates	β	SE	β	SE	β	SE	β	SE	β	SE
Intercept	**1.63**	0.66	**-2.78**	0.74	**2.20**	0.82	**-5.95**	1.09	**2.58**	1.26
Minutes after sunrise	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs1	0.09	0.13	**-0.59**	0.18	**-0.36**	0.18	**-1.20**	0.28	0.21	0.33
Obs2	0.51	0.37	**-0.68**	0.36	-0.01	0.43	-7.63	17.60	0.79	0.58
Obs3	**-0.41**	0.11	**-0.52**	0.13	**-0.46**	0.14	**-0.32**	0.14	**0.52**	0.21
Obs4	0.00	0.13	0.12	0.18	**0.81**	0.18	**-1.82**	0.34	-0.07	0.34
Obs5	**0.74**	0.12	**0.38**	0.12	**0.35**	0.12	**-0.44**	0.15	**1.16**	0.20
Julian day	**-0.01**	0.00	**0.01**	0.00	**-0.02**	0.00	**0.03**	0.01	**-0.03**	0.01
Cloud cover (%)	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00

Table 10. Parameter estimates (β) and standard errors (SE) for the response of six songbird species' abundance to habitat management variables including stocking rates, management intensities, and grazing strategies. Abundance covariates are on the log-scale, and detection covariates are on the logit scale. Bold text indicates that the 85% confidence interval did not overlap zero. *ES = ecological site; **SR = stocking rate; ***MI = management intensity.

	Grasshopper sparrow		Western meadowlark		Lark sparrow		Horned lark		Dickcissel		Field sparrow	
Abundance covariates	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Intercept	**0.63**	0.05	**1.31**	0.10	**1.64**	**0.22**	**0.74**	0.17	**1.10**	0.38	-0.18	0.33
Total stocking rate											**-0.75**	0.15
Ownership	**0.67**	0.06										
Warm stocking rate			**0.29**	0.19								
Complex ES*					**-0.50**	**0.20**						
Sands ES					**-0.84**	**0.19**						
Sandy ES					**-1.37**	**0.32**						
High SR**, Low MI***							0.06	0.19	0.26	0.30		
High SR, Moderate MI							**-0.76**	0.20	**-1.13**	0.33		
Low SR, High MI							-0.17	0.18	**0.44**	0.26		
Low SR, Low MI							**0.37**	0.17	**-0.72**	0.29		
Low SR, Moderate MI							**0.32**	0.16	**-0.83**	0.27		
Dormant-season											-8.47	26.44
Deferred rotation											**0.98**	0.24
Management intensive											**1.64**	0.25
Fixed rotation											**1.24**	0.30
Detection covariates	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
Intercept	**1.80**	0.65	**6.20**	0.81	**-2.98**	0.73	**1.51**	0.82	**-6.63**	1.06	1.17	1.28
Minutes after sunrise	**0.00**	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Obs1	**0.23**	0.13	**-0.46**	0.12	**-0.80**	0.15	**-0.55**	0.16	**-1.71**	0.25	**-0.49**	0.26
Obs2	**0.66**	0.37	**-0.74**	0.30	**-0.83**	0.34	-0.38	0.40	-10.78	52.30	-0.20	0.45
Obs3	**-0.40**	0.11	**-0.33**	0.11	**-0.55**	0.14	**-0.46**	0.14	**-0.35**	0.15	**0.43**	0.21
Obs4	0.09	0.13	**1.43**	0.15	-0.06	0.14	**0.53**	0.15	**-2.23**	0.31	**-0.80**	0.28
Obs5	**0.77**	0.11	**-0.26**	0.10	**0.35**	0.12	**0.31**	0.13	**-0.55**	0.14	**0.98**	0.21
Julian day	**-0.01**	0.00	**-0.04**	0.00	**0.01**	0.00	**-0.01**	0.00	**0.03**	0.01	**-0.02**	0.01
Cloud cover (%)	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00

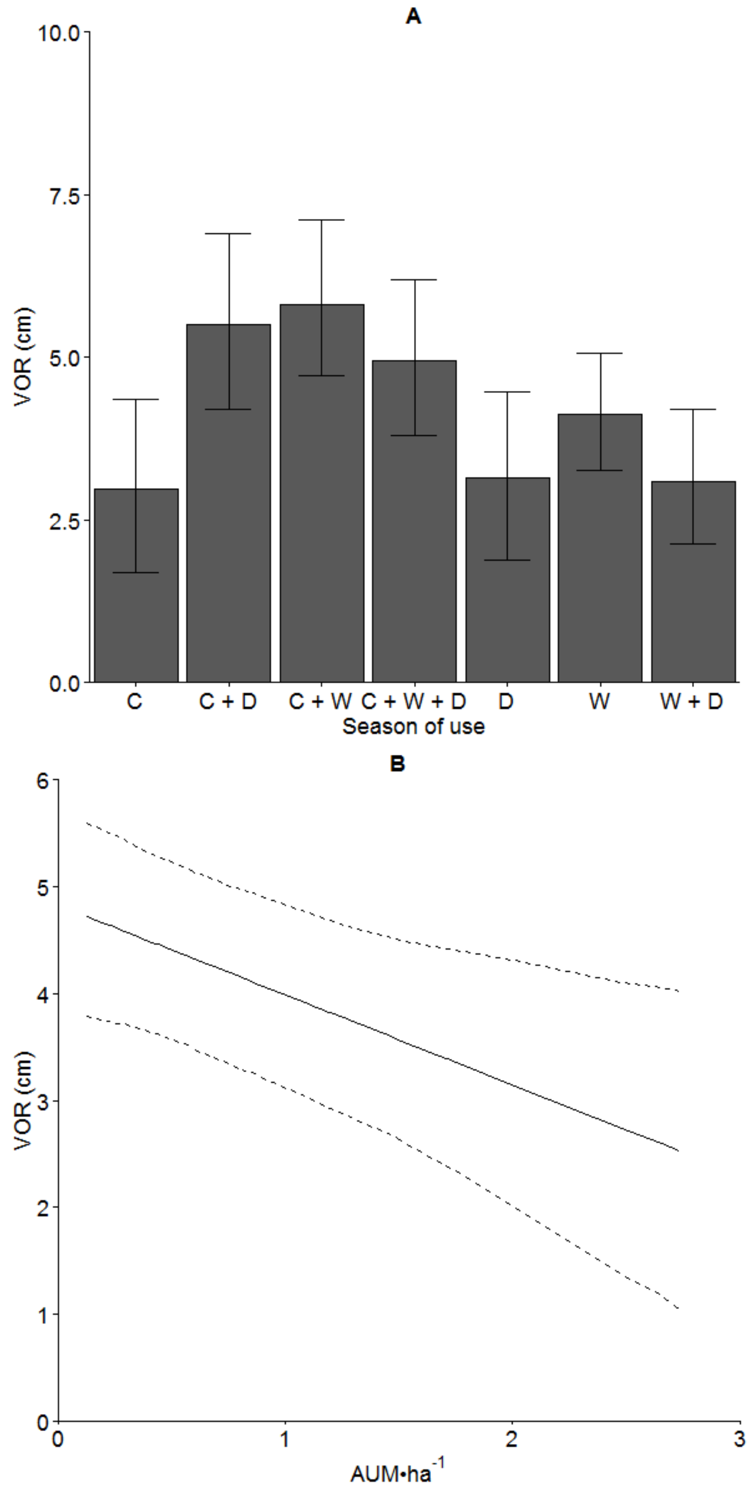

Figure 3. Response of visual obstruction reading (VOR) to season of use (A) and to stocking rates (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

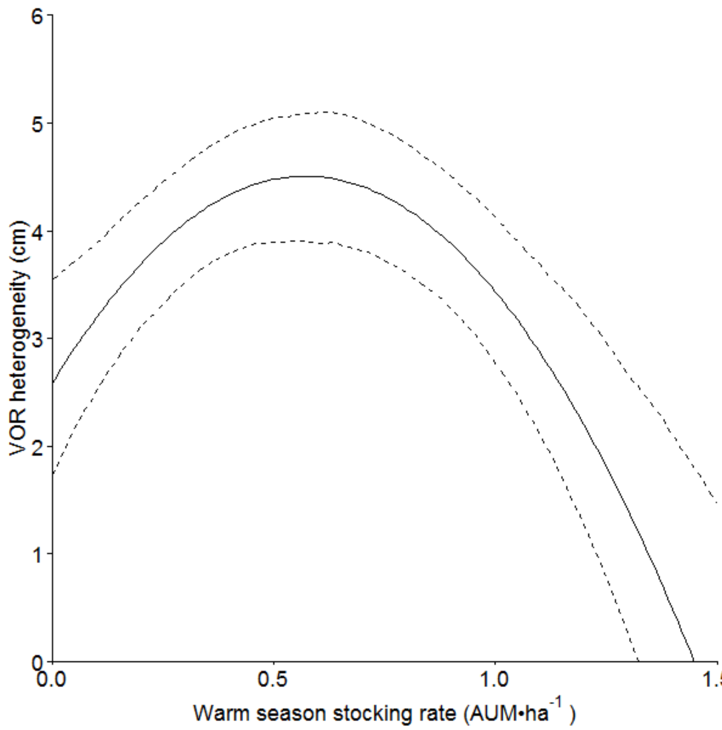

Figure 4. Response of VOR heterogeneity (SD) within each plot to warm-season stocking rate in the Nebraska Sandhills, 2014-2015.

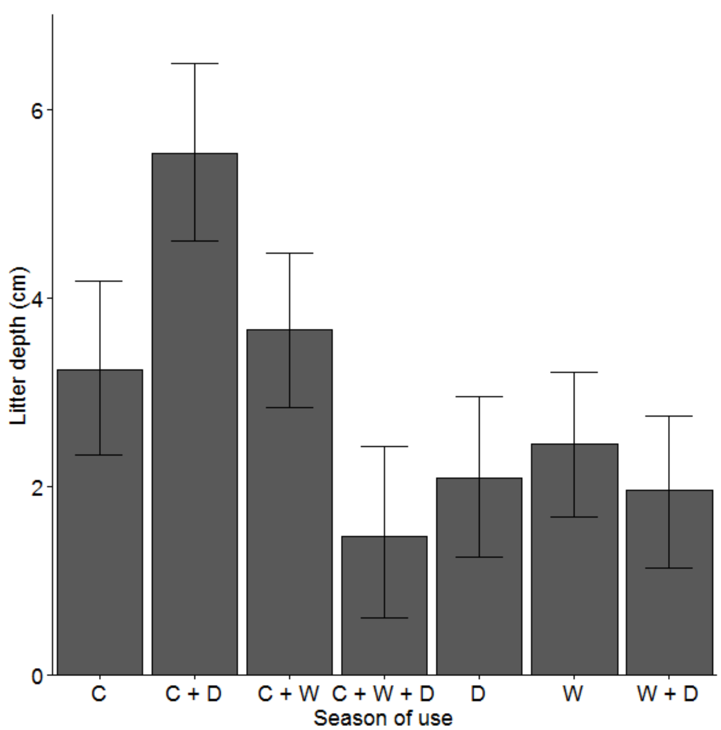

Figure 5. Relationship of litter depth (cm) to season of use in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

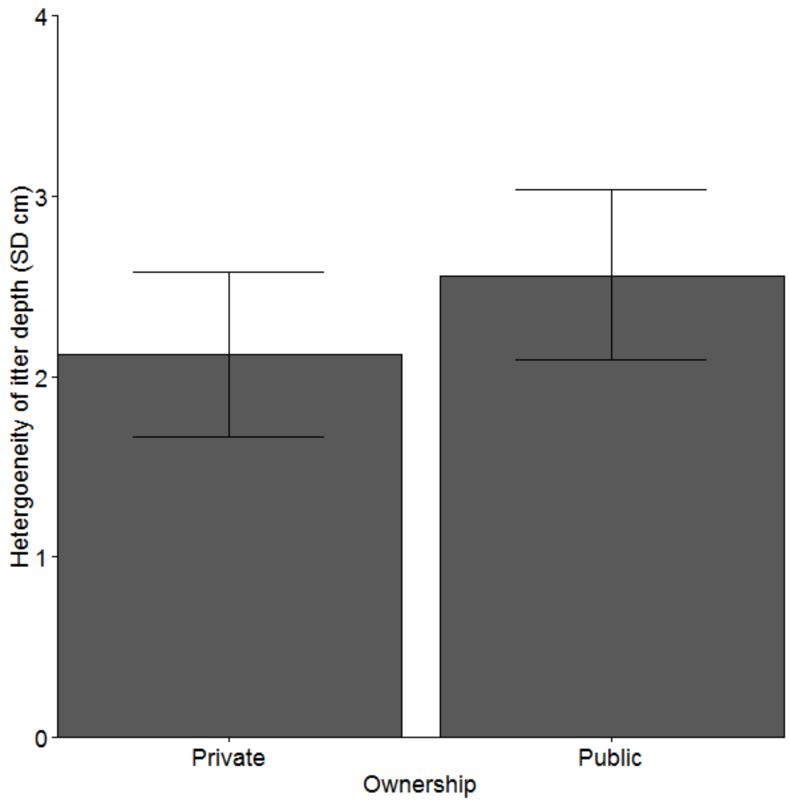

Figure 6. Relationship of heterogeneity in litter depth (SD) within each plot to ownership (public or private) in the Nebraska Sandhills, 2014-2015.

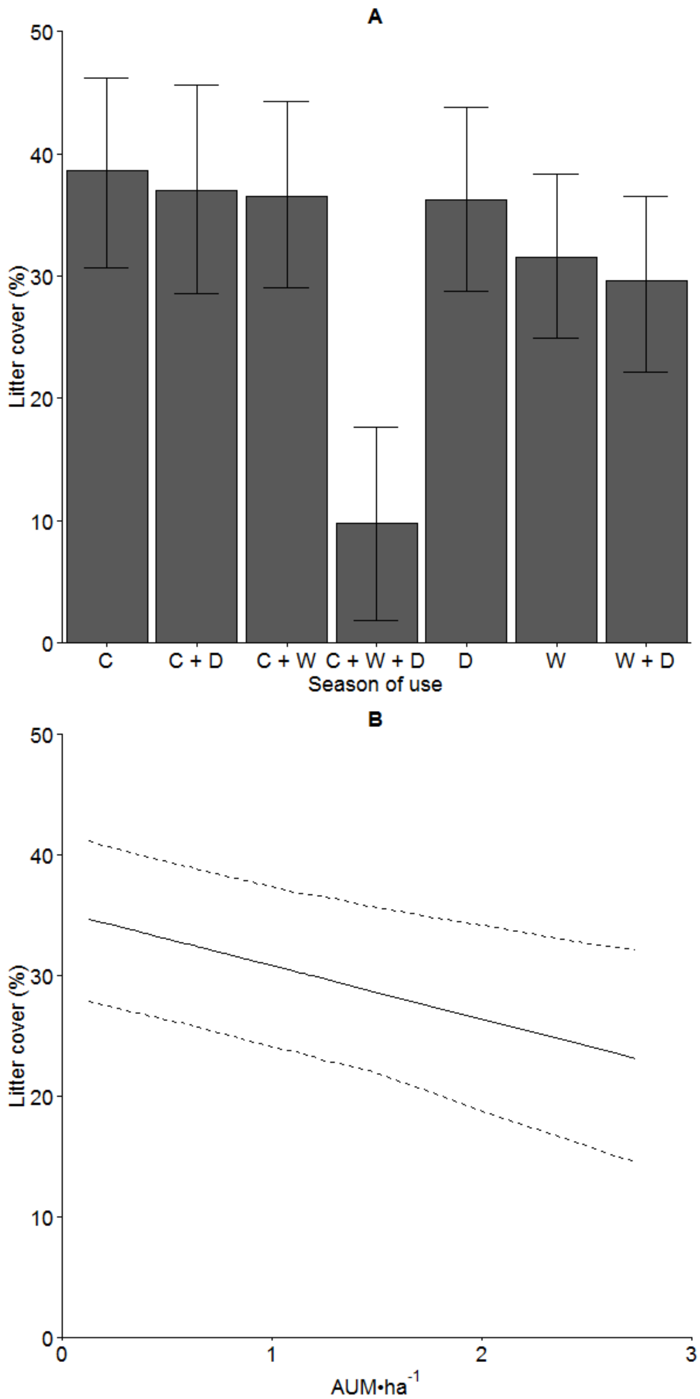

Figure 7. Relationship of litter cover (%) to season of use (A) and stocking rate (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

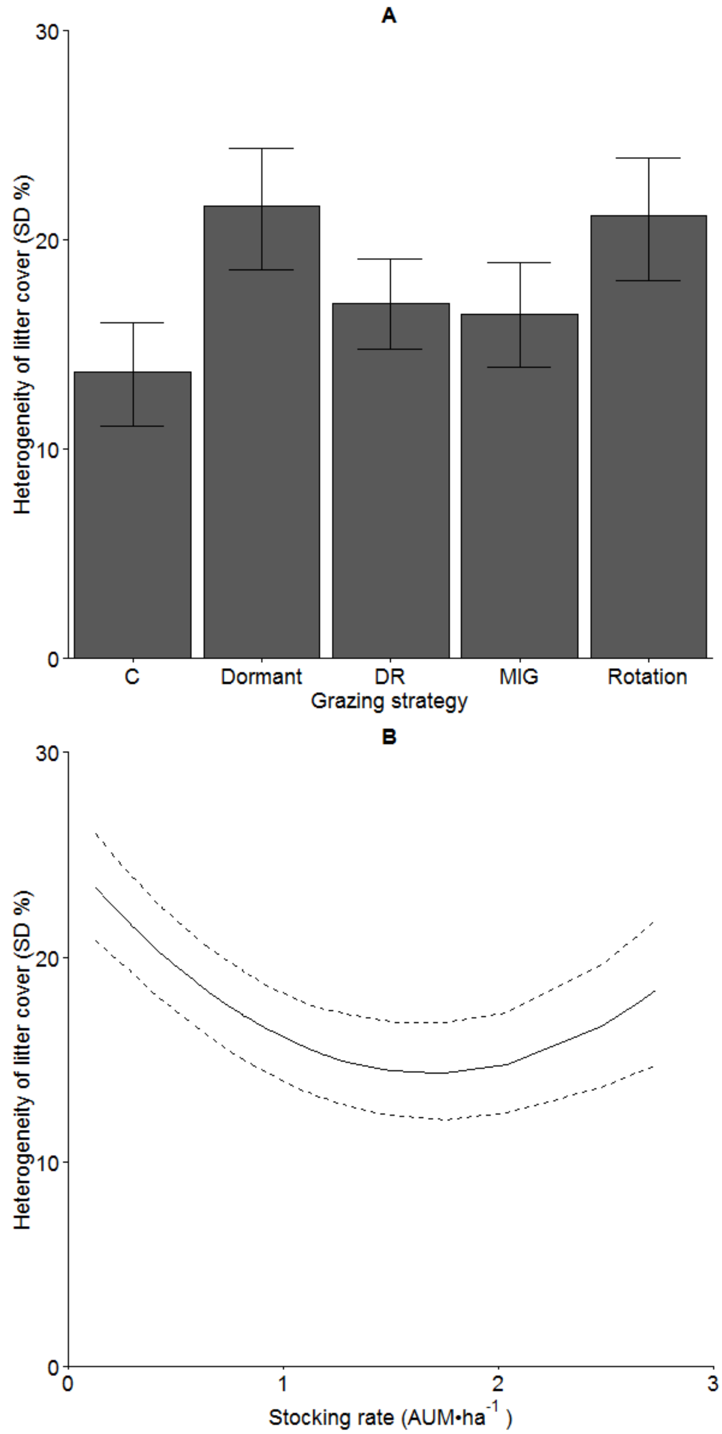

Figure 8. Relationship of heterogeneity of litter cover (SD) at the plot level to grazing strategy (A) and stocking rate (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = season-long, continuous; DR = deferred rotation; MIG = management intensive grazing.

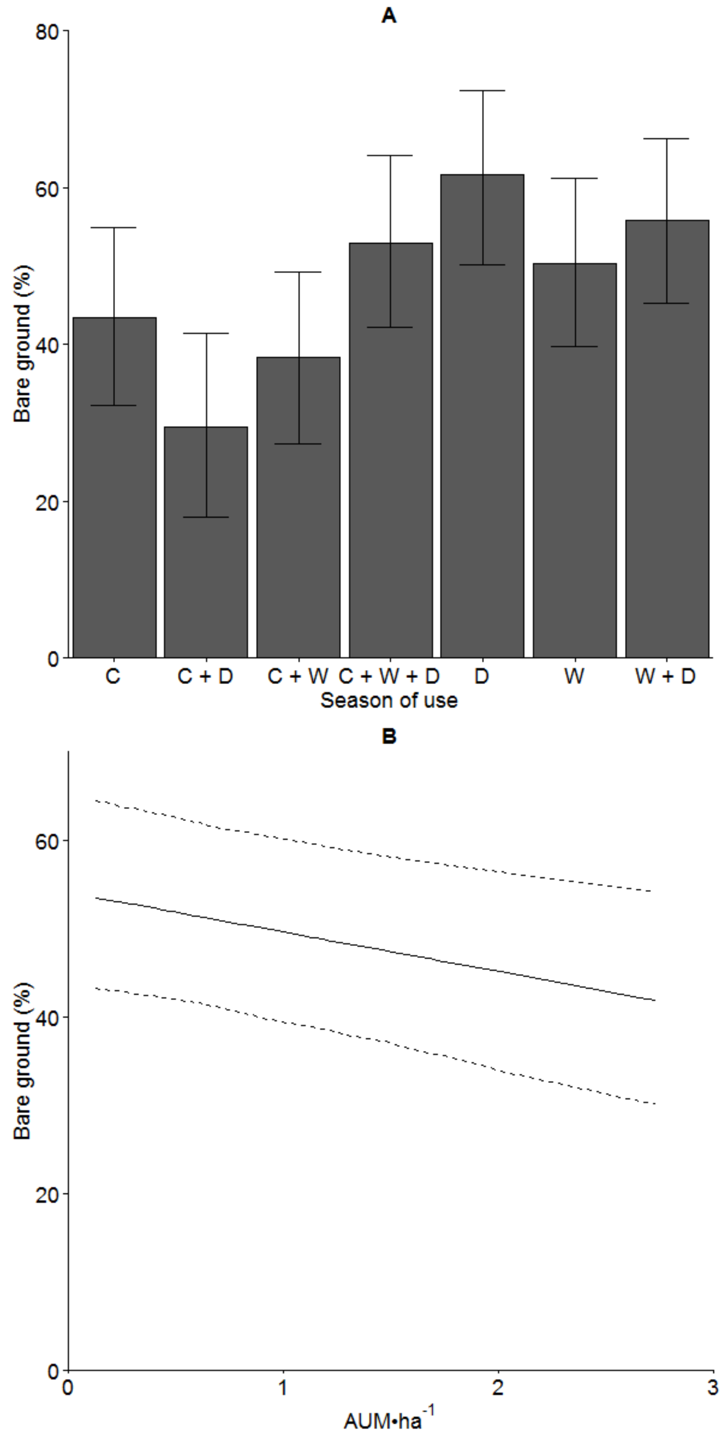

Figure 9. Relationship of bare ground to season of use (A) and stocking rate (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

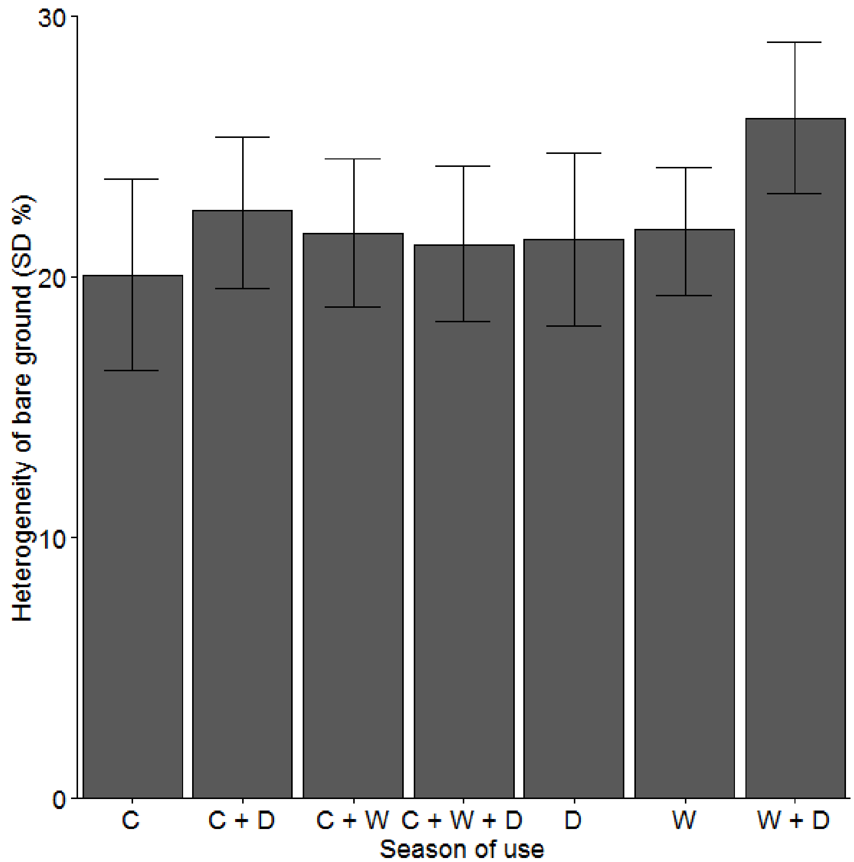

Figure 10. Relationship of heterogeneity of bare ground (SD) with season of use in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

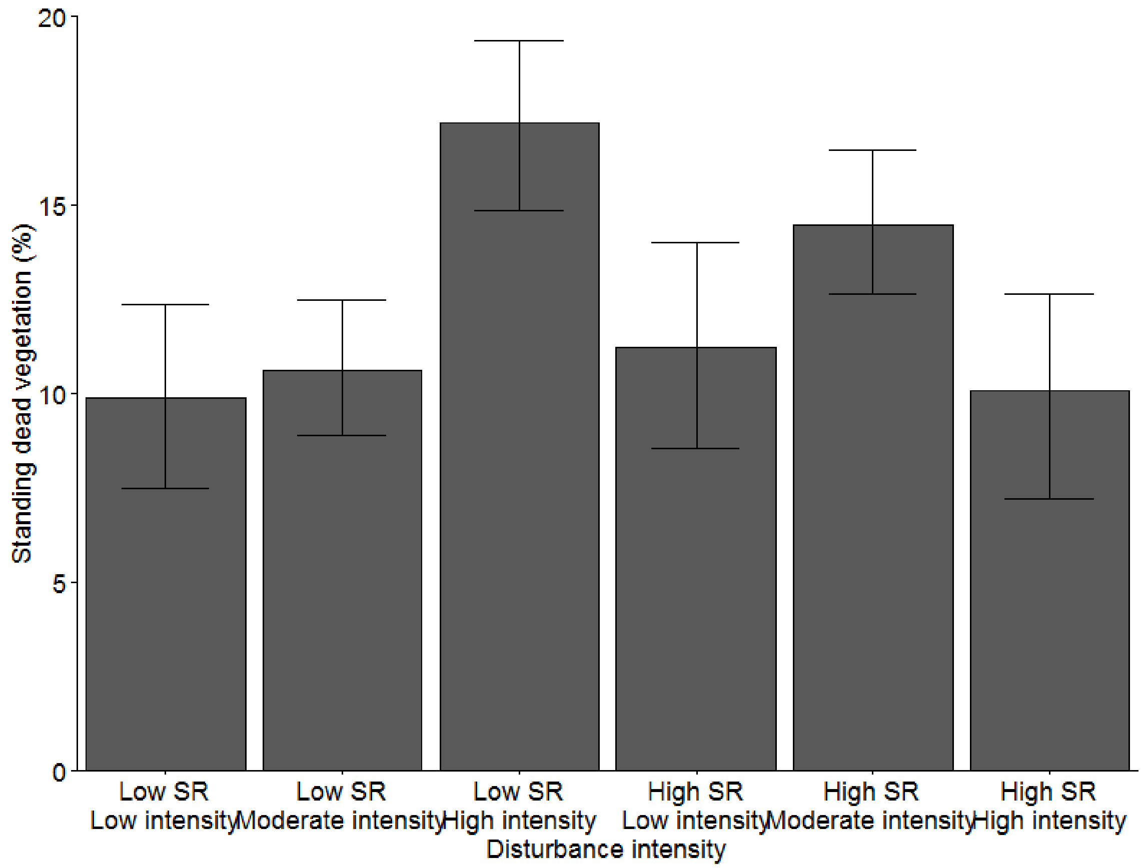

Figure 11. Relationship of standing dead vegetation cover (%) to disturbance intensity (i.e., categorical stocking rate + categorical management intensity) in the Nebraska Sandhills, 2014-2015. Abbreviation: SR = stocking rate.

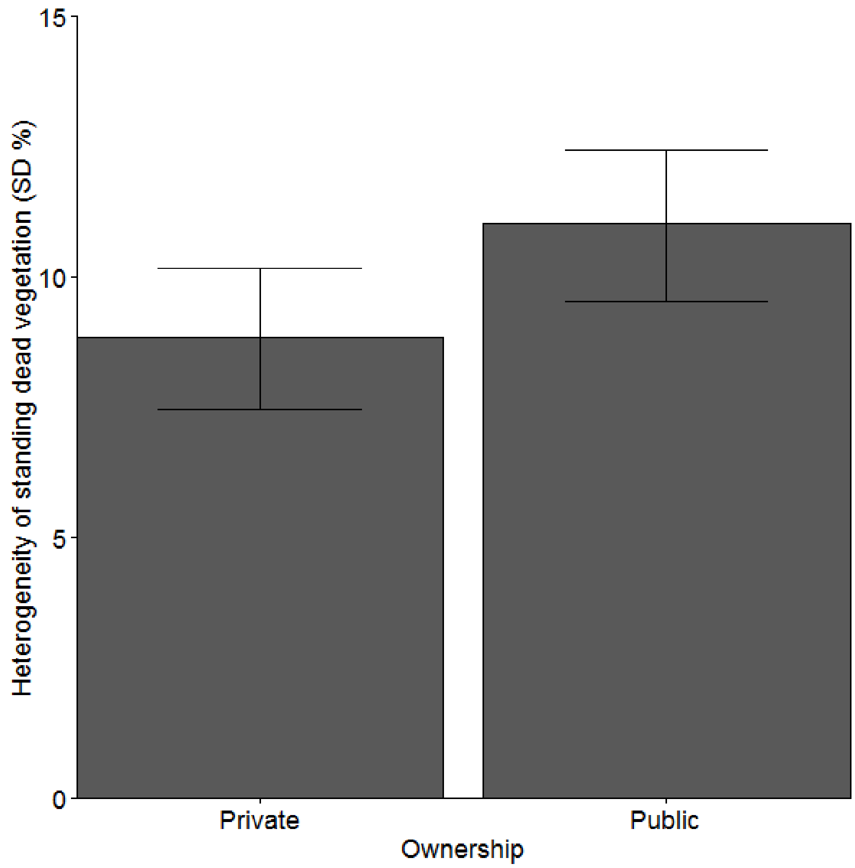

Figure 12. Relationship of heterogeneity of standing dead vegetation cover (SD) at the plot level to ownership (public or private) in the Nebraska Sandhills, 2014-2015.

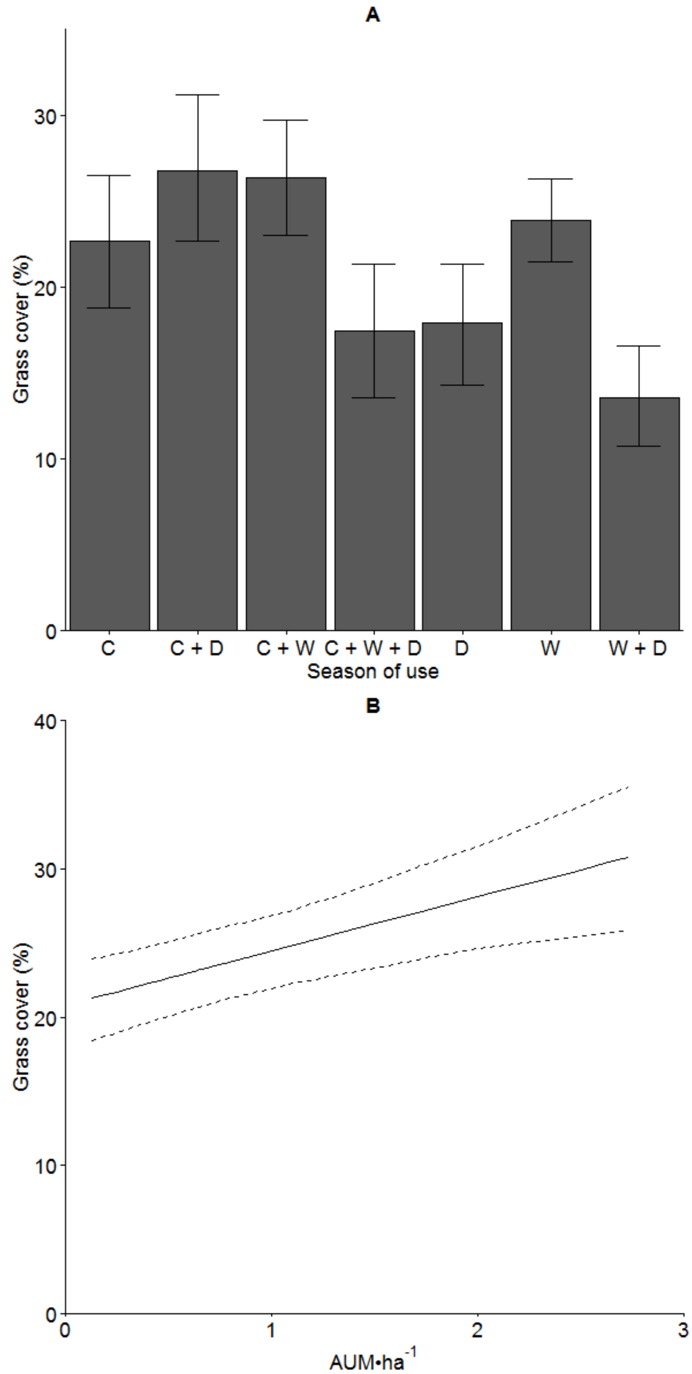

Figure 13. Relationship of grass cover (%) to season of use (A) and stocking rate (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = cool season, D = dormant season, W = warm season.

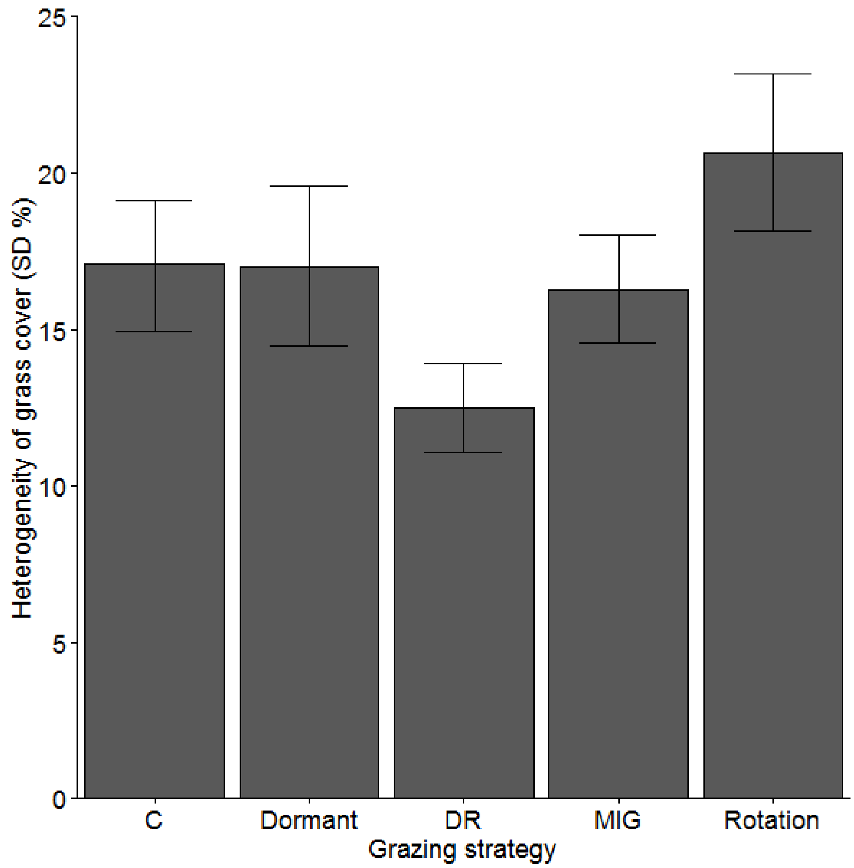

Figure 14. Relationship of heterogeneity of grass cover (SD) at the plot scale to grazing strategies in the Nebraska Sandhills, 2014-2015. Abbreviations: C = season-long, continuous; DR = deferred rotation; MIG = management intensive grazing.

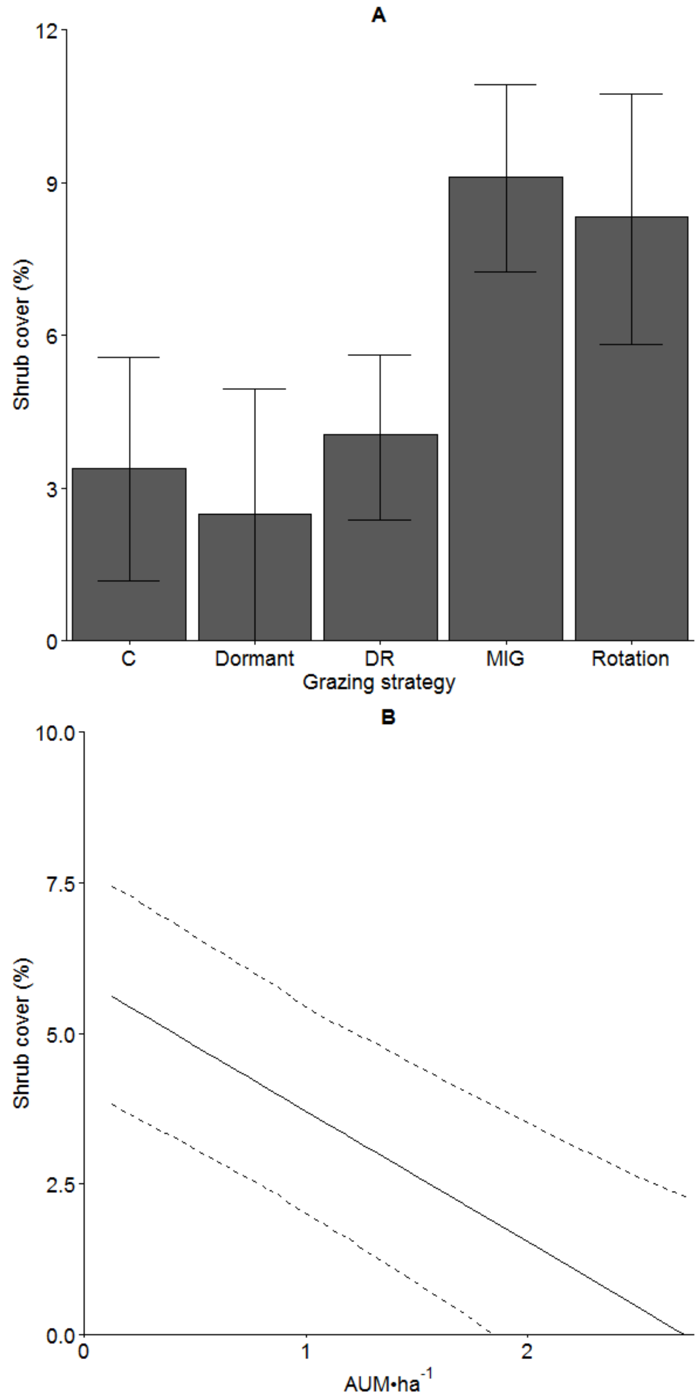

Figure 15. Relationship of shrub cover at the plot scale to grazing strategies (A) and stocking rates (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = season-long, continuous; DR = deferred rotation; MIG = management intensive grazing.

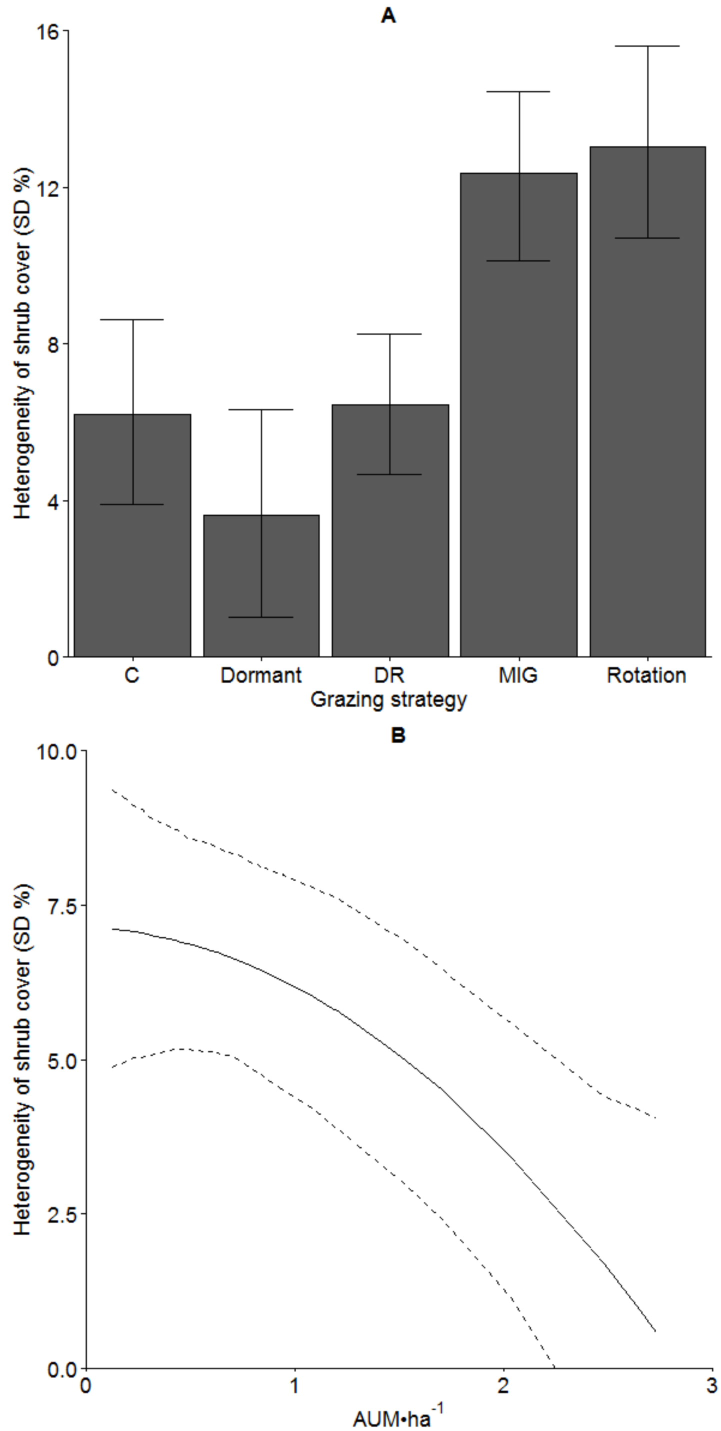

Figure 16. Relationship of heterogeneity of shrub cover (SD) at the plot scale to grazing strategies (A) and stocking rates (B) in the Nebraska Sandhills, 2014-2015. Abbreviations: C = season-long, continuous; DR = deferred rotation; MIG = management intensive grazing.

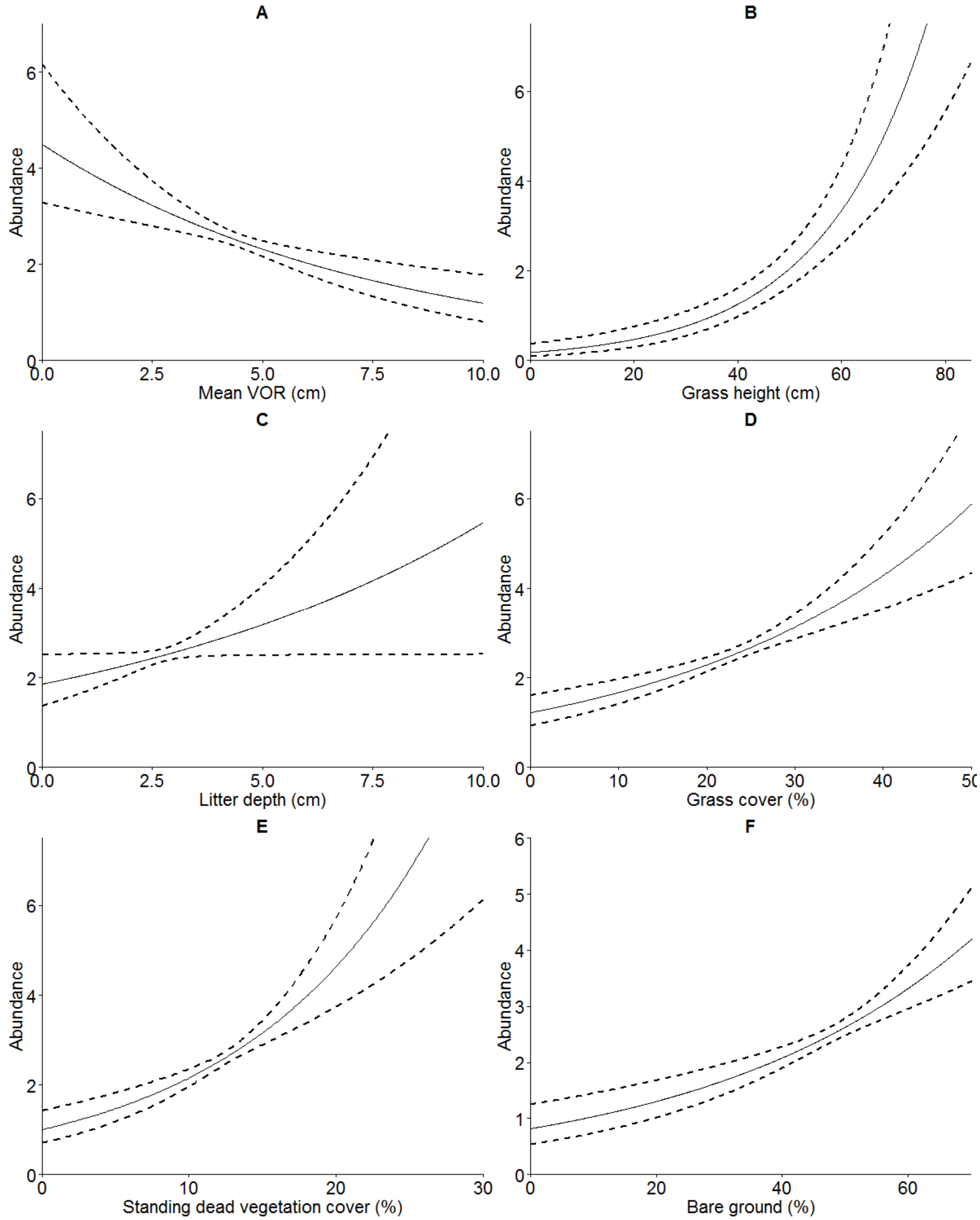

Figure 17. Response of grasshopper sparrow to VOR (A), grass height (B), litter depth (C), grass cover (D), standing dead vegetation cover (E), and bare ground (F) in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

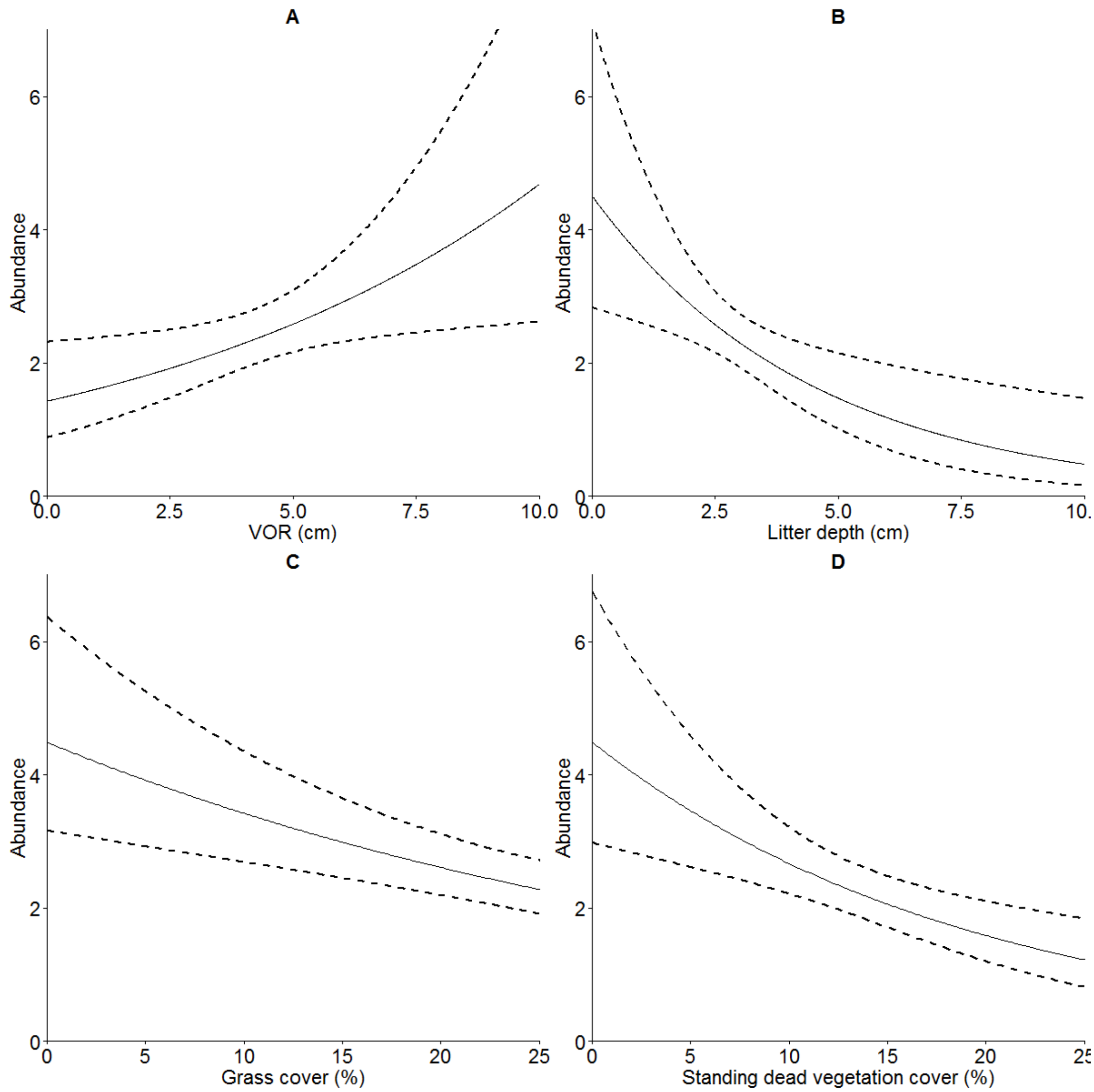

Figure 18. Lark sparrow response to VOR (A), litter depth (B), grass cover (C), and standing dead vegetation (D) at the management unit scale in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

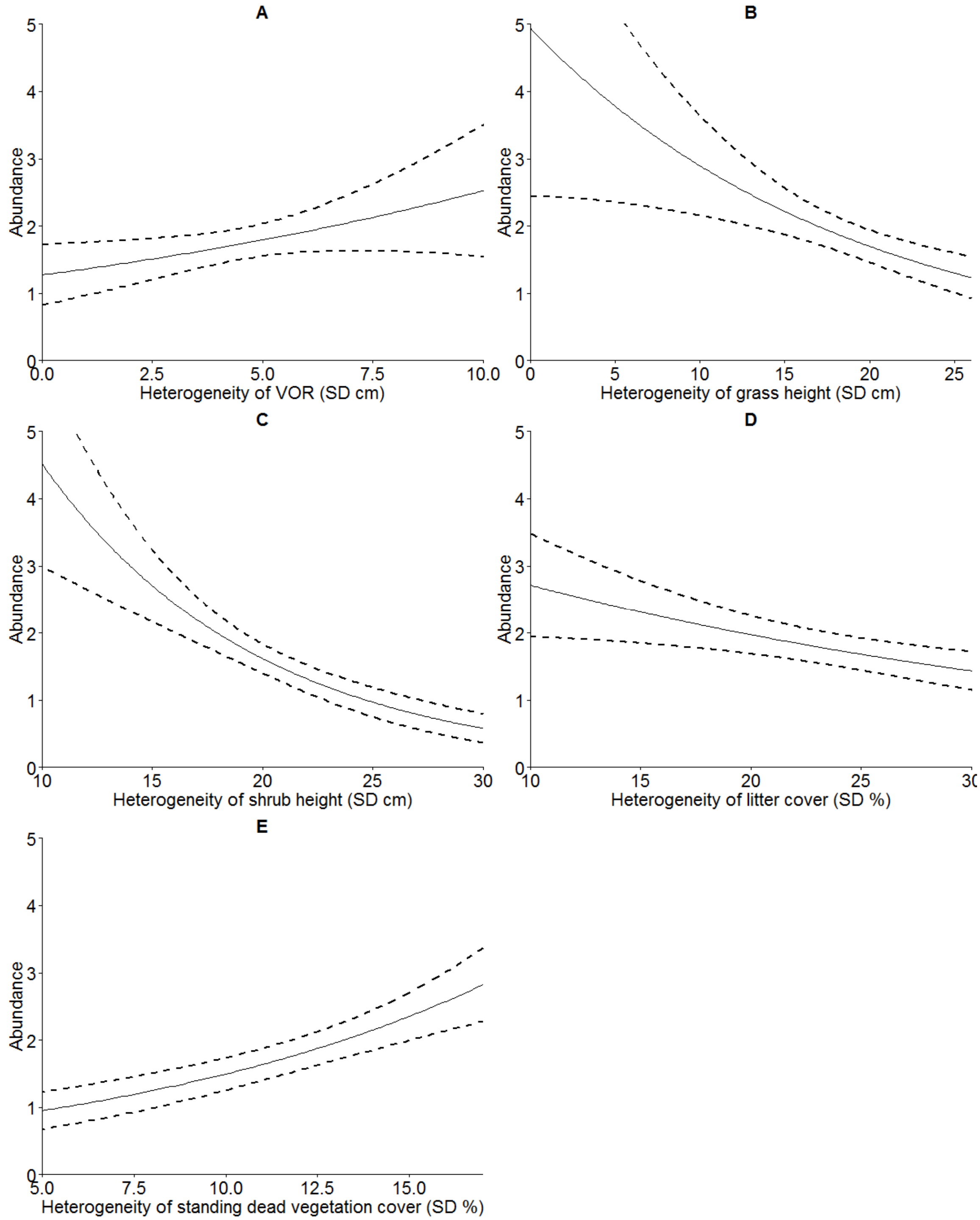

Figure 19. Response of horned lark abundance to heterogeneity of VOR (A), grass height (B), shrub height (C), litter cover (D), and standing dead vegetation (E) at the management unit scale in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

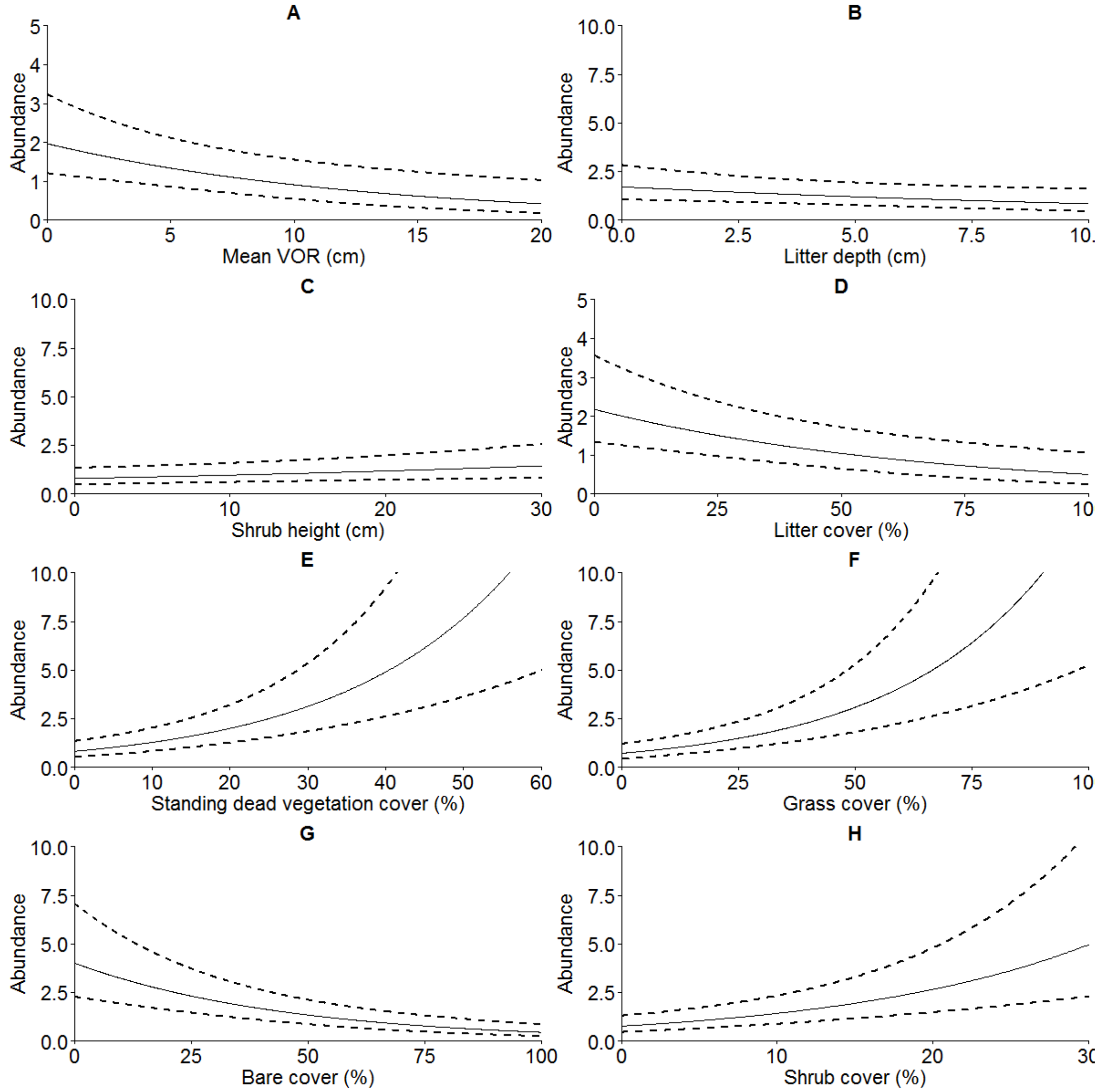

Figure 20. Dickcissel response to VOR (A), litter depth (B), shrub height (C), litter cover (D), standing dead vegetation (E), grass cover (F), bare ground (G), and shrub cover (H) at the plot scale in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

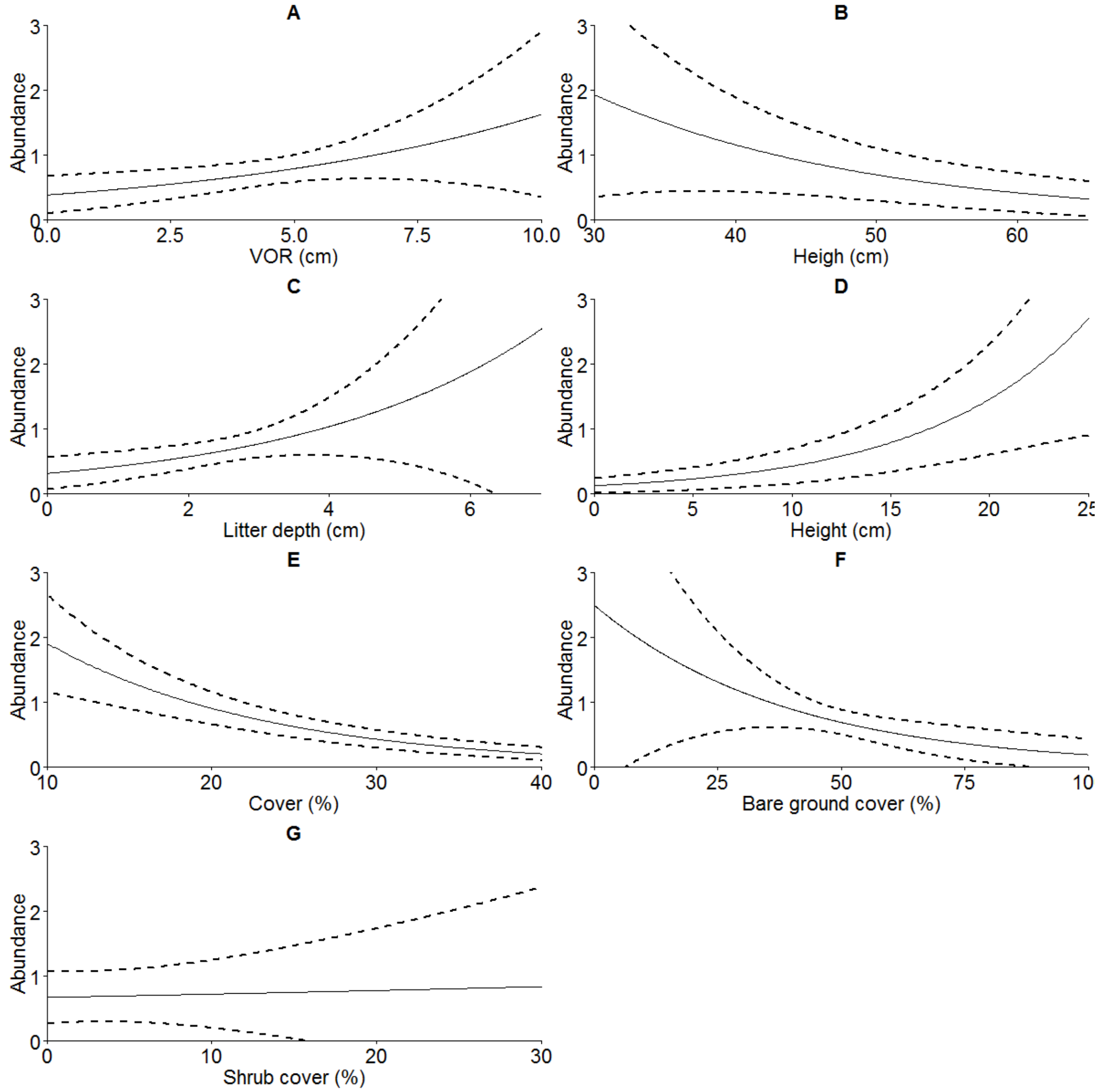

Figure 21. Field sparrow response to VOR (A), grass height (B), litter depth (C), shrub height (D), grass cover (E), bare ground (F), and shrub cover (G) at the management unit scale in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

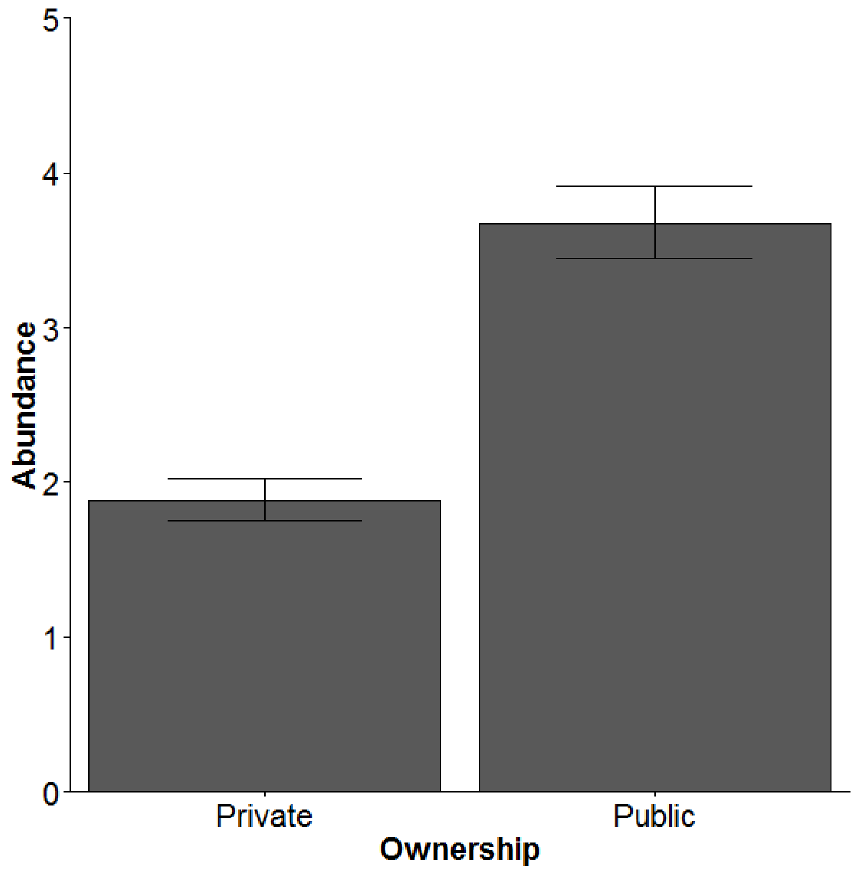

Figure 22. Relationship of grasshopper sparrow abundance to ownership (public or private) in the Nebraska Sandhills, 2014-2015. Error bars are 85% confidence intervals.

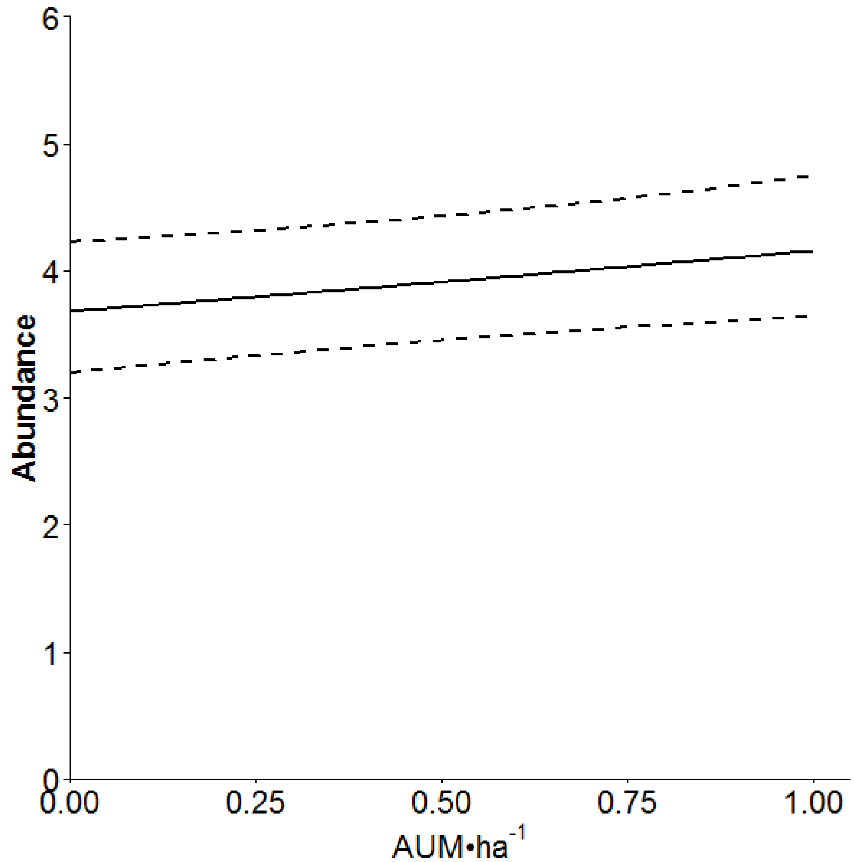

Figure 23. Relationship of western meadowlark to warm-season stocking rates in the Nebraska Sandhills, 2014-2015. Dotted lines are 85% confidence intervals.

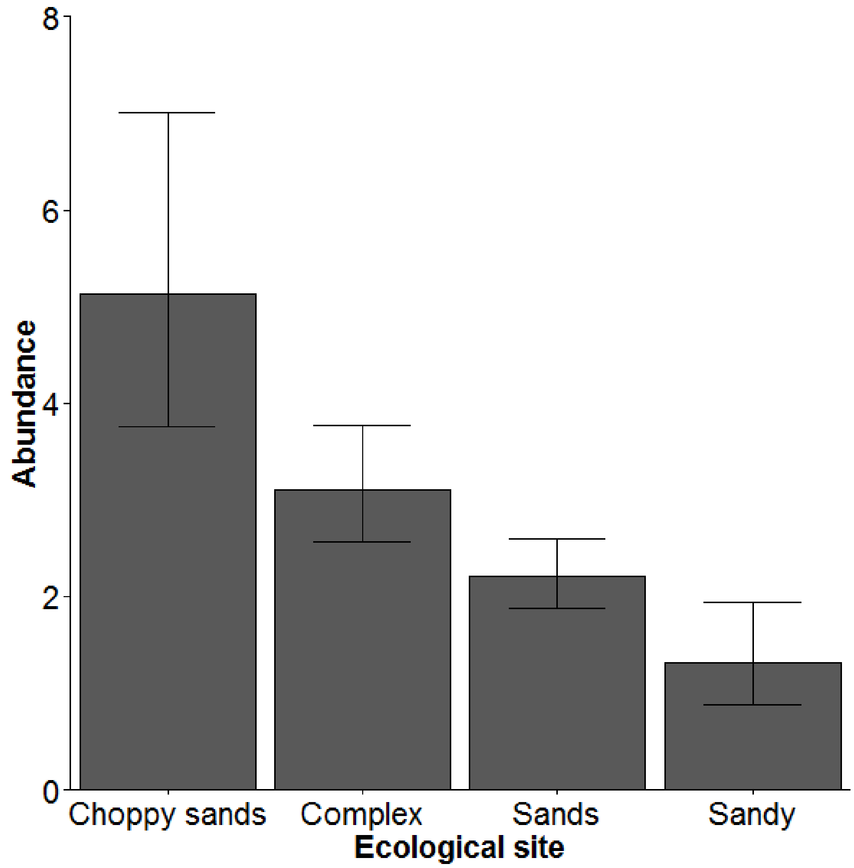

Figure 24. Relationship of lark sparrow to ecological site in the Nebraska Sandhills, 2014-2015. Errors bars are 85% confidence intervals. “Complex” ecological site indicates that there was no predominant ecological site across the eight frames within a sample plot.

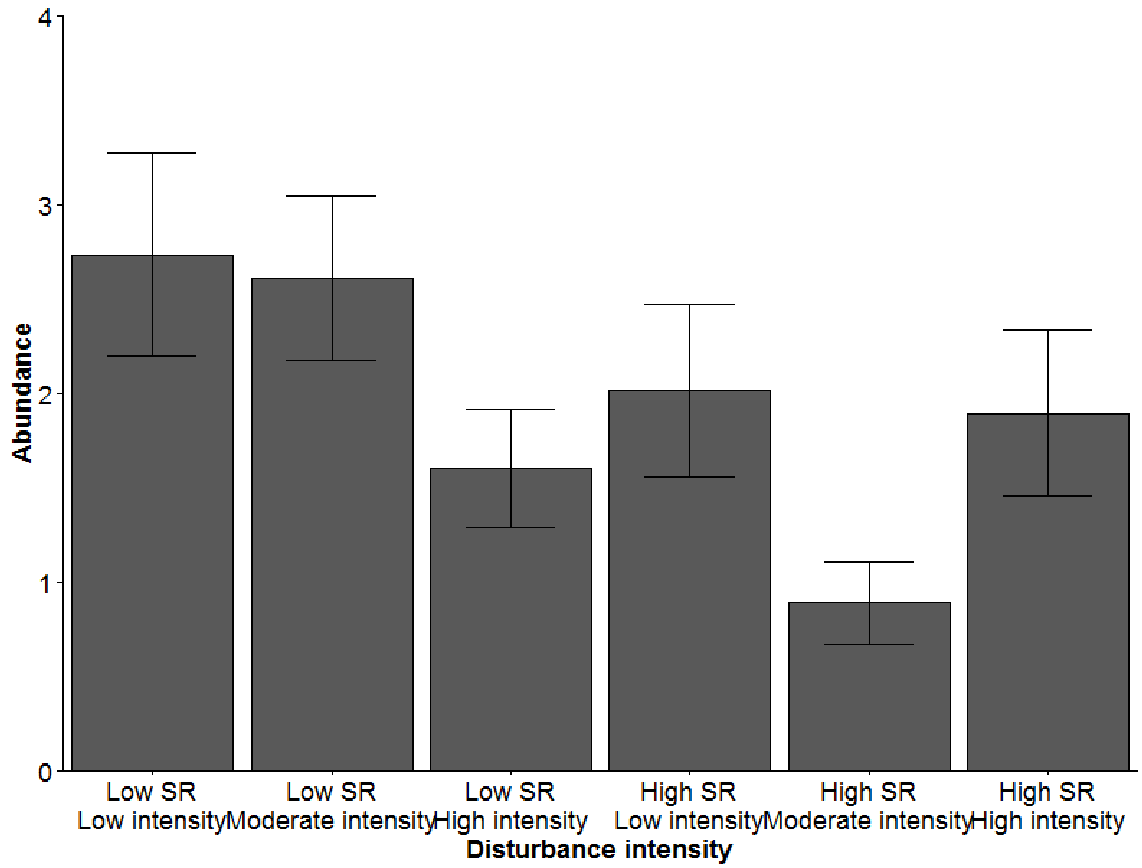

Figure 25. Relationship of horned lark abundance to the disturbance intensity (i.e., categorical stocking rate + categorical management intensity) in the Nebraska Sandhills, 2014-2015. Abbreviation: SR = stocking rate. Error bars are 85% confidence intervals.

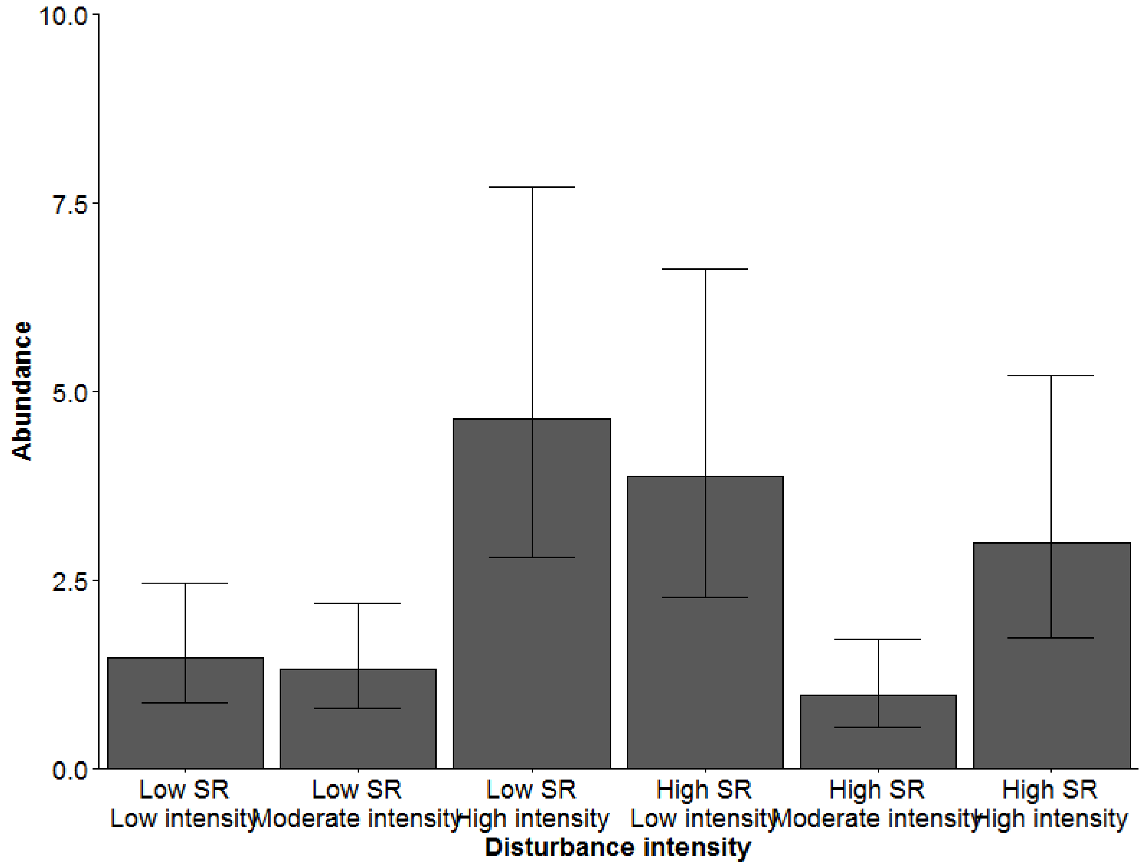

Figure 26. Relationship of dickcissel abundance to disturbance intensity (i.e., categorical stocking rate + categorical management intensity) in the Nebraska Sandhills, 2014-2015. Abbreviation: SR = stocking rate. Error bars are 85% confidence intervals.

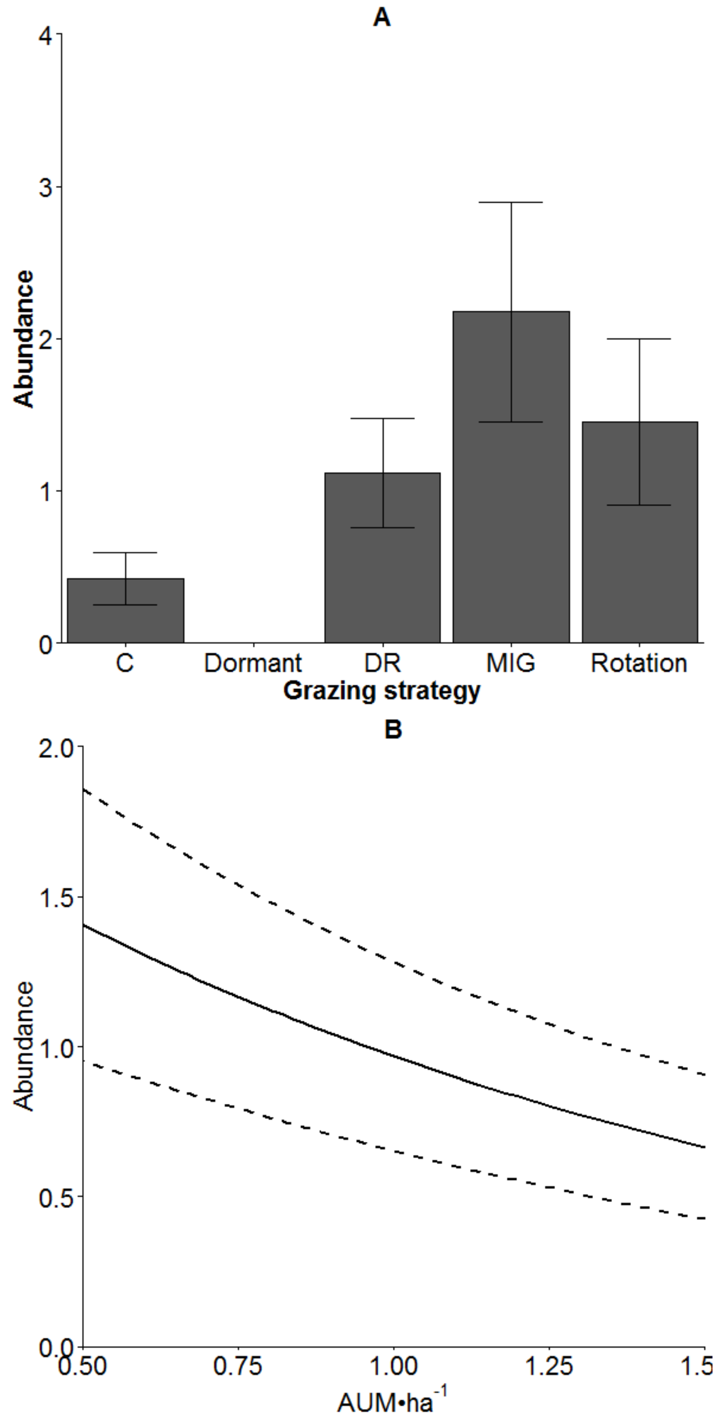

Figure 27. Relationship of field sparrow abundance to grazing strategy (A) and stocking rate (B) in the Nebraska Sandhills, 2014-2015. Error bars and dotted lines are 85% confidence intervals. Abbreviations: C = season-long, continuous, DR =deferred rotation, MIG = management intensive grazing, Rotation = fixed rotation.

CHAPTER 3: Grazing strategies, structural heterogeneity, and bird communities in the Nebraska Sandhills[2]

ABSTRACT

Structural vegetation heterogeneity is important for biodiversity, and restoring heterogeneity by mimicking historical disturbance regimes is a prolific area of research; this is especially true in rangelands where the paradigm has shifted to managing for heterogeneity with fire-grazing interactions. However, the majority of remaining native rangeland is privately owned and managed for beef production using grazing strategies, the goal of which is optimal use and reducing variability; although some managers assume the use of multiple grazing strategies will inherently create heterogeneity on a landscape, there is little knowledge about the relationship between grazing strategies on private land and heterogeneity. Therefore, I conducted a study in the Nebraska Sandhills to examine heterogeneity and bird diversity on landscapes managed with multiple grazing strategies. I measured vegetation structure and songbird diversity on 11 management units that contained 5 different grazing strategies. I used simulations to combine one or more grazing strategies into landscapes to test the hypothesis that multiple grazing strategies would result in greater heterogeneity, and I used mixed models to examine the relationship of these bird diversity and communities to grazing strategies. None of the simulated landscapes had consistently greater heterogeneity than the rest, and the songbird communities were similar across the different grazing strategies. In my study area, grazing did affect bird diversity but a variety of grazing strategies did not increase

[2]This chapter will be formatted for submission to Journal of Wildlife Management. Co-authors will include Larkin A. Powell, Walter H. Schacht.

heterogeneity of vegetation structure across a landscape, thus making it important that managers use other strategies, such as prescribed fires and extreme stocking rates, to create structural heterogeneity to support a diverse grassland songbird community. Beef production and wildlife conservation are not mutually exclusive, but the goals of beef production, to use the resource optimally and sustainably, do tend to prevent extremes in habitat, such as bare ground, from forming. Incentives that help private producers reduce the perceived risks associated with extreme habitat conditions may be needed to create this habitat across the landscape.

INTRODUCTION

Habitat heterogeneity, or the availability of different niches, is considered the basis for bird species diversity (MacArthur and MacArthur 1961); some grassland species require short, sparse vegetation patches and other species require taller, thicker vegetation patches (Mengel 1970), thus wildlife biologists should ensure that all different types of habitats needed by different species are present across a landscape (Fuhlendorf et al. 2006, Toombs et al. 2010). Different types of habitat are created by patterns of precipitation, ecological sites, and through management strategies, which can include grazing and fire (Hobbs 1996, Lipsey 2015, Scasta et al. 2015). Structural heterogeneity may be increased through the use of historical disturbance regimes, such as the fire-grazing interaction (Fuhlendorf et al. 2006). However, there has been little research to understand heterogeneity on privately owned rangelands that are managed primarily for beef production. Understanding how grazing management affects biodiversity on private rangeland landscapes is crucial at this point in time because grassland biodiversity continues to decline (Askins et al. 2007, Sauer et al. 2013).

Grazing management strategies that promote homogeneity and suppression of fires can lead to degradation in native rangelands by altering vegetation structure and composition (Vickery et al. 1999, Fuhlendorf et al. 2006). One study suggested that beef production was homogenizing the landscape because grassland bird populations were unstable even in the largely intact, 2 million ha Flint Hills of Kansas and Oklahoma (With et al. 2008). Where conservation of grassland birds is of concern, the focus should be on land-management practices that increase heterogeneity of vegetation structure at large scales (With et al. 2008). Heterogeneity is needed at fairly large scales for at least four reasons: 1) conspecific attraction may play a role in habitat selection by grassland birds (Ahlering et al. 2006), 2) many grassland birds have minimum area requirements for nesting (Johnson and Igl 2001, Brennan and Kuvlesky 2005), 3) some grassland birds are semi-colonial (Skagen and Yackel Adams 2010), and 4) heterogeneity at small scales decreases the available habitat for any given species (Allouche et al. 2012).

The theory of neutral models supports the idea that disturbances that create structural heterogeneity is essential for diversity in rangeland ecosystems, because otherwise there is limited niche space available and diversity may decline (Caswell 1976). Neutral models show that niche theory is the best predictor of community composition relative to two other theories (cybernetic and control-theoretic), and that as environments become more stable, they may have lower diversity or higher dominance of certain species (Caswell 1976). Another important consideration for habitat management is the importance of vegetation structure and composition. There is some disagreement about whether vegetation structure or composition is more important to bird communities (Mac Nally 1990, Müller et al. 2010). Rangeland studies tend to focus on vegetation structure, since it has been shown to be more important than vegetation composition (Fisher and Davis 2010, Henderson and Davis 2014). Grazing by livestock is a disturbance that influences both vegetation heterogeneity and composition (Derner et al. 2009, Toombs et al. 2010, Lwiwski et al. 2015), and therefore is of concern in relation to bird communities.

Although many environmental variables cannot be controlled, such as precipitation and ecological sites, management tools such as grazing and fire can be used to manipulate structural heterogeneity and vegetation composition. Managers use grazing strategies to control how and when their livestock graze an area, often by reducing pasture size and distance to water (Vallentine 2001, Schacht et al. 2011). Each individual animal's ability to choose preferred forage species is restricted when the stock density reaches a minimum threshold (Hart et al. 1993), thus improving forage use efficiency (Teague and Dowhower 2003, Reece et al. 2007). Producers view season-long, continuous grazing, especially at high stocking rates, as detrimental to rangelands because it may result in shifts in species composition or overuse of areas preferred by livestock (Teague and Dowhower 2003, Sliwinski 2017 Chapter 4). Thus, there has been a shift away from season-long, continuous of pastures to rotational grazing strategies, which producers perceive as being more aligned with their goals.

A goal of the Natural Resources Conservation Service (NRCS) is providing conservation benefits through implementation of the Farm Bill; however, most funding went towards improving livestock distribution through intensive grazing practices from 2004-2007 (Toombs and Roberts 2009, Briske et al. 2011). Further, rotational grazing strategies are promoted by non-governmental organizations as being beneficial for wildlife conservation (e.g., Audubon Society's "bird friendly beef" program; Audubon Society 2016). The "bird friendly beef" program promotes Holistic Range Management (Savory Institute 2016), typically synonymous with management intensive grazing.

Improving grazing distribution and increasing forage use efficiency through rotational grazing across the Great Plains might be leading to structurally homogenous rangelands that do not support the full suite of grassland species (Toombs et al. 2010, Becerra et al. 2013, Sliwinski 2017 Chapter 2); this phenomenon is called "managing to the middle" (Fuhlendorf and Engle 2001, Toombs et al. 2010, Fuhlendorf et al. 2012). This may be contributing to declining grassland bird populations that require extremes of vegetation structure (e.g., high amounts of bare ground) that decline with rotational grazing strategies, even on large and intact rangelands (With et al. 2008). Thus, the goal of this study was to determine how a variety of grazing strategies across the landscape contributed to vegetation heterogeneity, bird diversity, and bird communities. I hypothesized that different grazing strategies would create different types of vegetation structure, which would support different bird communities. Conducting experimental studies on private land is exceedingly difficult because the researcher has no control over treatments applied, thus I used simulations to examine heterogeneity across the landscape.

I examined hypothetical pairings ("artificial landscapes") of empirical data from grazing strategies to determine if any combination of grazing strategies across a landscape would have greater heterogeneity of vegetation structure (Figure 28). I also examined differences in bird communities in relation to the variety of grazing strategies on a landscape and other management characteristics. A conclusion of some studies has been to encourage a variety of grazing strategies across a landscape to increase heterogeneity, which is typically measured by the standard deviation or coefficient of variation of a vegetation characteristic at the sampling or super-sample scale (Kempema 2007, Ranellucci et al. 2012). Thus, I hypothesized that a landscape that included at least two different grazing strategies would have greater structural heterogeneity than any landscape that only included a single grazing strategy; further, I hypothesized that a landscape with three grazing strategies would have greater structural heterogeneity than a landscape with only two grazing strategies.

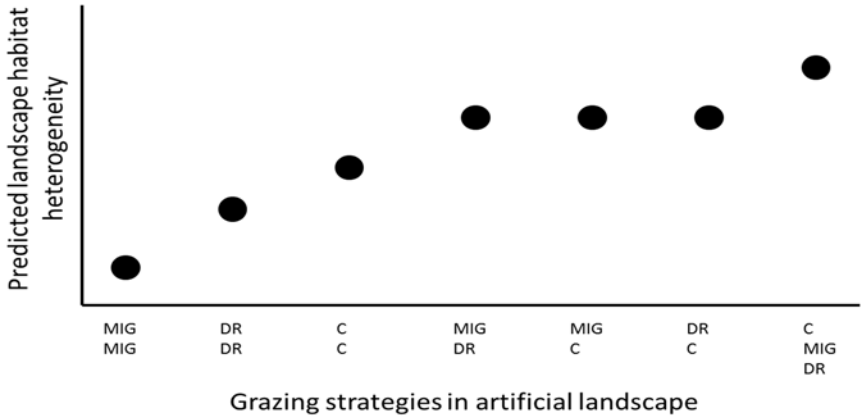

Figure 28. Hypothesized relationship of landscape heterogeneity to the number and type of grazing strategies in a landscape. Abbreviations: MIG: management intensive grazing; DR: deferred rotation; C: season-long, continuous.

METHODS

Field methods

This study took place in Cherry County, Nebraska, in the Nebraska Sandhills, a region with large, contiguous tracts of native private and public rangeland. The Nebraska Sandhills cover approximately 19,000 square miles and are over 90% intact native rangeland (Bleed and Flowerday 1998). The species present are a mix of short- and tall-grass prairie species, sand tolerant species, eastern deciduous forest and western coniferous forest species, and species associated with permanent and ephemeral wetlands and lakes (Potvin and Harrison 1984). Plant communities in the rangelands include the bunchgrass community, which include little bluestem (*Schizachyrium scoparium*), Junegrass (*Koeleria macrantha*), and needle-and-thread grass (*Hesperostipa comata*); the sand muhly (*Muhlenbergia pungens*) community, which commonly inhabits recently disturbed areas; and the blowout community, with blowout grass (*Redfieldia flexuosa*), prairie sandreed (*Calamovilfa longifolia*), and blowout penstemon ((*Penstemon haydenii*; Pool 1914 in (Bleed and Flowerday 1998). Although grasses make up the dominant cover type in the Sandhills, there are numerous species of forbs and some shrubby species, which make for a very diverse plant community (Bragg and Steuter 1996). Cherry County is approximately 87% rangeland (U.S. Department of Agriculture 2015).

There are seven species of grassland birds that are endemic to the Great Plains and breed in the Sandhills region, including greater prairie-chicken (*Tympanuchus cupido*), upland sandpiper (*Bartramia longicauda*), long-billed curlew (*Numenius americanus*), dickcissel (*Spiza Americana*), lark bunting (*Calamospiza melanocorys*), and chestnut-collared longspur (*Calcarius ornatus*; Bleed and Flowerday 1998); the ferruginous hawk (*Buteo regalis*) also breeds in the Sandhills and is considered a primary grassland endemic by Mengel (1970).

I sampled eleven management units to include a variety of grazing strategies, where a management unit was one or multiple pastures grazed by a single herd of cattle in a given year. Six management units were on private ranches, and five management units were on the Samuel R. McKelvie National Forest. Because this study was done on private land and public land leased to private producers, it was not possible to experimentally manipulate the grazing strategies or any other management variables of interest. I collected data over two growing seasons (2014-2015). Each management unit had 24 plots laid out in a grid across one or more pastures for a total of 264 sampling plots; I attempted to evenly divide points among the pastures on each management unit, but the limited size of some pastures prevented this in a number of cases. Sampling plots were placed at least 250 m apart, and at least 250 m from roads or other types of habitat (e.g., wet meadows, crop).

To reduce bias from topography and ecological sites among management units, I sampled only from upland habitats in an area with relatively low amount of lakes and wetlands and similar ecological site descriptions (Table 1). The predominant ecological site on these upland pastures was sands, which is comprised of grass-covered, rolling dunes. The choppy sands site, with steep slopes and lower plant density, as well as the sandy site, level areas between dunes with higher plan density, were less common. Active or recovering blowouts (an area of moving sand and limited vegetation) were scattered throughout the uplands but accounted for less than 1% of the sites sampled. I sampled only upland sites to limit the amount of variation that would be due to sampling different types or amounts of habitat at the different sites (e.g., wet meadows).

To measure bird abundance and diversity, I conducted point counts three times at each plot in each year for a total of six visits to each plot. Point counts were completed from 4 June through 3 July 2014 and 29 May through 30 June 2015. All points were visited by at least 4 different observers over the course of the study to limit observer bias. Counts were completed from ten minutes before sunrise until about 10:00 am on days with no rain, limited fog, and winds below 16 $km \cdot h^{-1}$ (Hutto et al. 1986). At each point, an observer recorded all birds that were seen or heard during six minutes. The species, sex, and behavior (observed singing, observed calling, heard singing, heard calling, observed only) of the bird were recorded.

To collect information about management characteristics on each private management unit, I visited with the landowners about their management. I requested grazing dates for each pasture that I sampled, herd numbers, and approximate animal weights. For the public management units, I requested the grazing schedules from the US Forest Service district responsible for grazing management (Bessey Ranger District, Halsey, NE). From these two sources of information I was able to calculate stocking rates, season of use, and categorize each set of pastures into a grazing strategy for both the private and public management units.

Landscape analysis

To examine my hypothesis that more grazing strategies on a landscape will create greater structural vegetation heterogeneity, I used my empirical data in a simulation analysis to assess heterogeneity in a set of artificial landscapes. I used this simulation approach because I did not have a balanced design to compare means across grazing strategies. Each artificial landscape included between one and three different grazing strategies. For this analysis, I included three types of grazing strategies: management intensive grazing ("MIG", n = 2), deferred rotation ("DR", n = 5), and season-long, continuous ("C", n = 2). From these three grazing strategies I created seven combinations of landscapes: MIG/MIG, DR/DR, C/C, MIG/DR, MIG/C, DR/C, and MIG/DR/C (Figure 28). For each landscape combination, I simulated 7,000 artificial landscapes using the following procedure with a "for" loop in R. I randomly selected the two or three management units from which the data should be drawn based on the grazing strategies in the landscape being created. I then randomly selected 96 vegetation structure samples or

64 vegetation structure samples from each of 192 samples from two or three management units depending on the number selected in the previous step. Ninety-six sampling frames represented half of the data available from each management unit, and when combined with the second randomly sampled management unit, a sample of the same size as one whole management unit in this study was created (i.e., 192 samples). Similarly, 64 sampling frames represented one-third of the data available. Once the data were selected, I calculated the standard deviation of the variable of interest (i.e., visual obstruction reading, litter depth, or bare ground) for the entire artificial landscape, and stored this in a separate data frame for further analysis. The result of this simulation was a dataset that included 7000 data points representing the heterogeneity (e.g., standard deviation of VOR) found on each artificial landscape (1000 data points for each of the seven landscape types), and a record of the two or three management units that were included in the landscape. From this simulated dataset, I created boxplots to assess if the results supported the hypothesized relationship among the different landscapes.

Diversity analysis

I calculated songbird richness, Simpson diversity, and Shannon diversity for each sample plot using package picante in program R (Kembel et al. 2010). To assess the relationship of songbird diversity to management, I used linear mixed-effects models in package lmer (Bates et al. 2015). The fixed effects of interest included grazing strategy, four stocking rate variables (stocking rate for the previous year, previous cool season, previous warm season, and previous dormant season), a categorical stocking rate variable (high > 0.35 AUM/ha, low < 0.35 AUM/ha), a categorical management intensity variable (low < 3 pastures in the strategy, moderate 3−6 pastures in the strategy, high > 6 pastures in the strategy), a disturbance intensity variable (combination of categorical stocking rate and categorical management intensity), season of use, ecological site, and ownership (public or private).

I examined the following models using AIC: 1) grazing strategy; 2) season of use; 3) the three seasonal stocking rates; 4) stocking rate for previous year; 5) previous cool-season stocking rate; 6) previous warm-season stocking rate; 7) previous dormant-season stocking rate; 8) previous year's total stocking rate + season of use; 9) previous year's total stocking rate + grazing strategy; 10) a categorical variable for previous year's stocking rate; and 11) a categorical variable for management intensity; 12) disturbance intensity 13) ownership; 14) null. The random effects that I included were year, management unit, and pasture.

Community analysis

I used a multivariate approach to examine differences in songbird communities across grazing strategies, management units, years, ownership (public or private), categorical stocking rates, categorical management intensities, and vegetation structure measures. Because pasture was the scale at which management occurred, I assessed bird communities at the level of the pasture. I included species that were detected in at least 10% or more of the pastures that I sampled (at least 3 pastures), and excluded those species that were not songbirds (e.g., ducks, raptors, shorebirds). I accounted for the different sampling effort in most pastures, by dividing the total number of detections in a pasture by the number of plots in that pasture. I calculated the Bray-Curtis dissimilarity on the square-root transformed species abundance data (Borcard et al. 2011) across all pastures and years (package vegan in program R; Oksanen et al. 2016). Then, I conducted a non-metric dimensional scaling analysis (Minchin 1987) to assess community similarity across different variables, including management unit, year, ownership (private/public), grazing intensity (high or low stocking rate, as defined above), management intensity (low, high, or moderate intensity as defined above), and grazing strategy (*metaMDS* function in package vegan; Oksanen et al. 2016). I then fit the vegetation structure measures to the resulting NMDS to examine the relationships of the bird community to vegetation structure features (*envfit* function in package vegan).

To determine what variables best explained the songbird community assemblages, I used a multi-response permutation procedure (Mielke et al. 1976) using the *mrpp* function in package vegan to calculate the percentage of the variation in the multivariate bird community that is explained by a given variable. The variables I assessed included management unit, year, ownership (public or private), categorical stocking rate (high or low), categorical management intensity (high, moderate, or low), and grazing strategy. The chance-corrected within-group agreement value (*A*) indicates variation that is explained by a grouping factor in the MRPP and is comparable to a coefficient of determination in linear regression (Oksanen et al. 2016). I used *A* and the significance value to interpret overlap of communities.

RESULTS

Descriptive

Managers used five different grazing strategies on the eleven management units selected for this study: season-long continuous grazing, deferred rotation grazing, management intensive grazing, dormant-season grazing, and a fixed rotation strategy. Each grazing strategy was represented on both public and private land except for dormant-season (private) and fixed rotation (private). The stocking rate was typically lower on public land than on private land (in 2014, mean stocking rate across the five public management units was 0.52 AUM·ha^{-1}, whereas mean stocking rate across the six private management units was 0.98 AUM·ha^{-1}; Table 2).

Across the study area, mean VOR and litter depth were greater in 2014 than in 2015, mean litter cover and mean bare ground were lower in 2014 than in 2015, and mean standing dead vegetation, mean grass cover, and mean shrub cover were similar in both years (Table 3). The mean heterogeneity of VOR (SD) calculated for each plot of 8 frames (n = 264 plots) was similar in 2014 and 2015, of litter depth was greater in 2014 than in 2015, and of litter cover, standing dead vegetation, grass cover, and bare ground were lower in 2014 than in 2015 (Table 4).

Landscape analysis

Among the vegetation structure variables examined in the simulations, more grazing strategies on a simulated landscape did not result in greater heterogeneity in measures of vegetation structure. The median heterogeneity (SD) of bare ground in the simulations ranged from 28-29% in 2014 and 27-29% in 2015 (Figure 29). The greatest range in variability in bare ground was on a landscape that included two deferred rotation grazing strategies in 2014, whereas the landscape with the greatest range in variability in bare ground included two season-long continuous grazing strategies in 2015. For litter depth, the ranges in heterogeneity (SD) were quite similar except that the landscape with only management intensive grazing strategies had very low heterogeneity compared to the rest of the landscape units in the simulated dataset in both 2014 and 2015 (Figure 30). Notably, any of the landscapes that included a management intensive grazing strategy had reduced heterogeneity of litter depth, and any landscape that included a season-long continuous grazing strategy had increased heterogeneity of litter depth. The opposite was true for VOR (Figure 31). Simulated landscapes with management intensive grazing strategies had the highest heterogeneity in VOR, where landscapes with season-long continuous grazing strategies had the lowest amount of VOR heterogeneity in both years.

Songbird diversity

Twenty-eight songbird species were detected in 2014 and 2015 (Table 14). The most common species were grassland birds, including grasshopper sparrows (*Ammodramus savannarum*), western meadowlarks (*Sturnella neglecta*), and brown-headed cowbirds (*Molothrus ater*). Vesper sparrows (*Pooecetes gramineus*) were uncommon. The five most common avian species made up 84% of my observations. Songbird richness ranged from 2 to 10 species per plot; the majority of plots had 5 or 6 songbird species. Shannon diversity ranged from 0.41 – 2.2, and Simpson's diversity ranged from 0.24 – 0.88. Each of the diversity measures I analyzed (Shannon diversity, Simpson diversity, and richness) was best explained by the previous dormant season's stocking rate (*w* = 0.72, 0.53, 0.79 respectively; Table E-1-3). Each of these measures decreased with stocking rate, although the effect was fairly minimal (Table 15, Figure 32). Richness declined by about 1 species per plot with an increase in 1 AUM·ha^{-1}.

Songbird community

The following seventeen songbird species were detected in at least 3 pastures, and thus were included in the community analyses: American goldfinch (*Spinus tristis*), Bell's vireo (*Vireo bellii*), brown-headed cowbird, blue grosbeak (*Passerina caerulea*), brown thrasher(*Toxostoma rufum*), dickcissel (*Spiza americana*), eastern kingbird (*Tyrannus tyrannus*), field sparrow (*Spizella pusilla*), grasshopper sparrow, horned lark (*Eremophila alpestris*), lark sparrow (*Chondestes grammacus*), mourning dove (*Zenaida macroura*), orchard oriole (*Icterus spurius*), red-winged blackbird (*Agelaius phoeniceus*), spotted towhee (*Pipilo maculatus*), vesper sparrow, and western meadowlark.

The community analysis using NMDS revealed a high level of overlap in bird communities (species composition and abundance) among the different variables I examined. Songbird communities in management units with six or more pastures (i.e., management intensive grazing) had more Bell's vireos (*Vireo bellii*) and spotted towhees (*Pipilo maculatus*), whereas those in management units with a moderate intensity had more orchard orioles and eastern kingbirds (Figure 33). Privately managed land had more orchard orioles and eastern kingbirds, and public land had more dickcissels and Bell's vireos (Figure 34). There was a high degree of overlap of NMDS hulls in pastures that were managed with a high stocking rate and with a low stocking rate (Figure 35). There was also a high degree of overlap of NMDS hulls in songbird communities in 2014 and

2015; 2014 had more field sparrows and dickcissels, and 2015 had more vesper sparrows and orchard orioles (Figure 36). The NMDS plot for songbird communities on management units showed two management units (numbers 3 and 11) that had different bird communities from the rest, because they had more orchard orioles and eastern kingbirds (Figure 37). Finally, there was a large degree of overlap in the NMDS plots for grazing strategies (management intensive, continuous, deferred rotation, dormant season, and fixed rotation; Figure 38). In each of these NMDS plots, the most common birds, such as grasshopper sparrows, western meadowlarks, and lark sparrows, were at the center of each of the plots, indicating that they were fairly common among sample locations.

The plot overlaid with vegetation structure variables shows that songbirds were related to vegetation measures as expected; bare ground and stocking rates were correlated and vegetation cover and structure measures were related (Figure 39). Many species were correlated with greater vegetation cover and structure (e.g., dickcissel, Bell's vireo), but there were also a number (e.g., vesper sparrow, orchard oriole, lark sparrow) that were more correlated to bare ground and less vegetation cover. According to the MRPP, each of the five variables I explored were significantly related to the songbird community, but the effect sizes (A) were small for most. The variable explaining the most variation in bird communities was the management unit (i.e., ranch or grazing allotment, $A = 0.25$; Table 16). Year and grazing strategy both explained some of the bird community structure ($A = 0.07$, 0.08 respectively).

DISCUSSION

My hypothesis that multiple grazing strategies across a landscape would result in more heterogeneity of vegetation structure was not supported by the landscape simulation analysis. The amount of variability in the vegetation structure measures as a group appeared to be independent of the grazing strategies across a landscape, even if some landscapes had more variability than others. Also, the range of vegetation structure measures in these simulations was so small that it seems unlikely to be ecologically relevant, which is supported by the lack of differences in bird communities across the study area.

Although variation in the composition of songbird communities was significantly related to each of the variables I examined with the MRPP, the effect sizes were typically small. Ownership explained very little of the variation, even though there is a long history of relatively different stocking rates and seasons of use between public and private land. Thus, the conservative management on the Forest Service lands did not result in markedly different grassland bird communities. In a similar study, overall differences in stocking rate related to ownership (NGO vs. public) were found to explain little variation in a study in the tallgrass prairie bird community (Ahlering and Merkord 2016), providing additional evidence against the relative importance of grazing management when it is couched within a narrow range (i.e., no extremes). Only the management unit variable explained a substantial amount of variation in bird communities, a result that was supported by a post-hoc analysis that revealed that management unit explained songbird abundances far better than any of the other variables (e.g., stocking rate, grazing strategy, ecological site, ownership; Sliwinski 2017, Chapter 2 unpublished analysis). The differences among management units in the songbird communities were most likely not a result of grazing management, but rather due to landscape features, such as the proximity to forested wetland patches, or the presence of shrubs, two things that were common on the units that had more orchard orioles, eastern kingbirds, and brown thrashers.

Although previous dormant-season stocking rate was the best predictor of all three of the bird diversity indices, the effect sizes were very small. Unless managers are willing to use stocking rates above the range that is commonly used and recommended, it is unlikely that stocking rates will be useful in managing habitat for diverse bird communities (Sliwinski and Koper 2015).

I sampled 11 different management units, on both public and private land, across a 590 km^2 study area, and found very few differences in songbird communities and very similar vegetation structure. I found no evidence to support using grazing strategies, in their current formulation, as a way to create heterogeneity of vegetation structure on upland Sandhills rangelands. My results agree with other studies that concluded that grazing management on private and public lands contributes to the homogenization of rangelands by promoting forage use efficiency and preferred forage species (Fuhlendorf and Engle 2001, With et al. 2008, Toombs et al. 2010). Certainly, my data suggest that heterogeneity is not fostered through a variety of grazing strategies. Although every producer manages their land slightly differently, their goals are all similar: to sustain beef production through efficient use of the forage resource (Vallentine 2001, Reece et al. 2007). They all use similar stocking rates and manage for similar high-yielding, dominant plant species to optimize beef production, which, at least in the Nebraska Sandhills, leads to homogeneity.

Recent research suggests that biodiversity in the Great Plains region of North America is at risk of rapid decline as a result of land use change (Newbold et al. 2016). The bird communities I sampled show evidence of this because they were missing a number of species I expected to see, such as long-billed curlews (*Numenius americanus*), vesper sparrows (*Pooecetes gramineus*), lark buntings (*Calamospiza melanocorys*), common nighthawks (*Chordeiles minor*), and Swainson's hawks (*Buteo swainsoni*, "dark diversity"; Pärtel et al. 2011). This is not to say that land managed for beef production provides unsuitable habitat for grassland species; on the contrary, the habitat is high quality, but only for a subset of potential species. Many researchers suggest that fire-grazing interactions are needed to achieve higher levels of heterogeneity and biodiversity than exist currently in rangelands, because this will provide both heavily disturbed and rested habitat (Fuhlendorf and Engle 2004, Augustine and Derner 2012, Winter et al. 2012). Fire is not used often as a management tool in the Sandhills, which likely reduces the potential for rangeland vegetation heterogeneity, while also allowing the potential incursion of invasive species like eastern redcedar (*Juniperus virginiana*; (Fuhlendorf et al. 2017).

MANAGEMENT IMPLICATIONS

The Nebraska Sandhills are very effectively managed for sustainable, high-yielding forage species and even use throughout their extent. Grazing management practices (including grazing strategies and stocking rates) used in the Sandhills are designed and implemented with this in mind. My results showed that managers cannot assume that a variety of grazing strategies across a landscape will automatically result in vegetation heterogeneity and diverse bird communities. Because the bulk of remaining native prairie is privately owned (Reece et al. 2008, Freese et al. 2010), conservationists must work with private producers to create the full spectrum of habitats needed by wildlife if we hope to prevent continued declines and losses of prairie species. For example, in the Nebraska Sandhills, blowouts are an important habitat for the endangered blowout penstemon (*Penstemon haydenii*), but land managers typically manage against blowouts because they are not useful for beef production and are considered wasteful. The extremes of habitat recommended for avian diversity (Mengel 1970, Fuhlendorf and Engle 2001, Samson et al. 2004, Augustine and Derner 2012), and especially bare ground, have negative social connotations among landowners in the Great Plains because to them it indicates that a manager is not a good steward of the rangeland resource (Sliwinski 2017 Chapter 4).

As rangeland conservationists, we need to work with landowners to create vegetation heterogeneity specifically because there is not a range of structure across the landscape as it is currently managed, and many grassland bird species are in decline (Brennan and Kuvlesky 2005, Sauer et al. 2014). Of course, this is challenging because the Sandhills region, and most rangeland in the Great Plains, is privately owned and the sole use is livestock production; but private rangelands are ripe for increased conservation efforts (Neilly et al. 2016). We can look across a landscape to determine what species are missing (Pärtel et al. 2011), and then work to create the missing habitat through the management tools we know work: grazing management (e.g., stocking rates, season of use), burrowing animals, and fire. Further, it is important for the Natural Resources Conservation Service to take into consideration the result of promoting rotational grazing strategies, which is generally the homogenization of the landscape and other negative ecological effects (Toombs and Roberts 2009, Knight et al. 2011). If a goal of the Farm Bill is to provide conservation benefits, then it seems as though using payments to promote the use of fire on rangelands would be very appropriate. If private landowners are unwilling to create vegetation heterogeneity on their land, then there may be a need to use public land to ensure that the ends of the spectrum of habitats needed by wildlife is available.

Table 11. Vegetation structure measures across eleven sites in the Nebraska Sandhills, 2014-2015. Values represent means and standard deviations across 2112 sample frames.

	2014		2015	
	Mean	SD	Mean	SD
Mean visual obstruction reading (cm)	4.87	5.60	3.87	5.42
Litter depth (cm)	3.31	3.53	2.26	2.42
Litter cover (%)	25.91	20.40	34.58	28.36
Standing dead vegetation cover (%)	11.94	11.60	13.12	14.48
Grass cover (%)	22.76	19.60	22.60	19.42
Bare ground (%)	38.81	27.45	56.80	27.90
Shrub cover (%)	6.46	12.83	3.74	9.34

Table 12. Heterogeneity (SD) of vegetation structure measures across eleven sites in the Nebraska Sandhills, 2014-2015. Values shown are the standard deviations averaged across 264 plots plus their standard deviations.

	2014		2015	
	Mean SD	SD	Mean SD	SD
Mean visual obstruction reading (cm)	3.68	3.45	3.50	3.79
Litter depth (cm)	2.75	1.72	1.90	1.14
Litter cover (%)	16.40	7.32	19.91	7.80
Standing dead vegetation cover (%)	8.59	5.44	11.06	6.25
Grass cover (%)	14.09	7.77	16.12	6.71
Bare ground (%)	19.83	7.77	24.46	6.78

Table 13. Ownership, grazing strategy, number of pastures, and area of pastures (ha) sampled, and mean stocking rates (AUM·ha^{-1}) of previous year across all pastures sampled for each management unit for each year, Nebraska Sandhills, 2014-2015.

Unit	**Owner**	**Strategy**	**Pastures sampled**	**Area of pastures**	**2013 Total**	**2014 Total**
1	Private	Dormant	2	393	1.06	1.40
2	Private	C	2	671	0.76	0.62
3	Private	DR	2	467	1.14	0.71
4	Private	MIG	4	633	1.74	1.84
5	Private	Rotation	2	448	0.86	1.22
6	Public	C	1	656	0.31	0.43
7	Public	DR	2	1556	0.65	0.56
8	Public	DR	2	1296	0.81	0.73
9	Public	MIG	3	1150	0.18	0.32
10	Public	DR	3	1019	0.33	0.48
11	Private	DR	3	369	1.41	1.17

Table 14. Total detections of songbird species up to 150 m from the center of the point count plot, Nebraska Sandhills, 2014-2015.

Species	**Detections**	**Species**	**Detections**
Grasshopper sparrow	2606	Spotted Towhee	22
Western meadowlark	1859	Brown thrasher	20
Brown-headed cowbird	1068	Eastern kingbird	17
Horned lark	1028	Yellow-headed blackbird	14
Lark sparrow	1010	Common grackle	6
Dickcissel	437	Common yellowthroat	5
Field sparrow	327	Cassin's sparrow	4
Red-winged blackbird	224	Western kingbird	4
Mourning dove	110	Eastern towhee	3
Blue grosbeak	88	Lark bunting	3
Vesper sparrow	58	Barn swallow	2
Bell's vireo	44	Tree swallow	1
American goldfinch	27	Bobolink	1
Orchard Oriole	23	Loggerhead shrike	1

Table 15. Variances and standard errors for random effects, and parameter estimates and standard deviations for fixed effects for three songbird diversity indexes in the Nebraska Sandhills, 2014-2015.

	Shannon diversity		**Simpson diversity**		**Richness**	
Random effects	**σ^2**	**SD**	**σ^2**	**SD**	**σ^2**	**SD**
Pasture	0.01	0.10	<0.01	0.03	0.28	0.53
Management unit	0.00	0.00	<0.01	<0.01	0.00	0.00
Year	<0.01	0.07	<0.01	0.02	0.11	0.34
Residual	0.06	0.25	<0.01	0.08	1.69	1.30
Fixed effects	**Beta**	**SE**	**Beta**	**SE**	**Beta**	**SE**
Intercept	1.56	0.06	0.75	0.01	5.95	0.27
Dormant-season stocking rate	-0.21	0.05	-0.06	0.02	-0.99	0.27

Table 16. Multi-response permutation procedure (MRPP) results for five different management variables in the Nebraska Sandhills, 2014-2015.

Grouping variable	**Significance of test**	**Chance-corrected within-group agreement (*A*)**
Management unit	0.001	0.252
Year	0.001	0.077
Ownership	0.001	0.049
Stocking rate (high/low)	0.033	0.016
Management intensity (high/moderate/low)	0.001	0.051
Grazing strategy	0.001	0.081

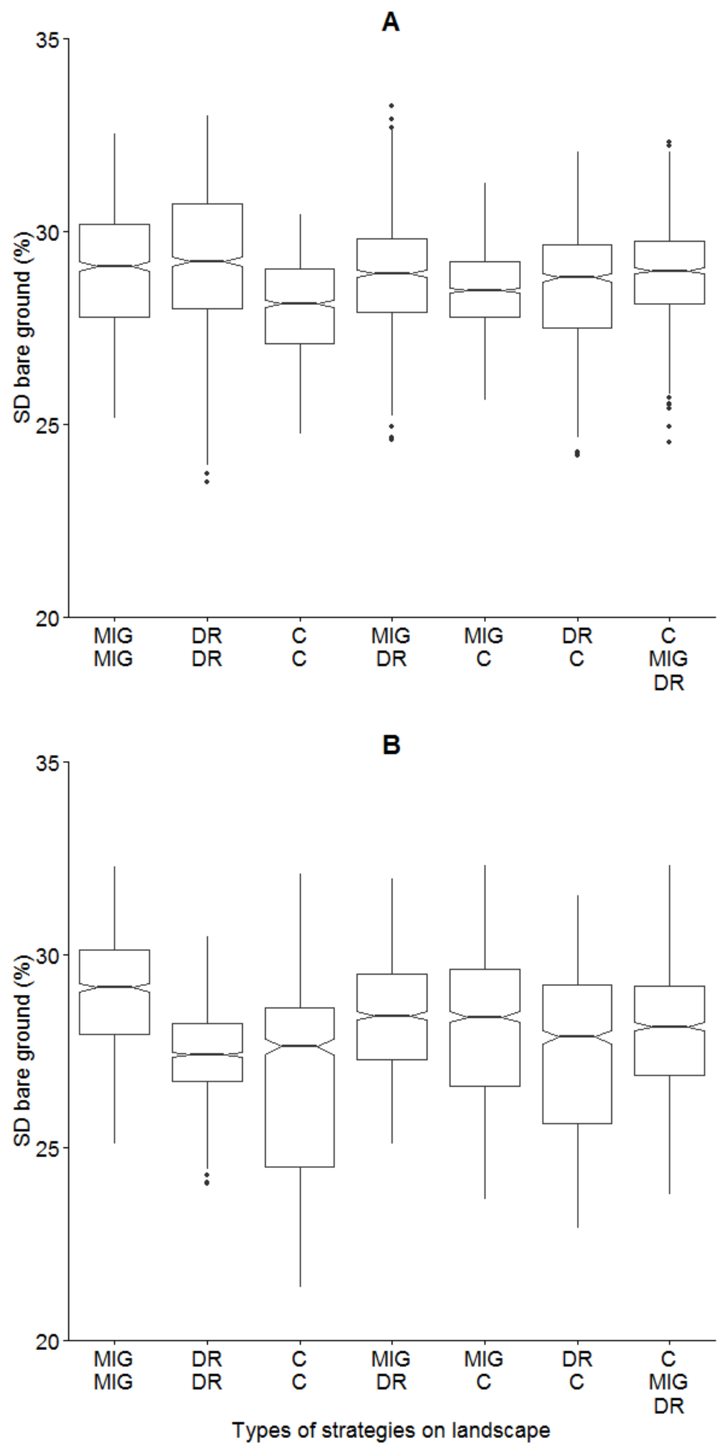

Figure 29. Mean heterogeneity (SD) in bare ground (%) on landscapes with various combinations of grazing strategies in 2014 (A) and 2015 (B). Notches indicate 95% confidence interval. Landscapes were simulated using random samples of empirical data from the Nebraska Sandhills, 2014-2015 (n = 7000).

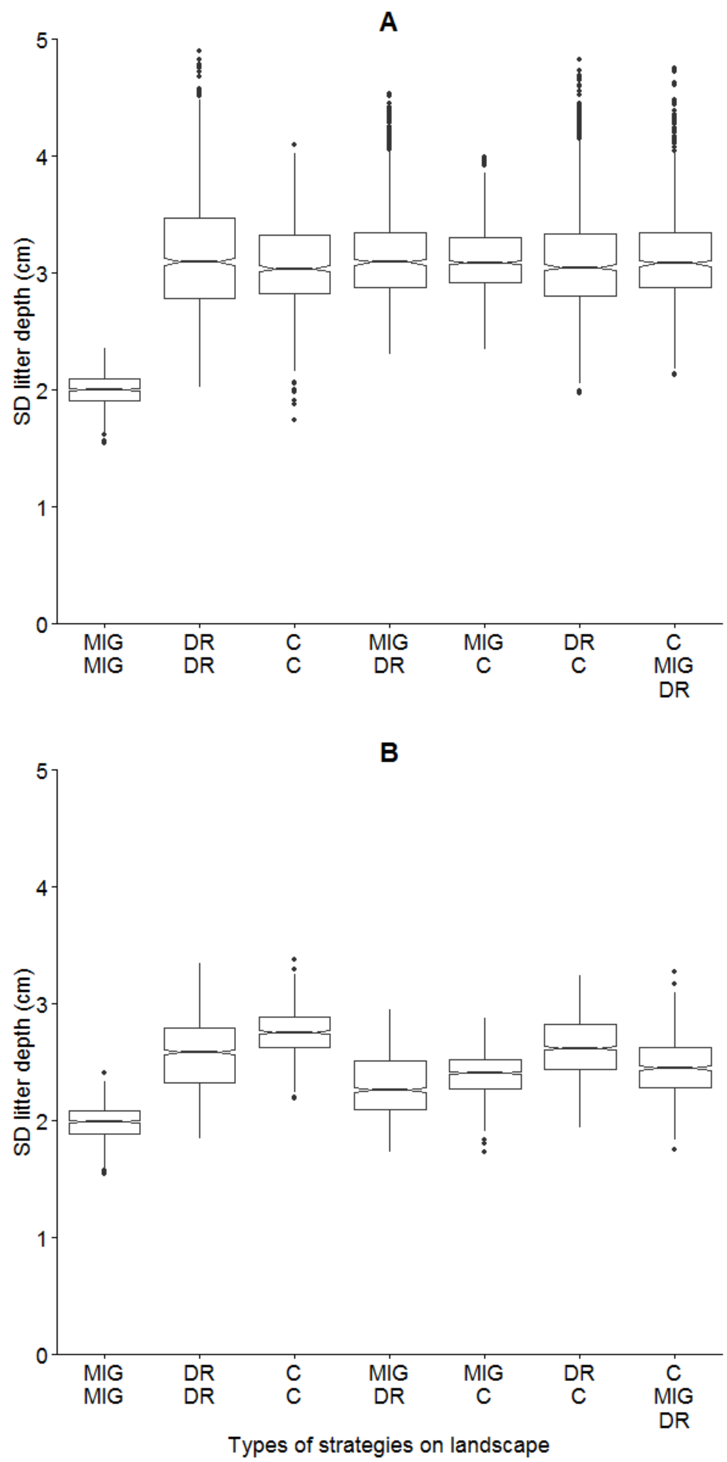

Figure 30. Mean heterogeneity (SD) in litter depth (cm) on landscapes with various combinations of grazing strategies in 2014 (A) and 2015 (B). Notches indicate 95% confidence interval. Landscapes were simulated using random samples of empirical data from the Nebraska Sandhills, 2014-2015 (n = 7000).

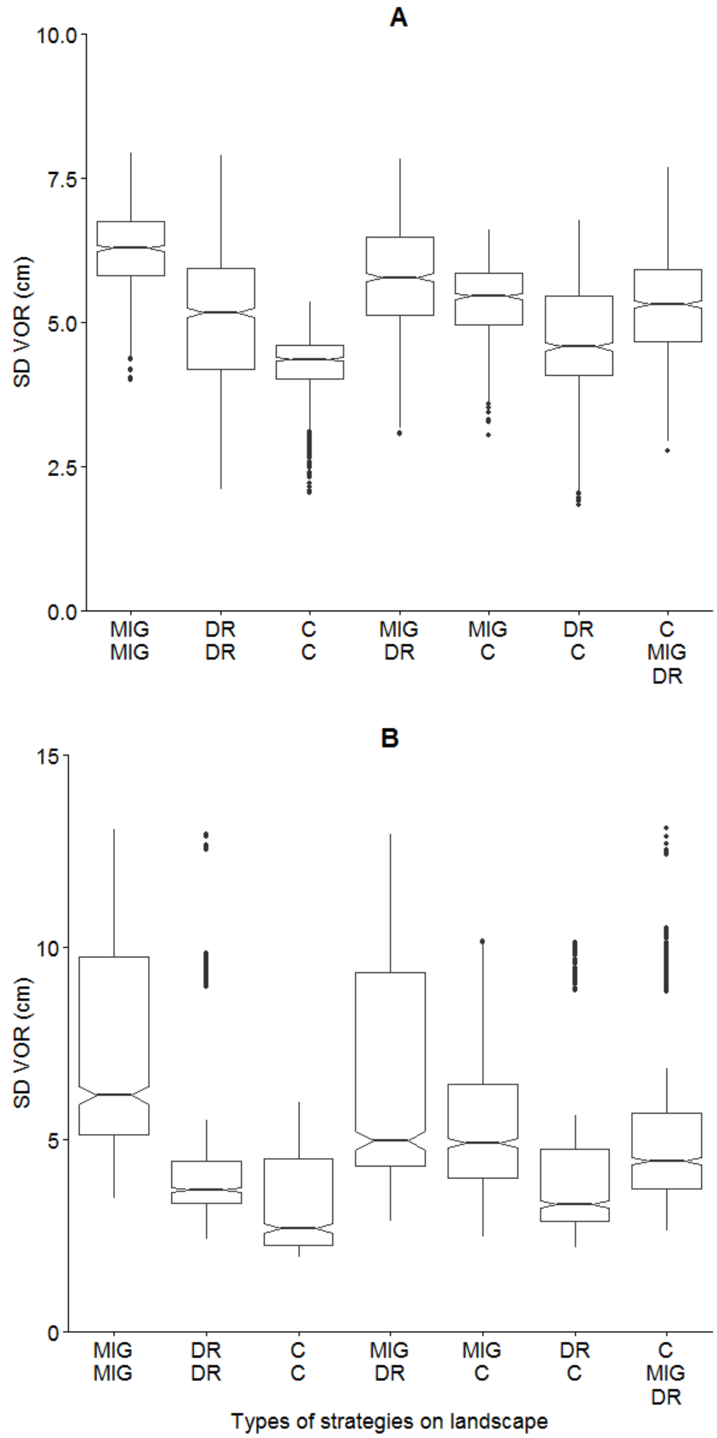

Figure 31. Mean heterogeneity (SD) in VOR (cm) on landscapes with various combinations of grazing strategies in 2014 (A) and 2015 (B). Notches indicate 95% confidence interval. Landscapes were simulated using random samples of empirical data from the Nebraska Sandhills, 2014-2015 (n = 7000).

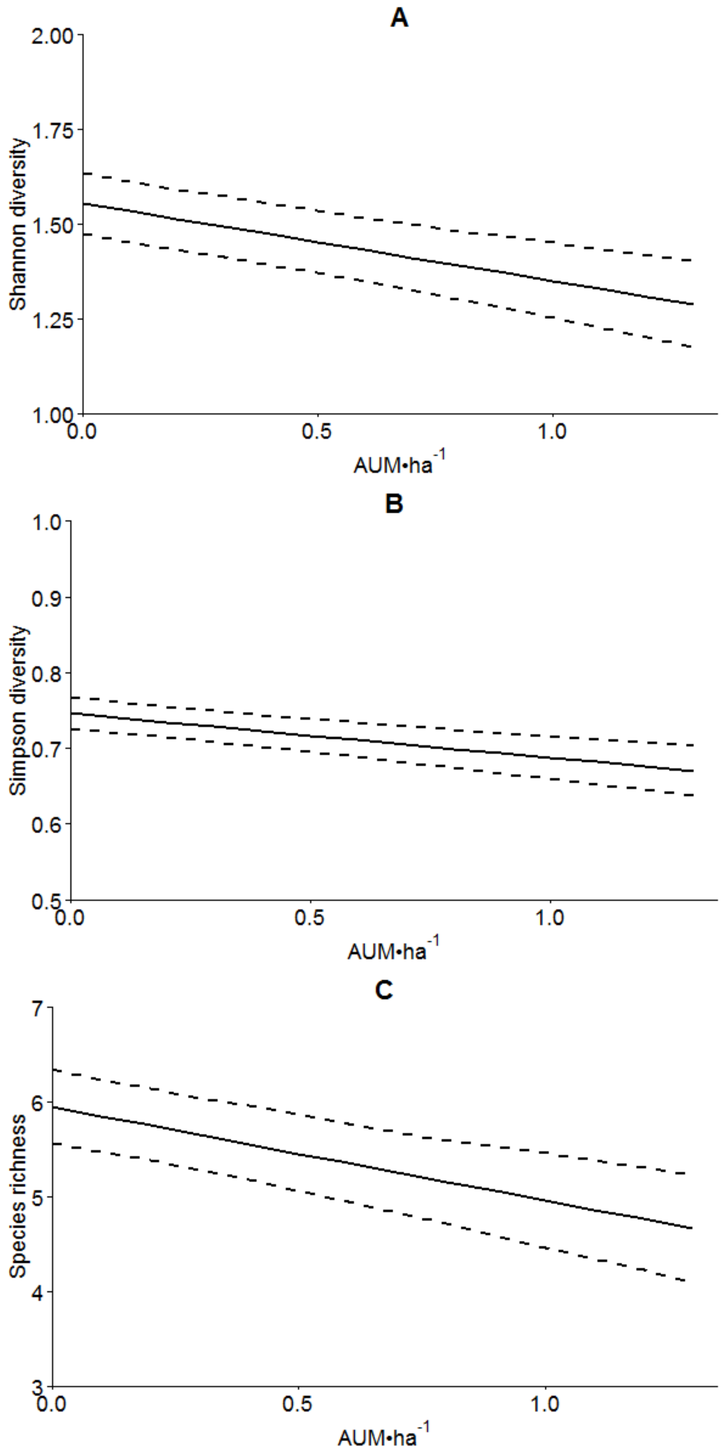

Figure 32. Relationship of Shannon diversity (A), Simpson diversity (B), and avian species richness (C) to warm-season stocking rates in the Nebraska Sandhills, 2014-2015.

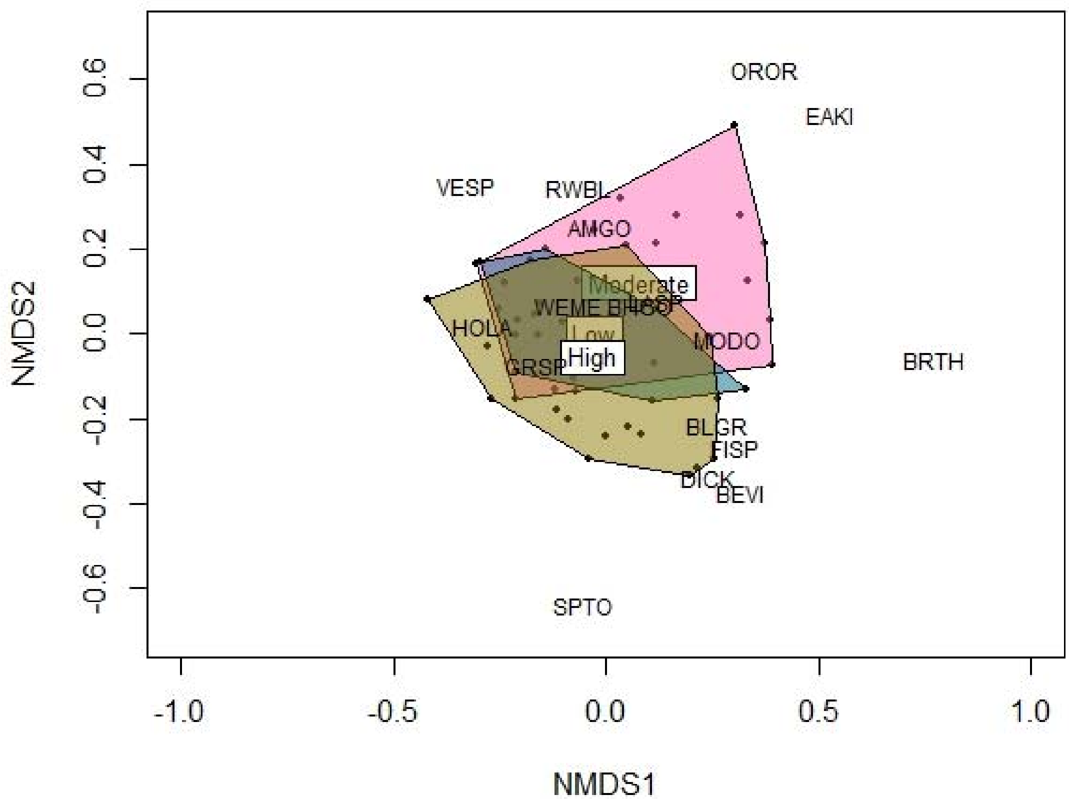

Figure 33. Non-metric multidimensional scaling plot of similarity indices for bird communities in pastures grouped by the different grazing management intensities in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. Brown = high management intensity (> 6 pastures); pink = moderate grazing intensity (3−5 pastures); blue = low moderate intensity (< 3 pastures). Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

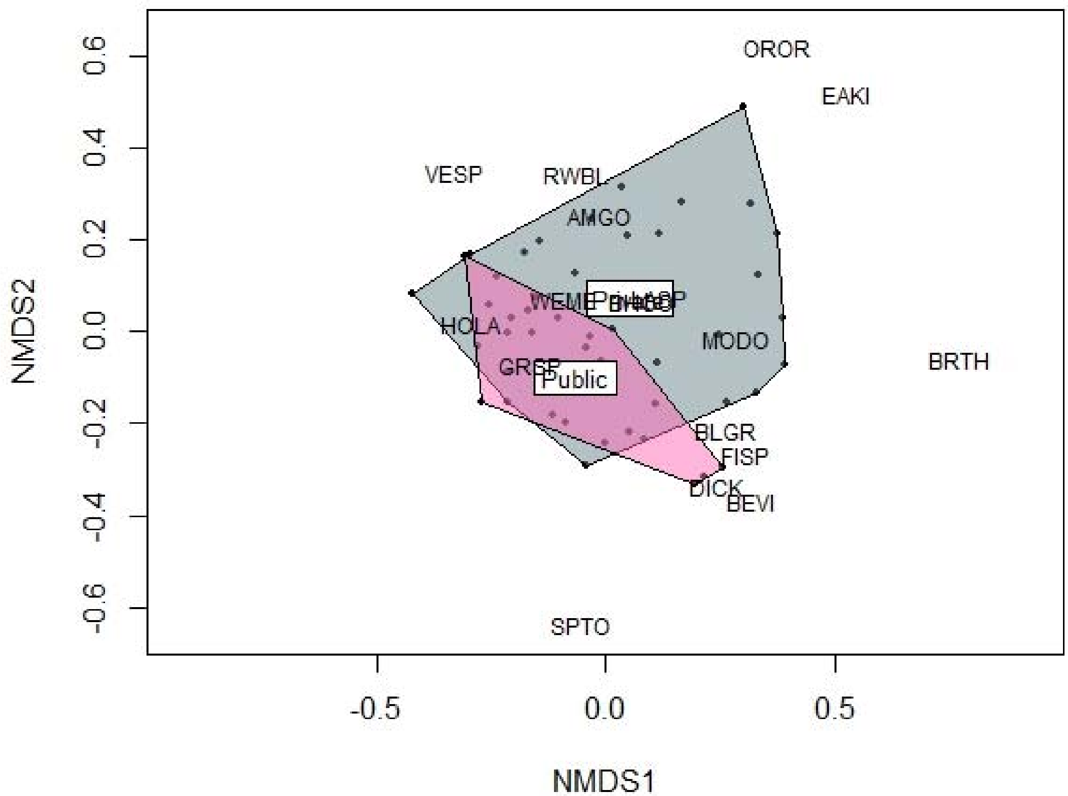

Figure 34. Non-metric multidimensional scaling plot of similarity indices of bird communities in pastures grouped by ownership in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. The colored overlays show public (pink) and private (grey) ownership. Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

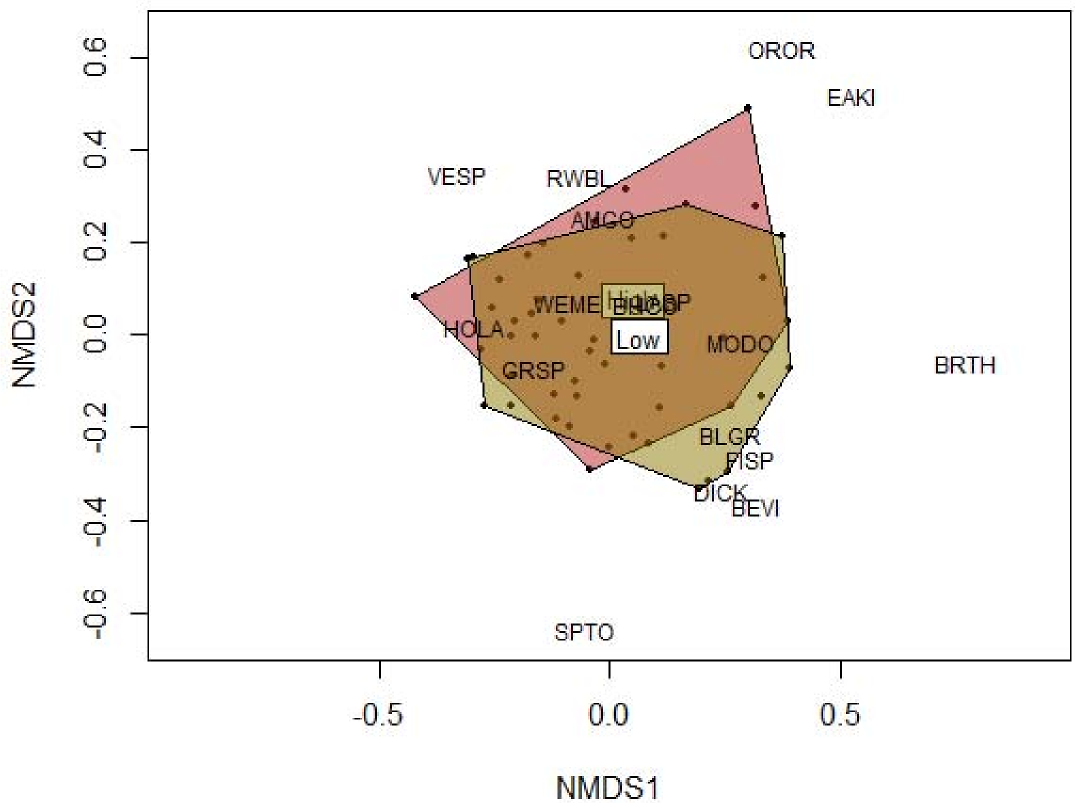

Figure 35. Non-metric multidimensional scaling plot for bird communities grouped by stocking rate in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. The colored overlays indicate high (pink) and low (brown) stocking rates. For bird abbreviations see Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

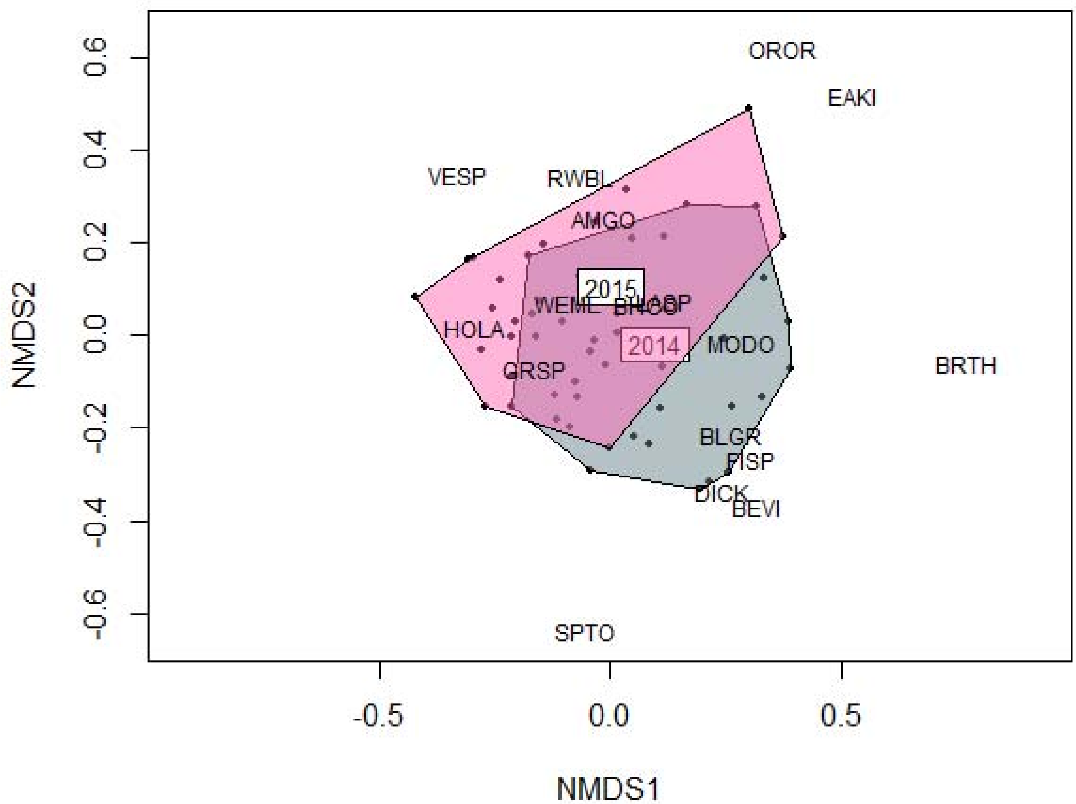

Figure 36. Non-metric multidimensional scaling plot of bird communities in pastures grouped by years in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. The colored overlays show data from 2015 (pink) and 2014 (grey). Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

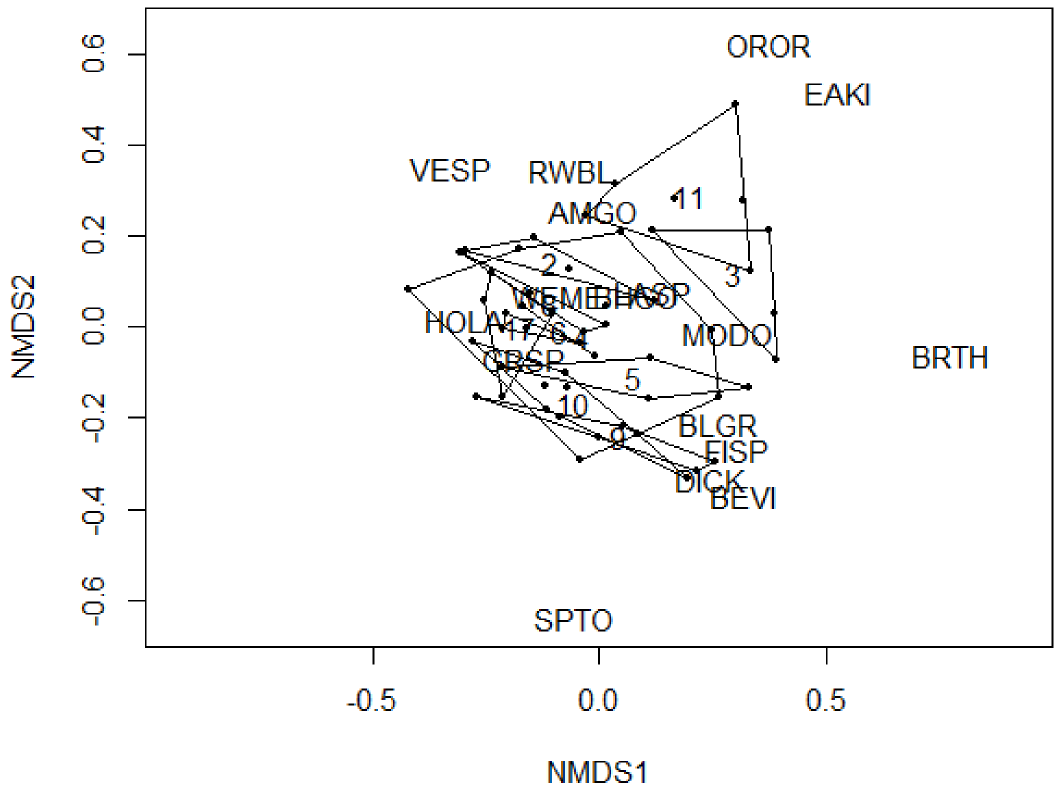

Figure 37. Non-metric multidimensional scaling plot of songbird communities in pastures, grouped by management units in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

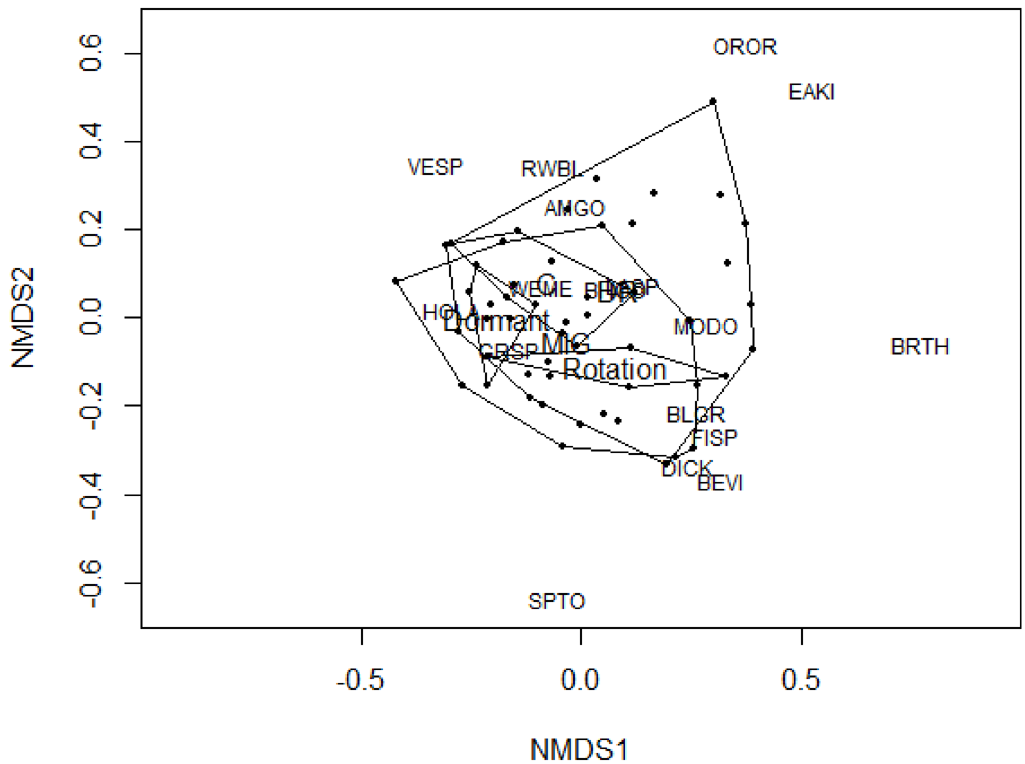

Figure 38. Non-metric multidimensional scaling plot of songbird communities in pastures grouped by grazing strategy, in the Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch).

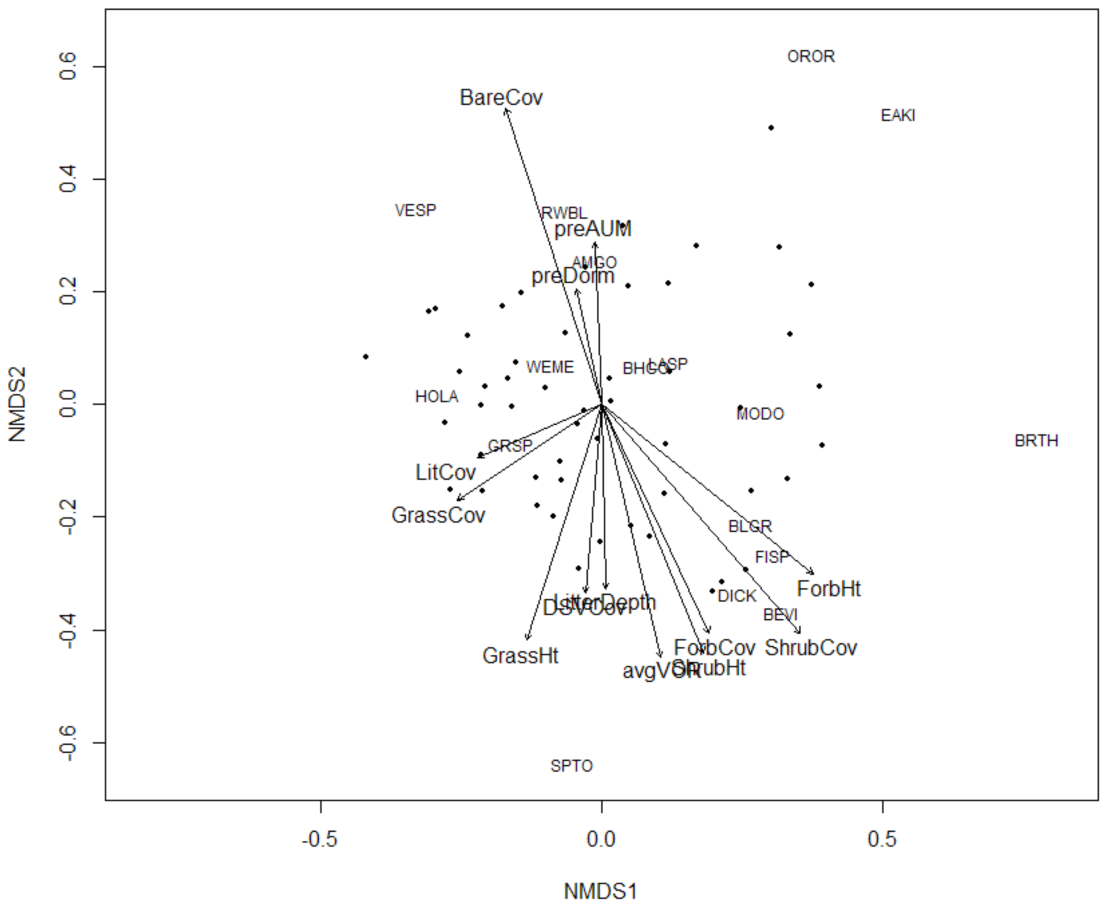

Figure 39. Non-metric multidimensional scaling plot of songbird communities in pastures overlaid with vegetation structure variables of interest, Nebraska Sandhills, 2014-2015. Points are pastures, and are arranged so pastures with more similar bird communities are closer in space; bird species in a given area of the plot indicate greater abundance of that species in that region of the plot. Arrows point in the direction of increasing vegetation measures. Bird abbreviations: SPTO (spotted towhee), BEVI (Bell's vireo), BRTH (brown thrasher), EAKI (eastern kingbird), OROR (orchard oriole), RWBL (red-winged blackbird), VESP (vesper sparrow), MODO (mourning dove), HOLA (horned lark), GRSP (grasshopper sparrow), WEME (western meadowlark), BHCO (brown-headed cowbird), LASP (lark sparrow), AMGO (American goldfinch). Habitat abbreviations: BareCov (bare ground), preAUM (previous year's stocking rate), preDorm (previous dormant season's stocking rate), LitCov (litter cover), GrassCov (grass cover), GrassHt (grass height), LitDepth (litter depth), DSVCov (standing dead vegetation cover), avgVOR (mean visual obstruction reading), ShrubHt (mean shrub height), ForbCov (forb cover), ShrubCov (shrub cover), ForbHt (forb height).

CHAPTER 4: Beef producers' perceptions of vegetation heterogeneity in the Northern Great Plains[3]

ABSTRACT

The rangeland profession has shifted to managing for vegetation heterogeneity in addition to beef production. Most remaining native rangelands are owned privately; however, there is little understanding of private producers' opinions about managing for heterogeneity, even though it will be imperative to engage private producers in rangeland conservation to prevent continued declines of rangeland wildlife. Previous research that examined the opinions of heterogeneity used a quantitative approach, but a qualitative approach is more useful in studying issues with little previous research. Thus, I conducted open-ended interviews with 12 beef producers in North Dakota, South Dakota, and Nebraska to gain a deeper understanding of their opinions about heterogeneity (specifically, the ends of the habitat spectrum in rangelands), and the techniques that can be used to increase heterogeneity (e.g., using fire, allowing prairie dogs to expand, etc.). My findings revealed a strong desire among private producers to maintain control over their operations, part of which involved reducing risks and being careful with who they trusted as advisors. Further, some of the characteristics associated with increased vegetation heterogeneity (e.g., bare ground) were associated with poor management, which will be problematic for conservationists who see a need for more bare ground in certain cases. The best way to encourage private producers to manage for heterogeneity with the tools available (e.g., fire) is to show them that heterogeneity is a viable option

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[3]Chapter formatted for submission to Ecology and Society. Co-authors: Mark A. Burbach, Larkin A. Powell, Walter H. Schacht

for their business. Many options are available to show producers the strategies that create heterogeneity, such as university ranches and experiment stations, but funding must be directed toward this goal.

INTRODUCTION

Rangeland biodiversity is declining as a result of both loss and degradation of habitat (Brennan and Kuvlesky 2005, Neilly et al. 2016). Rangelands are largely privately owned and managed (76% of the Northern Great Plains) and are underrepresented in protected areas, such as refuges and national parks, where biodiversity conservation is the focus (Samson and Knopf 1994, Hazen and Anthamatten 2004). Even when rangelands are owned publicly they often are leased to private individuals for beef production, which is the main industry in native rangelands (Freese et al. 2010). Thus, private individuals, mainly beef producers, will be the key to restoring and sustaining biodiversity in rangeland ecosystems (Neilly et al. 2016). Livestock production and wildlife conservation are not mutually exclusive (Krausman et al. 2009), but there are impediments to using livestock to manage for wildlife habitat on private land because of production goals and the producer mindset.

Increased livestock production is typically achieved by improving forage use through even grazing distribution (Vallentine 2001)(Fuhlendorf and Engle 2001, With et al. 2008), a strategy that has been embraced by producers and university Extension educators alike (Hart et al. 1988, Schacht et al. 2011). According to Toombs and Roberts (2009), improving livestock distribution was the primary use of the Natural Resources Conservation Service's (NRCS) rangeland investments from 2004-2007. Improving forage use and distribution across the Northern Great Plains may lead to structurally homogenous rangelands that greatly limit rangeland plant and animal biodiversity (Toombs et al. 2010, Becerra et al. 2013). This loss of heterogeneity is problematic because biodiversity, ecosystem services, and resilience are all at least partially dependent on structural heterogeneity (MacArthur and MacArthur 1961, McGranahan and Kirkman 2013, Hovick et al. 2014). The goal to continually increase production of livestock and efficiency of forage use on private ranches, then, is a possible cause of declining wildlife populations in Great Plains rangelands (Fuhlendorf et al. 2012), and biodiversity management is typically not a consideration in ranch management decisions (Knight et al. 2011). The lack of consideration of biodiversity in rangeland management was recently highlighted by a study that revealed temperate rangelands have the least intact biodiversity of all habitat types in the world, compared to historical values (Newbold et al. 2016).

Some range scientists are calling for a paradigm shift away from managing for even grazing distribution to managing rangeland ecosystems for structural heterogeneity at larger scales (Fuhlendorf et al. 2012, Freese et al. 2014). Various methods of restoring rangeland heterogeneity have been promoted in the literature (Fuhlendorf et al. 2009, Toombs et al. 2010, Johnson et al. 2011). However, most rangelands are privately owned (Freese et al. 2010), which complicates managing for processes that often occur at scales of management larger than a single ranch (Krausman et al. 2009, Fuhlendorf et al. 2012). Further, private landowners do not commonly work together to promote rangeland and wildlife conservation (Freese et al. 2014), although there are exceptions (e.g., Sandhills Task Force in Nebraska, http://www.sandhillstaskforce.org/).

Even though the human dimension of grazing management has been recognized as just as important as the ecological dimension (Briske et al. 2011), there is a knowledge gap concerning how private landowners' behaviors and attitudes contribute to increasing or decreasing rangeland heterogeneity on a landscape scale. Addressing this gap will be beneficial for ranchers, rangeland scientists, and advisors with state and federal natural resource agencies and conservation groups who have an interest in improving the resilience of rangeland ecosystems, improving rangeland biodiversity, and maintaining ecosystem services. Additionally, it is not possible for scientists to do intensive quantitative studies without first exploring the relevant issues with the study population. Thus, the purpose of this study was to explore landowners' opinions of vegetation heterogeneity and landscapes in relation to wildlife habitat in the Northern Great Plains. This study explored livestock producers' opinions of different types of habitat that are required by different species of wildlife, such as bare ground and denser grass or shrubby areas, and also explored their opinions regarding different ways that these habitats can be created, such as through grazing, fire, and burrowing mammals.

METHODS

To meet the purpose of this study, I chose to use a qualitative, naturalistic approach, which involved in-depth interviews. In-depth interviewing was used to collect rich and contextual qualitative data for this research study; this strategy is useful because it allows participants to talk both broadly and deeply about topics related to the vegetation heterogeneity, and allows the researcher to explore and clarify topics that arise during the interview (Marshall and Rossman 2010). Qualitative data are particularly well-suited for developing a deeper understanding of producers' experiences (Sayre 2004, Marshall and Rossman 2010) and thus fit the purpose of this research.

Participant characteristics

Qualitative interviews for this study were completed in Nebraska, South Dakota, and North Dakota. In all three states, I conducted interviews with producers in the western arid and semi-arid rangelands of each state. To identify beef producers for this study in Nebraska, I asked key informants from the University of Nebraska Extension Service to provide names and contact information for ranchers in Nebraska who would be willing to speak with me. In South Dakota, I contacted both a Natural Resources Conservation Service agent and members from the South Dakota Grasslands Coalition for names and contact information of beef producers. In North Dakota, I contacted mentors from the North Dakota Grazing Lands Coalition about completing interviews.

I completed eleven interviews with twelve individuals (one interview was with a husband-wife team), four in ND and SD, three in NE. Beef production was each participant's primary job; all but one of the operations were commercial cow-calf operations, and three offered custom grazing. Three of the producers also had secondary jobs. The beef producers I interviewed were predominantly men between the ages of 30 and 70, which is comparable to producer characteristics from the USDA Census of Agriculture (United States Department of Agriculture 2015). Grazing strategies used varied among the different ranches, with some following Holistic Range Management

(HRM) and others using more traditional practices like season-long, continuous grazing or deferred rotation grazing. Briefly, the HRM is "a way of producing a predetermined goal for the land in question" (Savory 1983), and is often associated with the rotation of a herd of livestock through many small, intensively managed paddocks.

Data collection

Beef producers were interviewed using a semi-structured, open-ended interview guide (APPENDIX G), and clarification and probing questions were used during interviews on topics that had not been previously considered by the researcher. A series of images of rangelands and management schemes (APPENDIX H) were used to help producers visualize the landscape and the various management scenarios that were the topics of questions. Each interview lasted approximately one hour. Interviews took place in a location of the participant's choosing, most commonly their home. The interviews were audio recorded and transcribed verbatim.

Analysis

I used a thematic analysis to interpret the interview responses (Marshall and Rossman 2010, Creswell 2014). The first step in the analysis was to read through the interview transcripts to familiarize myself with the data. While reading through the data, I made memos to indicate commonalities or disparities among beef producers. After this process, I coded each transcript using in vivo codes with the aid of MaxQDA analysis software (VERBI Software 2014). After coding was completed, an iterative process was used to collapse codes into overarching themes. The themes were generally limited to this study's central phenomenon of ranch management for vegetation heterogeneity, which helped ensure the themes were related to the research question (Saldaña 2013, Creswell 2014). I completed the process of coding and collapsing codes into themes twice approximately 6 months apart, to ensure that there was consistency in the interpretation of the interview data.

Rigor

One strategy for improving the reliability of qualitative research is to maximize the diversity of perspectives available in the data collection (Marshall and Rossman 2010). Having participants from three different states and varying backgrounds helped to increase the diversity of the sample, thus increasing the reliability of the data. This may also make the scope of inference of the findings broader.

I used member checking to ensure the findings were valid. To complete member checking, I mailed copies of the transcripts to participants and asked them to read the transcripts and alert me to any errors in my transcription of their answers or statements. Comments received from participants were used to revise the transcripts, and incorporated into the final themes and discussion where necessary. I also completed member checking with the initial findings to ensure that the themes and the supporting quotes were true to the participants' experiences and perceptions. None of the participants that responded requested any changes to the findings. Finally, an expert review was completed by the research advisor to assess the reliability of the findings.

Ethical considerations

To ensure ethical standards of research were met, the study was reviewed and approved by the University of Nebraska-Lincoln Institutional Review Board prior to data collection. Participants were asked to read and sign a consent form (APPENDIX F) prior to completing the interview. The consent form explained the purpose of the study, the requirements of participation, and that the interview was confidential. I kept all documents associated with the participants' names on a locked laptop or in a locked desk at my office.

FINDINGS

The eleven interviews resulted in 141 pages of single-spaced textual data. Through a thematic analysis of the interviews, seven themes emerged relating to producers' views of heterogeneity, biodiversity, and ranch management. One theme had four sub-themes. Each of these themes is described below.

Theme 1: Maintain control by reducing risk and increasing flexibility

Producers constantly deal with things that are beyond their control, such as wild swings in the weather and swiftly changing markets for their products. Thus, it was important for the producers I interviewed to be able to control as much as possible about their management strategy, because this would ensure that the ranch would still be around the next year. Producers often do this by reducing risk and increasing flexibility wherever possible.

1.1: Making a living

All the producers I spoke with talked about the importance of ensuring that they could feed their families or otherwise make a living from ranching, and they could only do that if their ranching operation was prosperous. One producer said "I am still looking out trying to make sure I am going to have enough to eat next year and five years from now…. It's been my family's way of staying alive for 130 years."

However, one producer talked about how things are different today than they used to be, and that producers generally have more freedom today to try different things than their parents did, simply because the financial pressures they are facing are not as grave. He said "since all this land and the ranches have been in families so long, people don't have as much financial pressure as they used to…Just like my Dad, he didn't *want* to abuse the land, but he needed to make it work." He talked about the fact that much of the land, cattle, equipment, and inventory are paid off, and this allows beef producers today to be more considerate of non-production outcomes. Further, producers now have safety nets from the government that were only available to crop farmers in the past. These factors take some of the pressure off producers.

Other beef producers lamented that the promise of fast money seemed to encourage overgrazing and converting rangeland or CRP to cropland. With high cattle prices, one producer complained that a lot of people were overgrazing. Another talked about how his county used to be half cropland and half pasture, but now there was more than twice as much cropland as pasture, and he blamed this change on the high price of corn. Even so, the participants agreed that "we're all driven financially."

Some of the producers I interviewed were using incentive programs to help them maintain their income while also managing for conservation objectives. When I asked what might encourage a producer to engage in conservation activities, one participant said "Benefits. Usually that means either on the ground or quite frankly cash. The Great

Plains Project, when I started dividing my pastures, paid for 75% of the fencing. So most of these people are financially driven." Another said "I'm sure you dangle the monetary carrot in front of producers, they'd be willing. Money will make most people do anything." Thus, even though the promise of money can cause some producers to engage in practices that are bad for conservation (e.g., converting CRP back to crop), it can also be wielded by conservation agencies for the good of conservation and wildlife.

1.2: Managing for the weather

The weather weighs heavily on the minds of producers as an uncontrollable, unpredictable factor when they are considering their management options: "grasslands are awful tough to deal with because of drought and weather. So I used [my] irrigated land to change that variability." Many of the producers I interviewed talked about managing in such a way that protected them from drought specifically: "[Ungrazed areas] leave us some forage and protection for the next year even in a drought when we don't get good growth." Producers commonly assumed they would get inadequate rainfall over the next year, and thus managed their land with drought in mind, thus adding some flexibility into their operations. They reported trouble caused by mismanagement on neighboring land: "One pasture was overgrazed last year, but we've had quite a wet year, and the individual has gotten by with it. But if we wouldn't have gotten the rain, he was looking at selling a third of his livestock." This particular individual concluded that a producer who managed without the threat of drought in mind was apt to be living paycheck to paycheck, a situation that would be avoidable with proper management.

1.3: History of what works

Many producers talked about a reluctance to change because “the easiest way to lose your shirt is doing something different than grandpa did.” A change in management is a risk when there is a long history of doing things a certain way on a given ranch, and when that certain way has kept the family in business for multiple generations. However, there also was the recognition that it can be important to understand *why* something is done a certain way: “I think sometimes in our field, it’s very easy for people to get stuck in a rut of ‘well, we’ve always grazed the south pastures in July because Grandpa did’, and we don’t have a reason why.” This statement agrees with another beef producer who said “if you want to be rich, don’t ever experiment. You see what somebody else does, what works.” Thus, by continuing to do what had worked in the past and only what had worked for others, beef producers were able to maintain control and reduce perceived risk in their operations.

1.4 Change is slow

Most producers agreed that change will be slow and difficult because of unpredictable weather and the ranching culture. One producer talked about how it took him twenty years of observing, learning, and making small, incremental changes before he fully bought into the HRM. Another said “change happens one generation at a time, one funeral at a time.” One thing that speeds up change very quickly is the threat of going broke: I asked one producer why he had decided to change his management style in the past, and he responded “I was about to go broke.” Another said “what really pushed us over the edge was…no income. I had to figure out, how can I get this land productive without all these expensive inputs?” Finally, a third producer said “not being profitable speeds up change pretty quick." So, although change was often slow and difficult for producers I interviewed, there were times when change made sense and happened quickly. Change was often correlated with maintaining control and ensuring that the family would continue to be supported by the ranch.

Theme 2: Wildlife are not our focus

Many of the producers I interviewed appreciated wildlife on their land, and felt that their management strategy supported wildlife, but when asked about certain types of wildlife they clearly stated that wildlife was not one of their top concerns. For instance, one producer told me that "making sure I can still afford to pay the taxes is way more valuable to me than making sure the mountain plover has habitat." Some producers were not concerned about managing habitat for wildlife because they did not believe rangeland wildlife could ever be completely lost, or that perhaps ecologists try to position wildlife in certain habitat categories that the wildlife do not actually need (e.g., "wildlife tend to adapt…we try to put everything in these boxes").

Prairie dogs are a particularly controversial subject for beef producers, because of the view that prairie dogs degrade areas and compete with cattle for forage (Lybecker et al. 2002). This concern was voiced during interviews because I was interested in hearing producers' perspectives on prairie dogs when considering them as a keystone species that provide habitat for other species. One producer said "they're more of a nuisance than anything else…once they're established, that resource is essentially destroyed for anything other than a prairie dog town or wildlife habitat." Some producers even talked about prairie dogs being bad from an ecosystem standpoint, while at the same time expressing an understanding that they are part of the native ecosystem. The reason underlying this view of prairie dogs likely relates back to the first theme, with producers wanting to control their resource. Prairie dogs represent something that landowners can control, and beef producers typically have a desire to do so. One producer said “I don’t care what kind of program there is, prairie dogs need not be involved in ranching. I’d be very staunch on that point. They get out of control too quick.” Conversely, one producer joked that if he could have a shooting range for prairie dogs, and thus be making money off them, he might be more willing to host a prairie dog town on his land. Another producer echoed this sentiment: “[Imagine] I’m a farm manager and I’m working with absentee landowners, I need to have dollars. Bottom line dollars. If you have a guy that is living and working on his own land, you have to show him that managing for wildlife will also increase the productivity of his land.”

These negative sentiments for prairie dogs were also expressed in discussions about wildlife that requires more bare-ground habitat, like McCown’s longspurs (*Rhynchophanes mccownii*), mountain plovers (*Charadrius montanus*), or burrowing owls (*Athene cunicularia*). One producer said “I’ll be very honest with you, I have not given much thought to those species that require bare ground”, while another expressed that he was fine with birds that require denser vegetation thriving more so than bare- and short-vegetation birds thriving.

Although wildlife is not the focus for producers, a number of them talked about native diversity serving as a goal: “I see multitude of species, both plants, animals, and insects, as the benchmark or template of what we should be using in production agriculture." Another producers said "I think diversity and balance is very important. I'm a firm believer in the importance of diversity because we lost our diversity."

Theme 3: The miracle of animal impact

Prior to European settlement, animal impact in the Great Plains was primarily a result of large herds of bison moving through areas relatively quickly and small mammals, such as prairie dogs (Truett et al. 2001). Today, most animal impact results from domesticated livestock, but involves the same general impacts as bison: consumption of forage, trampling of vegetation, and the deposition of dung and urine. The producers that I interviewed held strong beliefs in the importance of livestock for the health of rangelands. About half of the participants I interviewed followed HRM, and talked about the importance of animal impact and how the benefits from grazing livestock were almost like a miracle. One said "as far as the grass that comes, the weed suppression, what it does for the trees, I mean it's unbelievable. And it's all animal impact." Many of the landowners who participated in these workshops also talked about how their management was recreating what the bison had done for millennia, with quick heavy impact and then long periods of rest. One producer said "that's exactly what all of us are trying to do, mimic nature. That same concept. Just much smaller scale."

On the Great Plains, bison movements were strongly associated with fire (Biondini et al. 1999), but fire was not part of the management strategy of any of the producers I interviewed. When I asked about fire, landowners mostly agree that fire was a "tool in their toolbox", but that they had no interest in using it. Private producers view fire as negatively affecting rangeland productivity and forage availability. For instance, one producer said “I don’t ever want to burn a pasture that I can graze. If I can stomp the material into the ground it makes more sense to stomp it in than it does to burn it off.” This was echoed by producers who followed HRM: “Myself personally I think fire is not good, I think it can be a tool, I think it’s overused in a lot of senses.” Because this sentiment was echoed both by the producers who did and did not participate in HRM, it is obvious that the distrust or dislike fire is strong among producers in the Great Plains.

Grazing by livestock was the principal tool for rangeland management by beef producers I interviewed, especially because producers viewed fire as unsafe and not providing any benefits that were different from grazing. One of the beef producers I interviewed lived on the outskirts of an urban center and practiced regenerative land management. He explained how fragmentation in his area made the use of fire impossible, even though he thought it could be beneficial. Another producer said “I can string up an electric fence a whole lot faster than I can put a fire out.” Other producers were more concerned with the smoke from fires causing problems for neighbors and nearby communities, indicating that they were considering multiple factors when making management decisions. Thus, livestock were easier to manage than fire, and safer than fire as a management tool. One producer said “in this part of the world, that [residual dead vegetation] can be maintained for years if it isn’t broken up by something. Once it falls over, it can’t be broken up by anything but hooves.”

Theme 4: Managing to the middle?

I asked participants’ about the different types of habitat that are required by the spectrum of bird species that exist in the Great Plains. Most of the participants thought that there was a lot of habitat variability across the landscape, sometimes because of management and sometimes because of abiotic factors. For example, one producer talked about some spots in his pasture not being able to support any grass: “We have bentonite clay pan areas that pretty much stay bare, they used to be bigger areas that were bare, now we shrunk them way down.” This particular producer was using management that encouraged the growth of vegetation in bare areas, and the reduction of bare areas was desirable. One producer’s statement sums up what seems to be a general mindset among producers, especially those who use the HRM:

> Well I’m trying to be here in the middle. And there’s a reason. Originally when we first started talking about range management, it was take half leave half. With the idea of having grass left over, was kind of an achievement. But I find that it isn’t so, that you need to graze down fairly hard in order to control weeds. So I think you need to lean down toward the short end of grazing. So what we do is move a lot of cattle in and graze it off pretty hard, for less than 30 days, and then get out.

For producers, “managing to the middle” was a product of managing their risk. Producers did not want to risk soil erosion, they want to be resilient in the face of drought, but they do not want to let too much grass remain unused because that is considered wasteful and risks wildfires. One participant said “I think cover is the key to a lot of this…you have to keep the soil covered, you have to keep your rangeland covered.” Most producers did not want bare ground because this would negatively impact long-term production and cut into their net return; however, some ranches have an area that is consistently used to extremes because of logistics: “I have a calving area and just dedicated that to destroy that piece of land.” If many producers have a dedicated calving pasture, there is likely some habitat at the bare-ground end of the spectrum across the landscape, which is necessary for wildlife diversity.

Most of the producers I interviewed were strongly opposed to managing any of their pastures expressly for bare ground: “You’re going to have a real difficult time convincing most holistically-minded ranchers that they should have bare ground. That, for one thing it’s just so devastating to the soil ecosystem.” Some of the producers I spoke with talked about how they had worked very hard to move their operations away from having a lot of bare ground and that it is a constant battle to ensure that the land does not go in that direction.

Theme 5: Perceptions of the good rancher and maintaining relationships

Most producers I interviewed were concerned about being viewed as a good rancher by their peers, because as one participant stated “everybody looks over the fence.” Further, some spoke about how some of their neighbors were not being good ranchers. This reality has an impact on how producers are managing their pastures. When I asked participants what their opinions were of some photos that showed bare ground, a common response was “bare ground just means someone’s not monitoring something very closely” or “that’s a detriment of overgrazing…you find those things when things are overgrazed.”

The strong disapproval of prairie dogs has not changed even as scientists have gained a better understanding of their relevance to rangeland ecosystems (Davidson et al. 2012). The desire to maintain neighborly relationships is one potential reason underlying the slow acceptance of prairie dogs. One participant said this:

> If a prairie dog town got over onto my neighbor’s and he wasn’t getting any money for it, and despised prairie dogs and wouldn’t care if someone was willing to pay him $10,000 a year for a prairie dog town, then that causes a conflict between my neighbor and I, and I don’t want that.

A different participant said “money may not be enough to keep friendships” when prairie dogs are involved. The same might be said for using prescribed fires: “If I go out here and light a pasture on fire my neighbor in going to hate me.” One participant said outright that “There’s a lot of fear of what your neighbors are going to think or what they’re going to say that holds a lot of things back.” Maintaining good relationships in a ranching community is important; thus, neighbors’ perceptions can limit change and the acceptance and adoption of different management strategies. On the flip side, these relationships can encourage change, like increased efforts to control invasive species. One producer mentioned how he was very happy to help his neighbors implement a grazing management program that was similar to his own, after they expressed an interest in obtaining similar results.

Theme 6: Trust insiders, mistrust outsiders (in-group versus out-group)

The participants I interviewed seemed to naturally trust the motivations and intentions of people within their communities, like cattlemen’s associations, and naturally mistrusted those who were from the outside, like non-profit organizations. One participant stated that they want to know where outsiders’ money was coming from, or in other words what their underlying motivation was for speaking with producers. With familiar sources of information, or individuals who interact regularly with the producer community, there is a level of trust and understanding that is not present when a non-profit organization tries to work with producers: “Nobody likes to be told something, which is the way a lot of conservationists come across.” One participant described why he trusted the Grazing Lands Coalition, a grassroots organization, in his state: “I know a lot of the guys that are on their board, or have a lot of the influence with them and I trust their opinions."

Generally, producers reported some level of disregard or distrust of information coming through outside or unknown channels. Many of the participants talked about how researchers or scientists often do not or cannot understand the intricacies of ranching and how everything a family does revolves around their business, saying "They're scientists, they don't come live in our shoes," and "I bet there's very few of your ecologist buddies that ever get out on a ranch. I mean to actually talk." Participants talked about how research is done in a controlled setting: "Yeah, the university did it, and they can control different things", and "they have plenty of research, but it's the application that they lack." Participants also lamented the abundance of resources that a university or research organization has, which gives them the flexibility to try risky activities, approaches that are not available to most producers. Finally, some participants view some research as patronizing: "It's the PhD attitude. I'm just, we're just dumb ranchers, and I'm the PhD. When you sit down, you gotta get past that."

A remedy for this may come from finding common ground and having a positive attitude towards the ranching community. One participant had this advice for fostering a productive dialogue: "I think it's really important to approach it to understand enough about both sides that you can really find a common ground." A number of participants commented that the only reason they were willing to speak with me for their interview was because I had asked a university Extension agent in their area if they could get permission for me to call. I made a link to the ranching community through an individual they trusted. Another participant said “First they have to know something; they just can’t be a stand-around-feel-gooder.” Some participants talked about Audubon’s Bird Friendly Beef program, and how Audubon had approached the producers for advice and consulting: “Get those partnerships going. I’ve actually been working with Audubon since they actually approached us. Those kind of groups make me kind of nervous. But he wanted to talk to me, so we talked.”

Theme 7: Love of rangelands

I first asked participants to describe what they valued in the rangeland landscape. Participants clearly loved not only the rangeland landscape, but also their role in protecting and managing their land. One participant said this about the importance of protecting rangeland:

> The rangeland plays a major part in human’s existence…I mean it’s no different than eliminating rainforests. There’s the same value to me in [rangeland] as what there is a rainforest, or any forest for that matter. It’s all part of a balance that we need to maintain as a society.

Many of the participants talked about the love of wide open spaces, or of being able to see long distances. One participant said “It was the life, living in the country, and that feeling of wide open spaces, working hard and sleeping well at the end of the day.”

Even with the strong belief in the importance of ranching and rangelands, there were mixed goals for the next generation. Multiple participants were encouraging their children to get into ranching and agriculture and enjoyed teaching them about the rangeland, while a different participant had told his children to get out of agriculture, saying “I don’t believe it’s really a viable way to make a living in the future.” Most of the participants, however, were excited and encouraging to the younger generation. “So many people in agriculture aren't very positive. I mean it's a challenge, it always is, but there's so many opportunities." Two separate participants had been told by their parents to leave, get an education and a job, which they both did, but later they went back to ranch. One said "we moved back for family. Well, family means the ranch."

The participants also expressed dissatisfaction in the way that society viewed them and their livelihoods: "We have to defend our actions all the time. We spend so much time defending ourselves in what we're doing, that we don't have time to do the good things." Some participants were hopeful that the efforts they have been making are improving their reputation. "We have the responsibility to educate these urban folks, and apparently we're getting a little better at that." One participant contradicted these statements with "I get really tired of hearing that farmers and ranchers are the best caretakers of the land." To put his statement in context, this participant was frustrated by the continued conversion of rangeland and CRP to cropland, and what he saw as extensive degradation of rangeland through inappropriate grazing practices.

DISCUSSION

Efficient and sustainable beef production is paramount in the private producer's worldview. Although there has been a paradigm shift within rangeland conservation circles towards managing for heterogeneity (Fuhlendorf and Engle 2001, Freese et al. 2014), my interviews showed that a similar shift has not occurred among private producers or those who advise them. Rather, the private producers I interviewed managed their land for beef production and were very aware of how their management affected the sustainability of their ranch from the standpoint of beef production. These disparate views among conservationists and those managing the land sets up a dichotomy that must be overcome if rangeland biodiversity is to be restored.

The producer as steward

The beef producers I interviewed held strong views about what qualifies as good stewardship of rangelands, including sustainable use of the forage resource, water infiltration, preventing soil erosion, and ensuring that there is vegetation cover on the ground whenever possible. The producers observed ecological benefits, such as improved plant and insect diversity, in response to implementing stewardship practices. Inefficient use of forage plants for livestock production and allowing bare ground to expand are viewed as poor stewardship. These factors align closely with the rangeland health paradigm, which is used by both government agencies and university Extension educators when providing technical assistance to producers (Symstad and Jonas 2011). Thus, beef producers view themselves as stewards of their rangeland and are concerned about rangeland health. Plant diversity is appreciated because it assures good vegetation cover and sustained forage production in variable environmental conditions among years.

From the perspective of the beef producers I interviewed, fire was seen as negative because it removes forage for livestock. From the rancher's stewardship perspective, it is also logical that fire can be seen as negative because many view fire as degrading rangeland by creating bare ground, thus decreasing rangeland health as it is typically measured by the USDA (Briske et al. 2005, Symstad and Jonas 2011). Thus, fires do not easily align with livestock production goals, and they do not align with stewardship goals. This viewpoint is supported by NRCS policies: landowners are sometimes paid to not graze after a fire even though functional rangelands have fire-grazing interactions and grazing following fire does not necessarily have a negative consequence (Allred et al. 2011, Scasta et al. 2015).

There were strong views among private producers I interviewed that "prairie dogs have no place on the ranch". This most likely stemmed from both the stewardship perspective, where bare ground is bad when assessing rangeland health, and the production perspective, where prairie dogs compete with livestock for forage (Lamb and Cline 2003). However, producers may internalize disparate views about prairie dogs: that prairie dogs are a natural part of many rangeland ecosystems, that "God must have put prairie dogs there for a reason", but that they should be eradicated. State and federal policies that support the control and eradication of prairie dogs support the production and stewardship perspectives of beef producers, where the goals are to decrease bare ground and increase vegetation cover.

Soil health was an important consideration for many private producers I interviewed, especially those who followed HRM. In situations where a beef producer is restoring cropland or degraded areas to rangeland, strategies for improving soil health may be an important starting point for restoration, where HRM was initially focused (Savory 1983). For instance, in a system that is constantly disturbed, it is important to keep the soil covered to prevent or reduce erosion (Rahm and Huffman 1984). Because of society's continued aversion to livestock grazing in the western USA (Fleischner 1994, Gutwein and Goldstein 2013), the adoption of rotational grazing practices may have increased because this strategy has been used to reduce degradation (Gutwein and

Goldstein 2013). The continued belief in the power of livestock grazing, as was described in the "miracle of animal impact" theme, is supported by NRCS policies that promote rotational grazing through fence installation at the expense of other management goals (Toombs and Roberts 2009).

Challenges to overcome

Some producers I interviewed had worked very hard through carefully planned grazing management to reverse trends of increasing bare ground, degradation, and erosion. Thus, asking a producer to increase bare ground habitat on their ranch for the benefit of certain wildlife species is problematic because it increases risk and decreases flexibility. In a volatile system like the livestock industry, moving beyond the basic need of providing a living for their family to higher level considerations, like wildlife management, may be difficult to justify (Maslow 1954). This is a possible reason that the paradigm shift occurring among some rangeland professionals has not crossed to private producers; it is easy for those of us without "skin in the game", whose basic needs are met through means other than ranching, to make recommendations about management. Cinner and Pollnac (2004) used similar reasoning to explain why wealthier families in a fishing village in Mexico were more likely to be amenable to a holistic approach to conservation than poorer families; wealthier families' basic needs were met, whereas poorer families' basic needs were not met. Ted Turner, an iconic rangeland conservationist and a champion for rangeland biodiversity on his ranches (Turner Enterprises, Inc. 2017), is a perfect example of this dichotomy. Turner is not supporting his basic needs from his bison (livestock) operations, and thus has the ability to take ecological conservation into consideration. Some of the participants in this study noted Turner's support of prairie dogs, and even praised him for it, but stated they could not be expected to support prairie dogs in the same way.

The contradicting belief that producers held about prairie dogs may be explained by the theory of cognitive dissonance (Festinger 1962). This theory posits that when confronted with information that conflicts with their views, people are more likely to maintain their views than change their attitudes or actions based on the new information, and may subsequently avoid situations where their views are challenged (Tanaka et al. 2011). However, cognitive dissonance can be motivational (Elliot and Devine 1994) and will have to be overcome to move towards managing rangelands as ecosystems on private land. Cognitive dissonance presents a unique challenge in that private producers may avoid information that challenges their beliefs, which will make the job of convincing them of the benefits of heterogeneity, fire, and even prairie dogs that much more difficult for outsiders, such as conservationists.

Another challenge similar to cognitive dissonance stems from the cultural cognition thesis, which suggests that individuals believe their behavior is socially beneficial when they and their peers find it honorable (Kahan et al. 2010). Thus, there is a self-reinforcing system that exists in agricultural communities, where there is a lot of pressure to manage in a way that is acceptable to the community, as was examined in the theme "perceptions of the good rancher and maintaining relationships". In this type of system, it may be difficult to enact change or to alter policies because of social pressures.

A final challenge is that heterogeneity is promoted by “outsiders” who do not necessarily understand beef producers and their systems. This problem has been documented in forest ecosystems, where “experts” ranked certain management practices as high priorities but the forest owners considered the same practices to be of minor importance (Van Gossum et al. 2005). The authors dubbed these practices as “academic” because they were well known within academic (“expert”) circles, but landowners did not know about or care about them (Van Gossum et al. 2005). This is similar to the challenge in rangelands, where heterogeneity is not a concept the beef producers are aware of; in fact, during member checking one participant commented that a value of the interview for him and other producers was simply learning about the different habitat needs of wildlife.

Possible solutions

If policies can be changed based solely on scientific understanding, there are two that might be changed easily. Policies that encourage landowners to be wary of fire reinforce existing beliefs about the harmfulness of fires in rangeland systems (e.g., signs along federally owned rangelands warning of the day’s “fire danger”, paying landowners not to graze after a fire). State and federal policies about prairie dogs also run counter to ecologists’ current understanding of the keystone role of prairie dogs in rangeland systems (Davidson et al. 2012). Rather than moving landowners toward an understanding of natural processes in rangeland ecosystems, these policies perpetuate misconceptions about fire and prairie dogs. Unfortunately, it is unlikely that these policies will change simply based on available science, because policies are value-laden.

Although it is important for policies to reflect current scientific understanding to help overcome the challenges I laid out, policies are often developed based on the constituencies' attitudes and values. Thus, it will be very important for rangeland conservationists to work with producers from the bottom up to begin the hard work of changing attitudes (Serbruyns and Luyssaert 2006, Pasquini et al. 2010). University Extension staff have a key role to play by acting as liaisons between producers and scientists (Pasquini et al. 2010), as do current efforts by non-profit groups like The Nature Conservancy's Fire Learning Network, which engages multiple stakeholders in restoring landscapes that rely on fire (The Nature Conservancy 2015).

Research has shown that strong motivators for staying in ranching are often non-economic (Liffmann et al. 2000, Rowe et al. 2001, Ellis 2013). I found this to be true among my participants, as can be seen in the theme "love of rangelands." However, ranchers want to maintain status within their community and be viewed as good ranchers, and are working in a difficult industry, which may limit their innovativeness (Burton 2004, Didier and Brunson 2004). Thus, social status, respect among community members, and the condition of the industry must be taken into account when developing new programs for ranchers to promote vegetation heterogeneity. Engaging with a community's respected producers and early adopters to promote new management strategies might be a useful strategy.

A barrage of educational materials is unlikely to help change attitudes among producers, because producers are unlikely to engage with information that conflicts with their values (Tanaka et al. 2011). Additionally, policies may not be accepted if the producer has to change his current management strategies (Serbruyns and Luyssaert 2006). Fortunately, participants in this study provided a solution to these problems: "seeing is believing". This idea is in line with previous research showing that innovations must be testable prior to full implementation (Pannell et al. 2006). Universities, state and federal agencies, and non-profit organizations must begin using their resources to show landowners the research that reveals the importance of heterogeneity, burrowing mammals, and fire in resilient and productive rangeland ecosystems. Field days, research ranches, and landowner workshops that focus on examining heterogeneity are some tools available. Van Gossum et al. (2005) came to a similar conclusion in their forest management study, and suggested that "local pilot forests could prove to be useful in removing some of the practical difficulties." University Extension and NRCS, two groups mentioned as trusted, will be key in encouraging producers to attend these types of events, and can also help provide education in less formal settings (Pasquini et al. 2010). Supporting Extension and NRCS agents in the difficult task of transferring complex science to producers is the responsibility of those conducting the research.

Incentive-based programs are popular to encourage behavior change on private land (Langpap 2006), and are used in many rangeland settings (e.g., Conservation Reserve Program). Indeed, many producers in my study mentioned that money can be motivational. Incentives for conservation are based on the premise that loss of biodiversity is a negative market externality, and the incentive serves to mitigate the externality by encouraging the maintenance of biodiversity (Pascual and Perrings 2007). Some issues with incentives that producers in my study highlighted included the loss of control over their own operations and concerns over what neighbors may think of their changed management.

In some cases, producers may already be supporting rare rangeland species on their property. Many of the producers I interviewed mentioned that they believed their management was conducive to diverse rangeland wildlife. These producers would be left out of any schemes to encourage behavioral change; therefore, payments for ecosystem services might be another necessary program in rangeland ecosystems, where conservationists are attempting to prevent land use change (Smith and Sullivan 2014). Further, some producers are engaging in activities to promote the use of historical disturbances in the Great Plains, like using fire to prevent shrub encroachment, because they view it as necessary to maintain their livelihoods (Twidwell et al. 2013). Others are engaged in ecotourism and fee hunting as a means of supporting efforts in managing for heterogeneity (Edwards 2013). These efforts should be supported and encouraged.

Finally, although money can be a driving factor that makes incentive based programs useful, research has shown that recognition for conservation efforts can be an effective strategy for encouraging behavioral change or maintaining good practices (Pasquini et al. 2010). This type of incentive is also less expensive. Thus, any of the above practices can be supplemented with awards that recognize producers who excel at conservation, and when there is a lack of funding, this type of program may supersede monetary incentives or payments for ecosystem services.

Conclusions

Although economic considerations are a necessity to keep the ranch in business, and producers may discount information that conflicts with their long-held beliefs, I am confident that conservationists and producers can work together to create heterogeneity and use some of the tools available, like fire, to do so. The producers I spoke with enjoyed having most types of wildlife on their property, and were proud of the efforts they had taken to support that wildlife. The onus is on those of us who work with private producers to challenge their beliefs in a respectful way, and with a full appreciation of the fact that beef production is their livelihood and outsiders are often not trusted. Incentives, both monetary and non-monetary, will be useful in engaging producers in conservation, but so will effective education and engagement strategies, such as field days, workshops, and developing relationships with influential community members. Finally, the best timing for implementing new programs will be when there is an economic downturn, when producers will be more open to alternative forms of income (Powell 2015).

CHAPTER 5: Attitudes towards prairie dogs and fire predict intentions to support landscape heterogeneity in the Northern Great Plains [4]

ABSTRACT

Wildlife populations that require native rangelands in the Northern Great Plains are declining, partly because of loss of structural vegetation heterogeneity across the landscape; structural heterogeneity is lost when land management is focused on optimizing beef production. Even though much of the remaining native rangeland in the Great Plains is owned by private beef producers, there is a lack of understanding of their attitudes about heterogeneity and landscape management. I developed a quantitative survey instrument that was mailed to 2873 landowners in North Dakota, South Dakota, and Nebraska in February 2016 following a modified Dillman method; 596 usable surveys were returned. Latent variable analyses were used to examine the relationship of attitudes about heterogeneity and landscape management to individual characteristics, such as risk aversion. I also used structural equation modeling to examine the relationships between attitudes and behavioral intent using the Theory of Planned Behavior (TPB) framework. Attitudes about fire and prairie dogs, two things that can increase heterogeneity, were largely negative, and were important predictors of the likelihood of participants to engage in heterogeneity-promoting behaviors. Perceived behavioral control was very strongly correlated to heterogeneity-promoting behaviors. Using trusted institutions, such as University Extension, to foster more positive attitudes about fire and prairie dogs will be a key strategy for improving attitudes about

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heterogeneity. More positive attitudes about heterogeneity should help conservationists to promote management strategies that support diverse native rangelands.

INTRODUCTION

Conservation efforts on rangelands of the Great Plains, which are mostly privately owned and used for cattle grazing (Askins et al. 2007, Schutz 2010), can be challenging because landowners may fear government regulations and loss of revenue, and landowners often do not trust those wishing to engage them in conservation (Janssen 1996, Sliwinski 2017 Chapter 4). Additionally, beef producers may not see a need for conservation efforts on their land, because they view themselves as the best stewards of native rangeland (Kreuter et al. 2005, Cross et al. 2011, Gutwein and Goldstein 2013, Sliwinski 2017). However, land use change has caused losses of biodiversity in temperate rangelands, including North America's Great Plains (Newbold et al. 2016), which highlights the need for effective biodiversity conservation strategies in the region.

Even though there are still large and intact areas of mixed-grass prairie, research has shown that these areas may not be capable of supporting historical avian diversity levels because land management objectives commonly do not include wildlife habitat or vegetation heterogeneity (With et al. 2008, Sliwinski 2017 Chapter 4). Typical management of rangelands focuses on optimizing beef production (Sliwinski 2017 Chapter 4), which emphasizes the promotion of preferred forage species and increasing the efficiency of the grazing process in harvesting available forage plants (Vallentine 2001). However, this may serve to homogenize the landscape, thus diminishing the habitat types available for different wildlife species (Fuhlendorf and Engle 2001, Sliwinski 2017 Chapter 2). This is counter-productive to conservation of avian diversity because a diverse grassland bird community requires multiple types of habitat, from bare ground (e.g., mountain plovers [*Charadrius montanus*]), to tall and dense vegetation (e.g., Sprague's pipit [*Anthus spragueii*]) (Askins et al. 2007). Thus, it is crucial to maintain vegetation heterogeneity in rangelands.

Because many bird species have minimum area requirements (Ribic et al. 2009), it is also important to maintain vegetation heterogeneity at large scales. Unfortunately, decisions about land management are generally made within the boundaries of a single property. This creates islands of native rangeland, which does not allow for the restoration of large-scale ecological processes that are required in rangeland ecosystems. Restoring disturbance regimes, such as grazing and fire, could promote heterogeneity at the landscape scale, and is necessary for the conservation of native prairie species and biodiversity (Pickett and Thompson 1978, Fuhlendorf and Engle 2001).

Previous work has shown that there are inroads to working with private producers for rangeland conservation, but success depends on fostering trust and convincing producers through hands-on examples that conservation can be good for their operations (Sliwinski 2017 Chapter 4). Research that is conducted in a way that producers can see the benefits of conservation activities is greatly needed, as is research that examines producer attitudes about conservation. This research examines the latter.

A prolific area of research related to the decision-making process of beef producers has been the development and examination of incentive programs that encourage involvement in various conservation initiatives (Elmendorf 2003).

Secondarily, research has focused on the manner in which personality qualities such as empathy (Sheeder and Lynne 2011), risk aversion (Bhattacharyya et al. 1997), or self-identity (Burton 2004, Ellis 2013) might influence uptake of conservation initiatives. Previous qualitative research showed that attitudes about fire and prairie dogs were generally negative, that maintaining control was an important aspect of management, that innovation and change were difficult, and that maintaining social norms was important to producers (Sliwinski 2017 Chapter 4). The primary objective of this research was to examine producer attitudes about landscape management and strategies to create vegetation heterogeneity, and to determine the factors that influenced landowner attitudes concerning vegetation heterogeneity and landscape management on their land, such as risk aversion, control, innovativeness, or demographic characteristics, such as age and education.

A second objective of this research was to examine the relationships between attitudes and behavioral intent using the Theory of Planned Behavior (TPB) framework (Ajzen and Fishbein 1970), which would allow me to make recommendations for points of intervention to increase behavioral intentions. The TPB is widely used to explain social and environmental behaviors (Fishbein and Ajzen 2010), and posits that attitudes about the behavior, norms related to the behavior, and perceived behavioral control will influence planned behaviors (Ajzen 1991). Willcox et al. (2012) used the TPB to examine factors related to wildlife management activities on livestock operations, and found that only wildlife attitudes and subjective norms were predictive of intent to manage wildlife.

In this study, I assessed a number of behaviors landowners could participate in that could promote vegetation heterogeneity and behaviors that included multiple ranches.

METHODS

I mailed surveys to landowners in eight Nebraska counties (n = 846), eleven South Dakota counties (n = 1096), and eight North Dakota counties (n = 931) covering four ecoregions (Table 17). I surveyed counties in the western parts of these states, where more native rangeland remains, according to recent land cover maps; all counties but one were west of the Missouri River. In Nebraska, my mailing list was primarily secured through the Nebraska Information Technology Council, and was augmented with a mailing list purchased for one county and a mailing list secured through the county assessor for another. I secured mailing lists for North and South Dakota primarily through a data purchase from InfoGroup USA, and I augmented this list with a number of lists secured through county assessors. In acquiring the mailing lists (both purchased and through assessors), I requested only addresses for landowners with 1000 acres of land or more with the assumption that this would result in a list that was primarily rangeland managers, rather than crop farmers or hobby farmers. I excluded mailing addresses from outside the three states because this likely indicated absentee landowners.

Table 17. Distribution of surveys by state and region.

State	Region	Surveys
North Dakota	Northwestern Glaciated Plains	280
North Dakota	Northwestern Great Plains	661
Nebraska	High Plains	374
Nebraska	Sandhills	453
South Dakota	Northwestern Great Plains	1105

To reduce sampling error, I used a robust implementation strategy following a modified Dillman Tailored Design method for survey mailings (Dillman et al. 2009). Additionally, I followed many design guidelines that have been shown to increase response rates (Dillman et al. 2009), such as demonstrating gratitude for completing the survey and indicating that many peers have returned the survey. Finally, I included endorsements from a number of organizations known to beef producers, including the Nebraska Cattlemen's Association and the North Dakota Grazing Lands Coalition.

Variables and Measures

I was interested in ranchers' attitudes about landscape management and strategies to create vegetation heterogeneity that promote rangeland conservation. The variables that I measured included attitudes about heterogeneity management, landscape management, temporal vision, behavioral intent, perceived behavioral control, land use values, innovativeness (social innovativeness, exploratory acquisition of products, and exploratory information seeking), individualism/collectivism, social norms, endangered species values, and risk aversion. To measure these fourteen variables, I used fourteen separate scales. A scale can contain one or multiple sub-scales, and each sub-scale usually contains multiple items. A scale is used to assess a given attitude, cognitive factor, intention, etc. Each item is a statement that the participant agrees or disagrees with. Each scale is described below. Demographic information was also collected.

Vegetation heterogeneity

Freese et al. (2014) proposed ten strategies for managing for heterogeneity; I used this framework to develop a scale to assess attitudes related to vegetation heterogeneity. I developed sub-scales for eight of the ten strategies of this framework. I omitted the "size of management units" strategy because I had a separate scale for landscape management, and the "temporal ecological variability" strategy because the suggestions in this strategy were similar to other strategies in the paper. After developing 23 items for the scale, my academic advisors reviewed the scale to assess face validity. I then conducted a modified Q-sort (Hoffman 2013) to test the construct validity of each item; construct validity is the degree to which an item fits into the sub-scale for which it was intended. To complete the Q-Sort, participants were asked to match each item to a definition, and to indicate how confident they were that their assessment was accurate. The initial Q-sort was conducted through Qualtrics online survey software (Qualtrics 2015), and I received responses from 30 participants on 23 items. Construct validity was achieved when there was ≥ 80% agreement among participants on the item matching the definition, and an average ranking of 5.6 on a 7 point Likert scale for confidence of accuracy (where 1 indicated poor fit and 7 indicated best fit). Eleven of the statements failed to meet the required criteria; I revised these statements and completed another Q-sort with 34 different participants. Eight of the statements were sufficiently improved, but three statements did not meet the requirements and were removed from the survey. This process resulted in 20 items that had high construct validity and represented eight of the ten strategies from the Freese et al. (2014) framework (Table 18).

Landscape management, temporal vision, T+E species

Rickenbach et al. (1998) developed three scales to measure attitudes related to three dimensions of landscape management (management across property boundaries), and I used two of them: landscape perspective and temporal vision. Landscape perspective refers to whether landowners believe their property fits into the large ecosystem, and temporal vision refers to whether landowners believe their property should be managed for future use (Rickenbach et al. 1998). The landscape perspective scale had 8 items (Table 19), and the temporal vision scale had 7 items (Table 20). These scales have been used subsequently for rural and individualistic communities in New England with robust results (Belin et al. 2005). I included two items from the third dimension of landscape management, which was called “small-scale sensitivity” (Table 21, Rickenbach et al. 1998) to assess participants’ values related to endangered species.

Perceived behavioral control

To assess perceived behavioral control I developed a six-item scale (Table 22). This scale included three items to assess perceived personal control (e.g., “I am able to manage my land to achieve desired outcomes.”) and three items to assess perceived control over the greater system (e.g., “How I treat my land affects the overall environment in my county.”). The construct validity of these items was assessed using the same Q-sort method described above. One statement was re-written to improve its construct validity.

Land use values

To assess the relationship that the participants had with the land I used the Land Use Values scale (Sweikert, in press); this scale was developed expressly for use in farming and ranching communities. The Land Use Values scale has 13 items in two domains: human centric and nature centric (Table 23). These domains were used to determine which of four categories each participant fell into: eco-social, naturistic, disconnected, or humanistic. Participants who ranked above the median score for human centric and below the median score for nature centric were categorized as humanistic; participants who ranked above the median score for human centric and above the median score for nature centric were categorized as eco-social; participants who ranked below the median score for human centric and above the median score for nature centric were categorized as naturistic; and participants who ranked below the median score for human centric and below the median score for nature centric were categorized as disconnected.

Innovativeness

Innovativeness was of interest because it is related to the uptake of new technologies and products (Goldsmith and Foxall 2003) and innovation can be difficult for producers (Sliwinski 2017 Chapter 4). Thus, innovativeness was of interest when examining what ranchers think about new management strategies. To measure participant innovativeness I used three separate scales, including the exploratory information seeking and exploratory acquisition of products scales (Baumgartner and Steenkamp 1996), and the social innovativeness scale (Roehrich 1994 as cited in Roehrich 2004). Each of these three scales had three items (Table 24), and the scales were kept separate for data analyses. Exploratory information seeking is the search for information on various topics or products and may not be directed at a single topic or product. Exploratory acquisition of products is the acquisition of products without full knowledge of its potential usefulness. Social innovativeness is associated with the need for uniqueness.

Individualism/Collectivism

Because of the growing interest in promoting landscape management through groups of ranchers, rather than working in islands of rangeland on individual ranches (Schutz 2010, Powell 2012), it was important to get an idea of how individualistic or collectivistic the participants were. Thus, I used a reduced version of a scale that measured horizontal and vertical individualism and collectivism (Table 25, Sivadas et al. 2008). The horizontal dimension emphasizes equality, whereas the vertical dimension emphasizes hierarchy. I included two items for each of the four domains, and subsequently collapsed the four domains into an individualism scale and a collectivism scale, each with four items.

Social norms

Social norms are important in the decision-making process of ranchers (Yung and Belsky 2007, Sliwinski 2017 Chapter 4) and are influential in determining pro-social behavior (Steg and de Groot 2010), such as considering ecosystem services in management decisions. Norms are “feelings of moral obligation to perform or refrain from specific actions” (Schwartz and Howard 1981). Thus, I developed a scale of five items (Table 26) to assess how much participants agreed with social norms related to rangeland management following the recommendations of Steg and de Groot (2010).

Risk aversion

Risk aversion was another potentially important cognitive variable. Risk aversion is thought to have an impact on how likely it is for a person to take up a new practice, and has been used in studies of agricultural communities (Ervin and Ervin 1982). One study showed that risk aversion has become less predictive of adoption of best management practices as best management practices have become more commonplace (Baumgart-Getz et al. 2012). However, I included a risk aversion scale (Table 27), which included eight items from Rohrmann (1997), because the management practices I asked about are not yet widely accepted.

Behavioral intent

To assess behavioral intentions, I developed a scale that asked participants about behavioral intent related to management across boundaries and management that could promote vegetation heterogeneity (Table 28). This scale included eight items; I used the scale as a measure of behavioral intent to be predicted under the framework of the Theory of Planned Behavior (Ajzen 1991).

Demographics

Demographics that were requested on the survey instrument included number of rangeland acres managed by the participant, number of generations on the ranch, experience in farming/ranching, education level, sex, birth year, what percentage of income was from off-ranch sources, and whether the participant was a Native American. County, state, and ecoregion classification from the Environmental Protection Agency's Level III EcoRegion framework (Environmental Protection Agency 2016) were linked to returned surveys through survey IDs.

Pilot Study

The final survey, including all scales and design considerations, was pilot tested by two ranchers, two graduate students, two faculty members, and two adults outside the

University. I also met with experts at the Bureau of Sociological Research and the Nebraska Evaluation and Research Center at University of Nebraska-Lincoln to review the survey. These individuals provided additional suggestions for refining the layout of the survey, if the survey flowed appropriately, and if any of the questions could be offensive or misunderstood by ranchers. This led to various formatting changes, but very few changes in the survey content.

Implementation Procedures and Timeline

Participants were asked to rate each scale item on a Likert scale of 1–5, where 1 was strongly disagree and 5 was strongly agree. For the future behaviors scale, 1 was very unlikely and 5 was very likely. A full page was left blank on the back of the survey for participants to write comments if they desired.

To improve response rates, I based my survey implementation timeline on knowledge of busy seasons for producers. Following a modified Dillman approach (Dillman 2002), I sent a pre-notice postcard, a survey mailing with cover letter, a follow-up reminder postcard, and a replacement survey with a modified cover letter.

1. Pre-notice postcard (Appendix I) sent out 6 days prior to first survey mailing. (mailed February 5th, 2016)
2. First mailing (Appendix J): The first mailing included the cover letter with informed consent information, survey (stapled in top left corner), and a business return envelope. (mailed February 11th, 2016)
3. Follow-up reminder postcard (Appendix K): The follow-up postcard was mailed to all participants of the study and showed appreciation to those who

had completed the survey, and served as a brief reminder to those who did not yet complete the survey. (mailed February 17h, 2016)

4. Second mailing: replacement survey (Appendix L): This mailing included a letter that used a stronger tone and indication that many surveys had been returned to encourage participation in the study. The importance of the study was reiterated, and I included endorsements from various groups (e.g., Sandhills Task Force and South Dakota Grasslands Coalition). This mailing was only sent to those individuals who had not yet returned the survey. (mailed March 11th, 2016)

To ensure confidentiality, each survey return envelope had a unique identifier that was marked as "returned" in the address database. The ID number was written on the top of the survey during data entry; I disassociated the ID from its address, but retained information about the state and county to determine ecological regions. Individual landowners were not identifiable.

Ethics

The Nebraska Institutional Review Board (IRB) reviewed this project and certified the project as “exempt category 2” with approval number 20141114643. The Nebraska Game and Parks Commission and USDA Sustainable Agriculture Research and Education North-Central Region provided funding for completing this study. These funding sources present no bias to the conduct of the study. The participants did not benefit directly from this study.

Data analysis

Scale items that were reverse coded were reversed prior to analyses (see APPENDIX N). Reliability of the various scales was assessed using Cronbach's alpha (*cronbach* function, package survey, Program R; Lumley 2004). Some items were removed from some scales to improve reliability (for finalized scales, see APPENDIX N). Pearson's correlation coefficients among the final scales were calculated (Table 29). I used analysis of variance (ANOVA) to determine if there were any differences among regions for five variables of interest, including attitudes about fire and prairie dogs (sub-scales of the heterogeneity attitudes scale), threatened/endangered species values, social norms, and behavioral intent.

To meet the first objective of this study, I assessed the relationship between four attitudes (landscape management, temporal vision, fire, and prairie dogs) and the personal characteristics measured (e.g., Land Use values, risk aversion, collectivism/individualism, etc.). I chose to assess fire attitude and prairie dog attitude sub-scales (Table 18) instead of the full heterogeneity scale because of the low Cronbach's alpha of the heterogeneity scale. In these models, I included two demographic variables, age and education, to assess their influence on attitudes. I used structural equation modeling (*sem* function, package lavaan, program R; Rosseel 2012) to allow me to model latent variables rather than observed variables for each variable. Latent variables are recommended because there is error in the measurement of attitudes and cognitive factors; thus, latent variables include each item from a scale instead of mean scores across the scale, which allows for the structural equation model to measure error in the measurement of the variables (Asah 2008, Leeuw et al. 2015). I assessed the fit of the structural equation models using the root mean squared error of approximation (RMSEA; MacCallum et al. 1996).

Prior to fulfilling the second objective of the study to examine behavioral intent using the Theory of Planned Behavior, I used a model selection process to choose the final form of my heterogeneity management attitudes scale, because of the low Cronbach's alpha value for this scale. I examined two models in which the only difference was a single independent variable: 1) the full heterogeneity management attitudes scale and 2) a reduced model that included only the fire and prairie dog sub-scales (Table 21); the dependent variable in both models was behavioral intent. Models with fire and prairie dog sub-scales fit better than the full heterogeneity management attitudes scale ($\Delta > 12.6$); thus, the two sub-scales were used for subsequent analyses.

To meet the second objective of this study, the Theory of Planned Behavior was used to determine predictors of behavioral intent, where social norms, perceived behavioral control, and the attitudes about the behaviors were used to predict behavioral intent. In this case, I assessed which independent variables, including 1) perceived control over management, 2) attitudes about landscape management, temporal vision, fire, or prairie dogs, and 3) social norms of ranch management, were predictive of behaviors that are expected to promote landscape vegetation heterogeneity. I used information gained from meeting the first objective of the study to create the structural equation model; specifically, I only included variables that were significant predictors of the attitudes in the structural equation models for attitudes. Finally, to simplify interpretation, I reduced the model by removing insignificant pathways from the full TPB structural equation model (Toledo et al. 2013). I assessed the fit of the structural equation model using the RMSEA (MacCallum et al. 1996).

RESULTS

Of 2873 surveys sent, 595 usable surveys were returned for a response rate of 21%; the High Plains region had 57 responses (15%), the Northwestern Glaciated Plains had 37 responses (13%), the Northwestern Great Plains had 295 responses (17%), and the Sandhills had 205 responses (45%). Most of the respondents were male (86%). The mean number of rangeland acres managed by participants was 6623 acres (range: 70–100000; SD = 9773; median = 3817 acres). Mean age of participants was 63 years, and 68% of participants had at least some college education or higher.

All of the scales had adequate reliability ($\alpha > 0.70$) except for individualism ($\alpha = 0.55$), collectivism ($\alpha = 0.60$), risk aversion ($\alpha = 0.59$), heterogeneity ($a = 0.63$), and the prairie dog sub-scale ($\alpha = 0.62$; Table 29). The only regional differences among survey participants were attitudes about prairie dogs (Table 30): attitudes were more negative in the Sandhills, Northwestern Great Plains, and High Plains than in the Northwestern Glaciated Plains region (Figure 40).

Attitudes about landscape management were high ($M = 4.03$, $SD = 0.62$) and were related to perceived behavioral control, land use values, education, and age (Table 31). Participants with higher perceived behavioral control had more positive attitudes about landscape management. Relative to individuals in the eco-social land use values category, disconnected and humanistic individuals had more negative attitudes and naturistic individuals had more positive attitudes about landscape management. Increased education led to more positive attitudes about landscape management, and increased age led to more negative attitudes about landscape management, but landscape management attitudes were positive overall (Table 29).

Temporal vision was high (*M* = 4.43, *SD* = 0.58) and was significantly related to social norms, perceived behavioral control, land use values, and age (Table 31). Participants with higher social norms and perceived behavioral control had more positive attitudes about temporal vision; as age increased, attitudes about temporal vision became more negative. Disconnected and humanistic individuals had more negative attitudes and naturistic individuals had more positive attitudes about landscape management compared to individuals in the eco-social land use values category.

Attitudes about fire were low (*M* = 2.51, *SD* = 1.10), and only two variables were significantly related to fire attitudes: values about threatened and endangered species, and exploratory acquisition of products; both were positively related to fire attitudes (Table 31). Prairie dog attitudes were low (*M* = 1.63, *SD* = 0.87) and were explained by values about threatened and endangered species, social norms, exploratory information seeking, and land use values (Table 31). Values about threatened and endangered species were correlated with attitudes about prairie dogs; negative attitudes about prairie dogs were associated with social norms and exploratory information seeking behavior. Finally, individuals in the "naturistic" land use value category had more positive attitudes about prairie dogs than the other categories.

Participants had neutral intent to engage in behaviors that promote landscape management and heterogeneity in my study (*M* = 2.95, *SD* = 0.67); using the TPB, behavioral intent was predicted most strongly by attitudes about prairie dogs, attitudes about fire, and perceived behavioral control (Figure 41). Although social norms were a significant predictor in the unreduced version of the SEM, once insignificant predictors were removed it became non-significant. However, social norms were still predictive of prairie dog attitudes ($\beta = -0.25$). All of the variables that had been significant predictors of the attitudes about fire and prairie dogs (first objective) remained significant in the final SEM. Both fire and prairie dog attitudes were positively related to behavioral intent ($\beta = 0.14$, 0.26 respectively). Perceived behavioral control was the strongest predictor of behavioral intent ($\beta = 0.57$).

DISCUSSION

My results indicate the importance of attitudes about prairie dogs and fire to engaging in behaviors that promote vegetation heterogeneity and landscape management. Given that few participants in my study had positive attitudes about fire and prairie dogs, it seems important to focus on these topics as intervention points to start managing for vegetation heterogeneity and landscapes in the Great Plains. However, rather than educational materials directed at these topics, a more appropriate strategy is to show producers the potential benefits through field days, workshops, and other outreach strategies (Sliwinski 2017 Chapter 4).

The development of a scale to assess attitudes related to vegetation heterogeneity proved difficult. The concept of heterogeneity is difficult to describe because it is dependent on geographic range of an area and many different factors can contribute to or diminish vegetation heterogeneity; additionally, the concept of heterogeneity is foreign to many landowners (Sliwinski 2017 Chapter 4). I followed a broad framework that proposed ten aspects of managing for vegetation heterogeneity (Freese et al. 2014), but the items within the scale did not correlate well enough with each other to use all the items. Future studies may find it more effective to focus on a small number of items that are very strongly related to vegetation heterogeneity at the geographic range of interest; in this case, focusing on attitudes about prairie dogs and fire was most relevant. Further development of scales to measure attitudes about heterogeneity and further testing to ensure their reliability will be important to understanding ranchers' attitudes and what factors contribute to those attitudes.

Social norms were important predictors of attitudes about prairie dogs, and thus might be an important focal area for conservation projects to change future behaviors. Because social norms are often so important to agricultural communities, and because social norms can limit ranchers' willingness to engage in new practices, it is crucially important to increase the dialogue between ranching communities and scientists so that both can understand and critically examine the reliance on social norms (Burton 2004, Didier and Brunson 2004, Knapp and Fernández-Giménez 2009, Sliwinski 2017). When individuals are confronted with information that conflicts with their beliefs, they are more likely to maintain their beliefs than change their attitudes or actions, and may avoid situations where their beliefs are challenged (Tanaka et al. 2011). Further, my results showed participants with negative attitudes of prairie dogs tended to have more exploratory information seeking behavior. Liffmann et al. (2000) reported that ranchers usually relied on information from other ranchers and cattlemen's associations, which would allow a rancher to score high on "exploratory information seeking", while potentially having existing social norms about prairie dogs reinforced. Many cattlemen's associations and state agencies support the control or eradication of prairie dogs (The Associated Press 2012, Schumacher 2016). Ranchers do trust university Extension educators (Liffmann et al. 2000, Sliwinski 2017), which makes them key to changing attitudes about prairie dogs and other conservation issues. Extension educators are mentors within the community rather than outsiders, and they also have connections to the scientific community; thus, Extension educators may be trusted sources of information that fosters the integration of wildlife into management decisions that leads to wildlife conservation. The more positive attitudes about prairie dogs in the Northwestern Glaciated Plains was most likely because that region is largely outside the prairie dog range.

Values about threatened and endangered species were indirectly related to behavioral intent through attitudes about both fire and prairie dogs. The Endangered Species Act is often feared by private landowners (Liffmann et al. 2000), in part because it represents a potential loss of control over management of private land (Janssen 1996, Knapp et al. 2015, Sliwinski 2017 Chapter 4). However, a better understanding of threatened and endangered species developed through relationships with trusted individuals can lead to more willingness to participate in beneficial management practices (Henderson et al. 2014). Tying information about threatened, endangered, and candidate species into educational programming done by Extension services may help to alleviate some fears of the Endangered Species Act, as will efforts to work with local partners on threatened and endangered species conservation (Brown et al. 2010, Knapp et al. 2015). These actions might improve participation in activities that promote wildlife conservation.

Exploratory acquisition of products (i.e., acquiring new products without full knowledge of their usefulness) was positively related to fire attitudes, while exploratory information seeking (i.e., searching for information) was negatively related to prairie dog attitudes, which is counterintuitive. However, exploratory acquisition of products may be a more accurate indication of willingness to try new technologies, whereas exploratory information seeking may be an indication that individuals are looking to reinforce their existing attitudes. This apparent contradiction requires further study to examine the differences in innovativeness that are measured by exploratory acquisition of products versus exploratory information seeking.

Because perceived behavioral control is an important predictor of behavioral intentions, it is important to reduce the effort required to implement new behaviors or different management strategies. Federal programs, like the Conservation Reserve Program and the Wetland Reserve Program, focus on ensuring certain types of habitat are in place (Brennan and Kuvlesky 2005, McGranahan et al. 2013). Thus, federal funding that promotes the implementation of rotational grazing management (Toombs and Roberts 2009) could instead be used to promote the conservation of prairie dogs and the use of prescribed fires, thus focusing on habitat rather than a management strategy.

There are three strategies for influencing behavior (De Young 1993): information techniques (e.g., education), positive motivational techniques (e.g., payments for good behavior), and coercive techniques (e.g., fines for bad behavior). Information techniques are used to modify an individual's attitudes and beliefs about an issue (De Young 1993), and are successfully employed by Extension educators through field days, workshops, meetings with producers, and courses (Richards and George 1996). Positive motivational techniques are used in incentive programs (Pascual and Perrings 2007); for example, the voluntary Conservation Reserve Program pays landowners to take fragile land out of crop production and plant it to grass (Reimer and Prokopy 2014). There are also other types of positive motivation that may be used, such as auctions for biodiversity conservation (Pascual and Perrings 2007), and non-financial strategies that rely on social norms, such as recognition for conservation efforts (Pasquini et al. 2010). Finally, coercive techniques include strategies like regulation, which can restrict or penalize certain behaviors (Serbruyns and Luyssaert 2006), or monetary disincentives, such as taxes on consumption (De Young 1993). Coercive strategies may actually be counterproductive: one study reported that producers planned to withdraw from conservation activities if a species was listed as endangered (Knapp et al. 2015). My survey results suggest that information techniques will be important for shifting attitudes on fire and prairie dogs, and that positive motivational techniques will be important for overcoming any social norms that restrict behavior and increase perceived control (whereby risk is reduced).

The predictive relationships that I confirmed are important, but it is also interesting to look at what factors were not predictive of attitudes or behavioral intentions that were expected to be predictive. Cultural orientations of collectivism and individualism were expected to influence attitudes about environmental behavior (Inman and Mcleod 2002, Smith et al. 2012, Cho et al. 2013); however, these orientations did not predict any of the attitudes I assessed. Cultural orientations were generally moderate on both individualism and collectivism. Attitudes about landscape management and temporal vision also were not significant predictors of behavioral intent, and these attitudes were generally very positive. Similar to the individualism and collectivism orientations, perhaps there was not enough variation in attitudes around landscape management and temporal vision (Table 29) to allow them to predict future behaviors. However, the overall positive attitudes about landscape management and temporal vision provide some potential for conservation planning, given that conservationists approach ranchers with this common ground as a starting point. The survey confirmed that landowners realize they are not isolated spatially or temporally, and that their management practices affect neighboring lands as well as the future health of the land. This supports previous research that suggested that ranchers consider themselves stewards of the land (Kreuter et al. 2005, Cross et al. 2011, Gutwein and Goldstein 2013, Kennedy et al. 2016, Sliwinski 2017 Chapter 4). Risk aversion was also not a significant predictor of attitudes or behavioral intent, which concurs with previous research (Prokopy et al. 2008, Lesch and Wachenheim 2014). In a qualitative study, producers stated that they perceived less risk than their parents experienced because assets are largely paid off and they have greater monetary flexibility (Sliwinski 2017 Chapter 4).

This survey provided valuable guidance on future directions for research, because there has been very little research of an exploratory manner with landowners in the Great Plains. The results also have important implications for where conservationists can begin programs to promote vegetation heterogeneity across landscapes. A number of successes can be seen across the Great Plains that use the model of working closely with private landowners during all phases of a program, including the Sage Grouse Initiative (Baruch-Mordo et al. 2013), The Nature Conservancy's Fire Learning Network (The Nature Conservancy 2015), and the World Wildlife Fund's Sustainable Ranching Initiative (World Wildlife Fund 2015).

IMPLICATIONS

Although the paradigm within rangeland conservation circles has shifted to fostering vegetation heterogeneity and landscape management, ranchers will need to be encouraged to embrace this paradigm shift if we hope to prevent the continued losses of native rangeland habitat and wildlife because they manage most of the remaining native rangelands in the Great Plains (Askins et al. 2007). However, changing behaviors is a very difficult task (De Young 1993). It is clear from this research that improving attitudes about fire and prairie dogs are crucial to increasing engagement in behaviors that promote vegetation heterogeneity and landscape management in rangelands. Existing resources, such as university ranches, could be used to model the management of fire and prairie dogs. Such a program could provide sufficient evidence to producers to improve attitudes about prairie dogs and fire, which will be important to promoting management for vegetation heterogeneity across landscapes. Thus, university ranches and other accessible research sites serve as a bridge from scientists to private landowners. Conservation campaigns might benefit from engaging locally respected individuals, such as Extension educators or community elders, to help change social norms around the issues of prairie dogs and prescribed fire, as has been suggested for other issues (Marchini and Macdonald 2012). Innovators and early adopters, those who implement new technologies first among their peers (Kreuter et al. 2005), may also serve as an important conduit from scientists to private landowners.

Table 18. Vegetation heterogeneity management scale developed following Freese et al. (2014). Constructs or management strategies are in the first column, items associated with each construct are in the second column. Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. Numbered items were included in the final data analyses. An asterisk (*) indicates a reverse-coded item.

Composition and productivity of plant communities	Converting native rangeland to any other use, such as cropland, is not valuable to me. Increasing rangeland productivity by interseeding tame grasses or through herbicide application are good practices on native rangeland.* I benefit from the diversity of plants and soil types in native rangeland.
Herbivory patterns	Restricting livestock grazing to a level that is sustainable (e.g., "take half, leave half") is a good grazing strategy.* Good management results in patchiness of grazing patterns (e.g., a variety of grass heights and densities). Patches of bare ground, resulting from cattle grazing certain areas more, are a natural result of any grazing management.
Fire	1. Periodic fire is vital in managing rangeland vegetation.[a] 2. Fire provides outcomes that cannot be reached with livestock.[a] 3. Areas that have had fires should be left alone until they heal.*
Habitat contiguity	Subdividing pastures using fencing is a good management strategy.* 4. Planting trees (e.g., for wind breaks or shelter belts) is bad for rangeland wildlife.
Stream hydrology	The best use of a small stream is to dam it for a stock pond.* Livestock access to streams and surrounding riparian areas should be limited.
Herbivorous mammals	5. Eliminating prairie dogs would be in the best interests of a ranch.*[b] 6. I would be fine with a neighbor having a prairie dog colony. [b] I would be unhappy if there were more deer, antelope, and/or elk on my ranch because they would compete with my livestock for forage.*
Fate of ungulate production	7. It is important to leave dead cattle in the pasture because the carcass provides a nutrient boost to the area. 8. Nutrient removal through annual sale of livestock is harmful for my native rangeland.
Apex predators	Predators are important components of the rangeland ecosystem. 9. I am worried about society's interest in increasing predator populations.*

[a] Indicates items included in the fire attitudes scale
[b] Indicates items included in the prairie dog attitudes scale

Table 19. Items included in the landscape management scale (Rickenbach et al. 1998). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

My land is part of a much bigger natural system.
My land is not important to other people. *
What I do on my land affects others' land.
My land provides important habitat for wildlife.
My land provides benefits for society.
My property is insignificant in the big picture of all land in the region. *
What my neighbors do on their land does not affect me or my land. *
I would consider working with others, if it meant the rangeland would be better off.

Table 20. Items included in the temporal vision scale (Rickenbach et al. 1998). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

What I do on my land will not matter in the long run. *
My land does not need to provide for future generations. *
My land should provide for the needs of future plant and wildlife populations.
I have a responsibility to leave my land in at least as good a condition as I found it.
The health of the land today is not a result of past activity. *
Land is a testament to the previous owners.
Actions of current land owners do not affect future owners. *

Table 21. Items included in the herbivorous mammals, fire, and threatened and endangered species attitudes scales. Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

Threatened and Endangered Species scale
I would be pleased if a rare or threatened species was found on my land.
Rare or threatened species should be protected.
Herbivorous mammals attitudes scale
Eliminating prairie dogs would be in the best interests of a ranch. *
I would be fine with a neighbor having a prairie dog colony.
Fire attitudes scale
Periodic fire is vital in managing rangeland vegetation.
Fire provides outcomes that cannot be reached with livestock.

Table 22. Items included in the Perceived Behavioral Control scale. Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale.

How I treat my land affects the overall environment in my county.
I am able to manage my land to achieve desired outcomes.
If I want to change my management, I have the resources to be able to do so.
What I do on my land effects the services (e.g., aquifer recharge, clean air, carbon storage) provided by the rangeland ecosystem to society.
I can change my management strategy if a newer, better option becomes available.

Table 23. Items included in the Land Use Values scale (Sweikert et al., in review). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale.

Human domain
Because farmers and ranchers' livelihoods depend on the land; they are the best stewards of the land.
The best use of land should be determined by the amount of profit that can be earned annually.
Farmers/ranchers should focus on optimizing production on their farm/ranch regardless of environmental costs.
Farmers and ranchers have the right to use the soil, water, plants, and wildlife on land they own in any way they see fit.
The needs of farmers and ranchers should take priority over the conservation of land.
Farmers and ranchers are masters of the land.
Nature domain
The diversity of plants and wildlife in an area is a sign of the quality of the environment.
Farmers and ranchers have an obligation to protect the soil, water, plants, habitat, and fish and wildlife on their land.
All parts of the ecosystem, down to the microorganisms in the soil, are important for proper functioning of the landscape.
If you take care of the land, it will take care of you.
Restored lands maximize both productivity and ecosystem function.
The quality of the land is positively influenced by the diversity of native plants and wildlife that live on or around it.
Farmers and ranchers are only temporary trustees of the land; it is their responsibility to take care of it for future generations.

Table 24. Items included in the Innovativeness scales. Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

Social (Roehrich 2004)
I am usually among the first to try new management strategies.
I know more than other people about the latest new ranching products.
I try new products before my friends and neighbors.
Exploratory acquisition of products (Baumgartner and Steenkamp 1996)
I would rather stick with a product I usually buy than try one I'm not sure of. *
I'm very cautious in trying new or different products. *
I rarely buy products if I am uncertain about their performance. *
Exploratory information seeking (Baumgartner and Steenkamp 1996)
I like to shop around and look at product displays.
I like to browse through catalogs even when I don't plan to buy anything.

Table 25. Items included in the individualism and collectivism scales (Sivadas et al. 2008). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

Individualism scale
I am a unique individual.
I enjoy working in situations involving competition with others.
I often "do my own thing."
Without competition it is not possible to have a good society.
Collectivism scale
My happiness depends very much on the happiness of those around me.
I would do what would please my family, even if I hated the activity.
Children should feel honored if their parents receive a distinguished award.
I feel good when I cooperate with others.

Table 26. Items included in the social norms scale (Steg and de Groot 2010). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale.

Most ranchers in my community act in the best interests of the rangeland.
I feel guilty if I do not act in the best interest of my rangeland.
My neighbors expect me to act in the best interest of my rangeland.
My neighbors act in the best interests of their rangeland.
I feel proud when I manage my rangeland properly.

Table 27. Items included in the risk aversion scale (Rohrmann 1997). Participants were asked to rate how much they agreed with each statement on a 5-point Likert scale. An asterisk (*) indicates a reverse-coded item.

I'm quite cautious when I make plans and when I act on them. *
I don't like to put something at stake, I would rather be on the safe side. *
I only set small work goals so that I can achieve them without difficulty. *
My decisions are always made carefully and accurately. *
I tend to imagine the unfavorable outcomes of my actions. *

Table 28. Items included in the behavioral intent scale. Participants were asked to indicate how likely they were to engage in the behavior on a 5-point Likert scale.

Alter management to provide habitat for threatened or endangered species.
Work with a neighbor on invasive species control.
Temporarily overgraze some of my pastures to create wildlife habitat.
Work with a neighbor on brush encroachment control.
Manage the threat of wildfires by using prescribed fires.
Change management practices to increase carbon sequestration on my ranch.
Be prepared for adverse weather, such as droughts.
Modify management to increase wildlife populations on my ranch.

Table 29. Correlation table for the dependent and independent variables in the survey analysis. Cronbach's alpha values are shown in parentheses along the diagonal.

Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1. Landscape attitude	4.03	0.62	(0.70)	**0.64**	-0.05	0.07	0.03	**0.20**	**0.50**	**0.29**	**0.15**	**-0.11**	**0.10**	**-0.18**	**0.17**	**0.29**	**0.20**	-0.03	-0.02	**0.10**	**-0.09**	-0.01	**-0.15**	**-0.10**
2. Temporal attitude	4.43	0.58		(0.71)	**-0.18**	-0.02	-0.05	**0.18**	**0.49**	**0.25**	**0.09**	**-0.17**	**0.15**	**-0.17**	**0.19**	**0.33**	**0.16**	-0.04	-0.01	**0.12**	-0.06	-0.03	**-0.15**	-0.06
3. Heterogeneity attitude	1.96	0.53			(0.63)	**0.62**	**0.66**	**0.17**	**-0.13**	**0.13**	0.08	**0.26**	**-0.16**	**0.09**	**-0.19**	**-0.21**	**0.30**	**0.21**	-0.04	-0.04	**-0.10**	-0.00	**-0.12**	-0.03
4. Fire attitude	2.51	1.10				(0.74)	**0.14**	**0.19**	0.07	**0.09**	0.07	**0.13**	-0.01	-0.05	-0.03	-0.01	**0.26**	0.05	-0.01	-0.03	-0.07	-0.02	-0.06	0.02
5. Prairie dog attitude	1.63	0.87					(0.62)	**0.18**	0.01	**0.20**	**0.13**	**0.21**	**-0.15**	0.03	**-0.12**	**-0.15**	**0.27**	**0.21**	-0.08	-0.00	-0.03	0.01	**-0.09**	-0.07
6. Planned behaviors	2.95	0.67						(0.75)	**0.31**	**0.15**	**0.28**	0.03	**0.16**	**-0.11**	**0.13**	**0.19**	**0.36**	-0.05	**-0.20**	**0.10**	-0.05	-0.00	**-0.09**	-0.03
7. Perceived control	3.97	0.62							(0.70)	**0.17**	**0.22**	**-0.22**	**0.13**	**-0.28**	**0.33**	**0.41**	**0.18**	**-0.21**	0.05	0.07	-0.04	-0.01	0.05	-0.08
8. Land Use Values											-0.01	-0.04	0.01	0.03	-0.01	-0.00	**0.25**	**0.13**	-0.03	-0.00	**-0.12**	**0.11**	-0.01	-0.00
9. Social innovativeness	2.79	0.80									(0.77)	**0.19**	0.10*	**-0.27**	0.07	**0.10**	**0.16**	0.04	**0.15**	0.08	**-0.14**	0.01	**-0.19**	-0.05
10. EAP	2.57	0.78										(0.71)	**-0.12**	**0.15**	**-0.23**	**-0.24**	0.04	**0.33**	0.02	-0.00	-0.08	0.03	**-0.09**	0.04
11. EIS	3.44	0.96											(0.74)	**-0.16**	**0.29**	**0.17**	0.08	**-0.21**	**-0.17**	**0.11**	0.09	0.04	-0.03	-0.07
12. Individualism	2.47	0.67												(0.55)	**-0.32**	**-0.32**	0.01	**0.11**	**-0.11**	-0.08	0.01	-0.02	**0.16**	0.02
13. Collectivism	3.73	0.66													(0.60)	**0.43**	**0.13**	**-0.31**	0.00	0.03	-0.01	0.01	**0.11**	-0.03
14. Norms	3.94	0.67														(0.78)	0.08	**-0.30**	0.05	**0.10**	0.01	-0.06	0.02	-0.04
15. T+E attitude	2.85	1.10															(0.76)	-0.02	**-0.11**	-0.01	-0.04	-0.05	-0.01	0.00
16. Risk aversion	2.70	0.58																(0.59)	0.061	-0.01	**-0.13**	**0.11**	**-0.14**	-0.03
17. Rangeland (acres)	6623.01	9773.58																		0.08	-0.02	0.05	-0.05	0.04
18. Generation[1]	3.02	1.03																			-0.04	-0.04	**-0.21**	-0.03
19. Education level[2]	3.53	1.40																				-0.04	**0.17**	0.05
20. Sex (1 = male)	1.14	0.35																					**-0.08**	**-0.13**
21. Age	63.59	11.46																						0.04
22. Region[3]																								

Note. Reliability coefficient estimates (α) are in Parenthesis along diagonals. Reliability for the nature factor of the Land Use Values (LUV) scale was 0.85; reliability for the human factor of the LUV scale was 0.70.

Bolded text indicates significance at $p \leq 0.05$. (Pearson test)

Sample sizes ranged from 435 to 596 due to occasional missing data.

[1]The generation of farmer or rancher that the participant is (e.g., how many generations have been farming/ranching in his/her family).

[2]Education levels: 1 (primary school), 2 (high school), 3 (some college), 4 (associate's degree), 5 (four-year college degree), 6 (advanced degree)

[3]Region: Northwestern Glaciated Plains, Northwestern Great Plains, High Plains, or Sandhills

Table 30. Parameter estimates (β), standard errors (SE), and *p*-values for regional differences in five variables in 2015. Bold text indicates a significant relationship at $p < 0.05$. Analysis was completed using analysis of variance.

	Fire attitudes			Prairie dog attitudes			T+E species values			Social norms			Behavioral intent		
Variable	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
Intercept	**2.51**	**0.15**	**<0.01**	**1.39**	**0.11**	**<0.01**	**2.79**	**0.15**	**<0.01**	**4.06**	**0.09**	**<0.01**	**3.00**	**0.09**	**<0.01**
NW Glaciated Plains	-0.04	0.24	0.88	**0.85**	**0.18**	**0.00**	0.45	0.23	0.05	-0.22	0.14	0.12	0.14	0.14	0.32
NW Great Plains	-0.05	0.16	0.75	**0.26**	**0.13**	**0.04**	0.07	0.16	0.67	-0.19	0.10	0.05	-0.12	0.10	0.22
Sandhills	0.08	0.17	0.61	0.17	0.13	0.20	0.00	0.17	0.98	-0.02	0.10	0.86	0.01	0.10	0.95

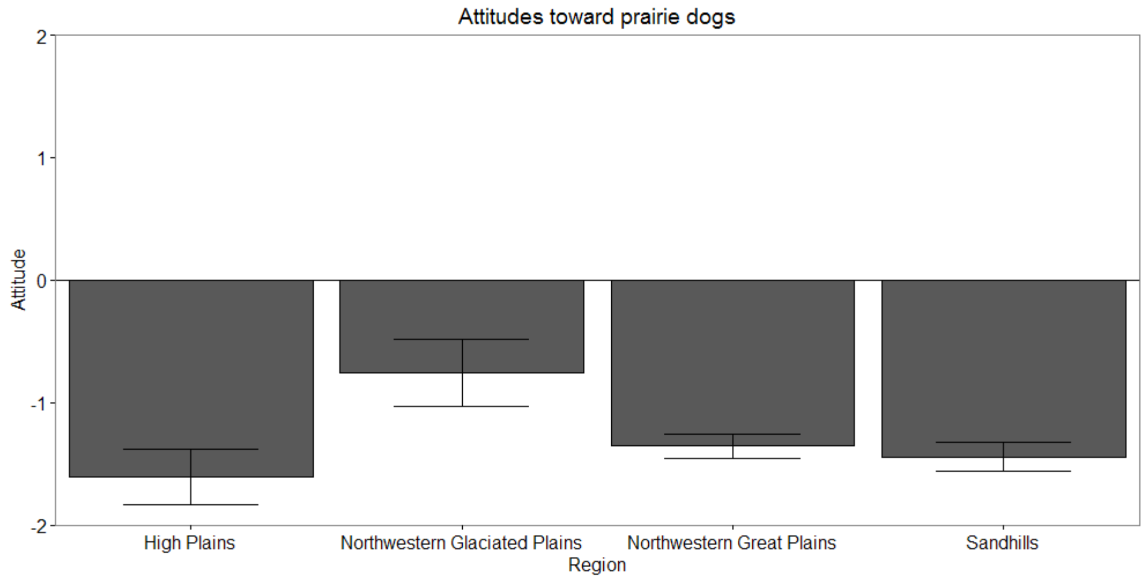


Figure 40. Predicted values and 95% confidence intervals of attitudes toward prairie dogs in four different regions of the Great Plains, 2016. Attitudes below zero are negative. High plains are in western Nebraska, Northwestern Glaciated Plains are in north-central North Dakota, Northwestern Great Plains are in western South Dakota and North Dakota, and Sandhills are in north-central Nebraska.

Table 31. Parameter estimates (β), standard errors (SE), and *p*-values for four attitudes related to landscape management, temporal vision, fire, and prairie dogs in rangeland ecosystems and the variables that were hypothesized to explain them. Bold text indicates a significant relationship at $p < 0.05$. Analysis was completed using structural equation modeling. Abbreviations: T+E = threatened and endangered; EAP = exploratory acquisition of products; EIS = exploratory information seeking; LUV = land use values scale.

	Landscape management attitudes			Temporal vision attitudes			Fire attitudes			Prairie dog attitudes		
Variable	β	SE	*p*	β	SE	*p*	β	SE	*p*	β	SE	*p*
T+E species	-0.02	0.04	0.63	-0.01	0.03	0.78	**0.37**	**0.09**	**<0.01**	**0.33**	**0.06**	**<0.01**
Social norms	0.05	0.08	0.52	**0.13**	**0.05**	**0.02**	-0.07	0.15	0.62	**-0.25**	**0.11**	**0.02**
Perceived control	**0.77**	**0.10**	**<0.01**	**0.49**	**0.08**	**<0.01**	0.25	0.17	0.14	0.08	0.12	0.50
Social innovativeness	-0.03	0.07	0.68	-0.05	0.05	0.36	-0.27	0.15	0.08	-0.02	0.10	0.83
EAP	0.03	0.08	0.70	-0.04	0.05	0.51	**0.42**	**0.16**	**0.01**	0.20	0.11	0.07
EIS	-0.02	0.11	0.85	0.11	0.09	0.23	0.20	0.26	0.44	**-0.53**	**0.21**	**0.01**
Individualism	0.13	0.18	0.49	0.16	0.12	0.19	-0.68	0.39	0.08	-0.33	0.26	0.20
Collectivism	-0.01	0.24	0.98	-0.07	0.17	0.67	-0.80	0.53	0.13	-0.17	0.35	0.62
Risk aversion	0.00	0.09	0.99	0.11	0.07	0.10	-0.23	0.19	0.21	0.09	0.13	0.48
LUV "disconnected"	**-0.45**	**0.19**	**0.02**	**-0.62**	**0.14**	**<0.01**	0.07	0.36	0.85	0.24	0.28	0.39
LUV "humanistic"	**-0.59**	**0.21**	**<0.01**	**-0.53**	**0.17**	**<0.01**	0.17	0.41	0.67	-0.39	0.31	0.22
LUV "naturistic"	**0.27**	**0.05**	**<0.01**	**0.11**	**0.04**	**<0.01**	0.05	0.10	0.57	**0.25**	**0.07**	**<0.01**
Education: high school	**0.52**	**0.20**	**0.01**	0.17	0.14	0.20	-0.25	0.37	0.51	0.30	0.30	0.32
Education: some college	**0.63**	**0.20**	**<0.01**	0.12	0.13	0.38	-0.07	0.38	0.85	0.44	0.30	0.15
Education: Associate's	**0.59**	**0.22**	**0.01**	0.09	0.14	0.56	-0.07	0.40	0.85	0.23	0.33	0.47
Education: Bachelor's	**0.64**	**0.20**	**<0.01**	0.19	0.14	0.17	0.08	0.38	0.83	0.40	0.31	0.19
Education: advanced	**0.74**	**0.21**	**<0.01**	0.05	0.14	0.72	0.27	0.40	0.51	0.45	0.32	0.17
Age	**-0.01**	**0.00**	**0.02**	**-0.01**	**0.00**	**<0.01**	0.00	0.01	0.84	0.00	0.00	0.57

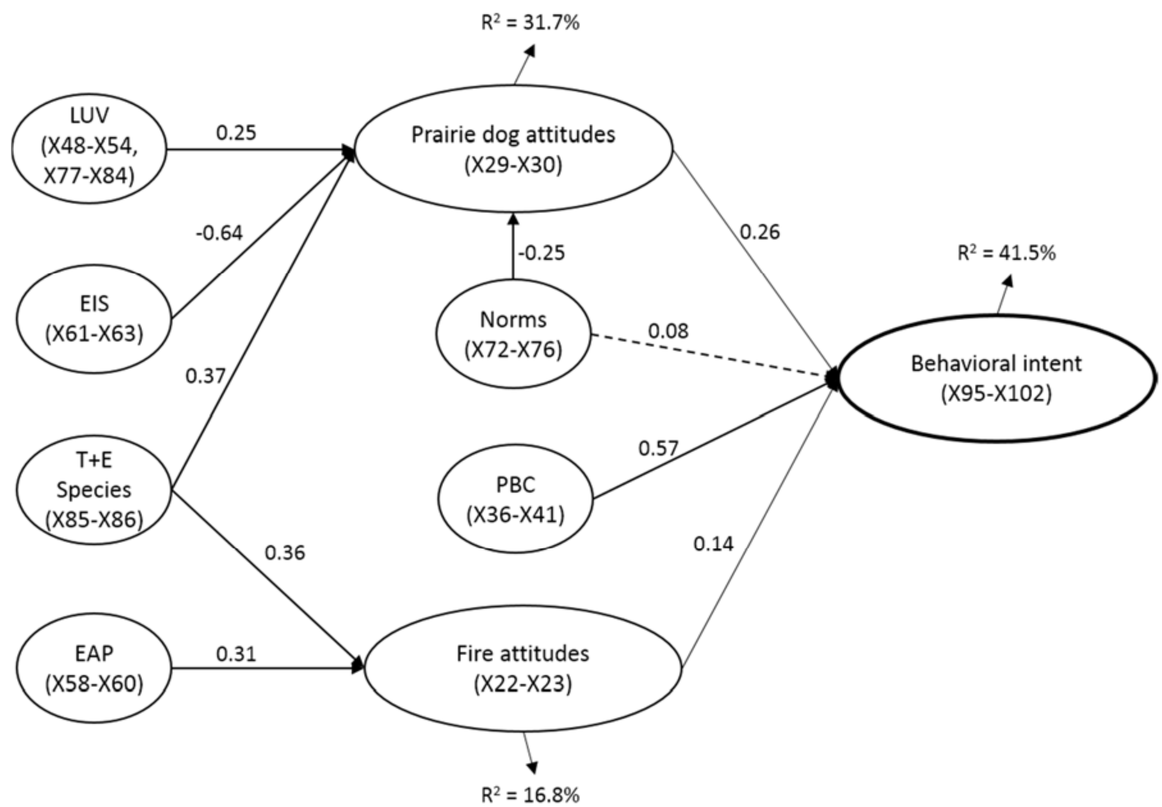


Figure 41. Theory of Planned Behavior (TPB) variables that predicted intention to behave in ways that contribute to landscape and heterogeneity management for participants in Nebraska, South Dakota, and North Dakota in 2016. Solid lines indicate significant relationships, dotted line indicates non-significant relationship. Values above lines are coefficients. Circles indicate that the variable is latent. The middle and right-hand side of the diagram is the original Theory of Planned Behavior, where attitudes, perceived behavioral control, and social norms predict behavioral intentions. The left-hand side of the diagram is a recent extension of the TPB, which uses other variables to predict attitudes. Abbreviations: LUV = land use values; EIS = exploratory information seeking; T+E species = threatened and endangered species; EAP = exploratory acquisition of products; PBC = perceived behavioral control. Numbers below the scale (e.g., X77-X84) names indicate the items included in the scale (Appendix N).

Table 32. TPB variables that predicted engagement in behaviors that contribute to landscape and heterogeneity management and their coefficient estimates (β), standard errors (SE), and *p*-values for participants from Nebraska, South Dakota, and North Dakota in 2016.

Regressions:	Estimate	SE	*p*-value
Behavioral intent ~			
Fire attitudes	0.14	0.04	<0.01
Prairie dog attitudes	0.26	0.06	<0.01
Norms	0.08	0.07	0.27
Perceived behavioral control	0.57	0.09	<0.01
Fire attitudes ~			
T+E Species	0.36	0.06	<0.01
Exploratory acquisition of products	0.31	0.09	<0.01
Prairie dog attitudes ~			
T+E Species	0.37	0.05	<0.01
Norms	-0.25	0.07	<0.01
Exploratory information seeking	-0.64	0.19	<0.01
LUV disconnected	0.34	0.30	0.254
LUV humanistic	-0.15	0.31	0.63
LUV naturistic	0.25	0.07	<0.01

CHAPTER 6: Conclusions

The purpose of this research was to understand the relationship of grazing management on private land to structural vegetation heterogeneity in a large, intact rangeland, and secondarily to understand the opinions and attitudes of private landowners to heterogeneity and landscape management. Heterogeneity refers to the variety of habitats that are needed by wildlife species, which is provided by structural and compositional variation in vegetation. Landscape management refers to the management of land across property boundaries. To meet these goals, I conducted an ecological field study in the Nebraska Sandhills in 2014-2015, and completed a human dimensions study across the Northern Great Plains in 2015-2016.

One assumption made by managers and conservationists is that using a variety of grazing strategies across a landscape will automatically result in greater vegetation structural heterogeneity for wildlife. My results in Chapter 2 showed that this assumption did not hold true in the Nebraska Sandhills; factors that were correlated with vegetation structure and heterogeneity were more commonly pasture-level management variables, such as stocking rate and season of use. Shrub cover, height, and field sparrows, which are associated with shrubs, were best explained by grazing strategies; however, I concluded that this was a spurious relationship and not the result of grazing strategies but rather pre-existing shrubby conditions on areas managed with management intensive grazing strategies.

My analysis of avian community data and landscape simulations provided more support for the conclusion that grazing strategies were unimportant to landscape level heterogeneity (Chapter 4). Songbird communities were similar across different management variables, including owner (public versus private), grazing strategy, stocking rate, and management intensity. Only the management unit (e.g., ranch or grazing allotment) explained a substantial amount of variability in bird communities. The landscape simulations showed that combining empirical data from multiple types of grazing strategies in a simulated landscape did not result in greater heterogeneity of vegetation structure; these simulations also highlighted the narrow range of vegetation structure available on the areas I sampled in the Nebraska Sandhills. Thus, I concluded that management for sustained beef production does likely result in a more homogenous landscape, which is a detriment to bird species diversity. Even though all beef producers have different management strategies and goals, they maintain their forage resource within an optimal level, thus "managing to the middle".

Even though conservationists agree that vegetation heterogeneity is required for biodiversity, it is reasonable that beef producers maintain their forage resource at "the middle" rather than across the spectrum of habitat structure, as my qualitative interviews in Chapter 4 showed. Most producers are concerned with the wise use of their ranch resources so that they can provide a sustainable income for their family, while also maintaining a good reputation within the community. Certain types of habitat, which conservationists see as heterogeneity (e.g., bare ground), are managed against because most beef producers label those areas as poorly managed. The interviews revealed that a key to influencing management on private land will be showing, rather than telling, beef producers the benefits of heterogeneity. It will be imperative to use existing resources, such as research ranches, for this purpose if we hope to engage producers in managing their private land as part of a functional ecosystem.

Even though there is a better understanding now than in the past about the importance of ecosystem services provided by functioning rangeland systems, and there is a paradigm shift to managing rangelands for heterogeneity among conservationists, my survey showed that this knowledge has not influenced ranchers' attitudes about managing for heterogeneity on private land (Chapter 5). However, attitudes about landscape management were positive overall. Attitudes about fire and prairie dogs were strongly correlated to future behaviors that promote landscape management and heterogeneity; therefore, it will be important for conservationists to focus on improving beef producers' understanding about these two topics, because they may be keys to increasing wildlife habitat in the Northern Great Plains.

My ecological study suggests that vegetation heterogeneity is low in the Sandhills relative to the historical range of variation, and my human dimensions study showed why this makes sense from the perspective of those managing the land. Although my results highlight the need for increasing the diversity of habitats in rangelands in the Northern Great Plains, and one could complain that neither conservationists nor beef producers are doing enough to support rangeland biodiversity, the truth is more likely that these two groups are only just starting to trust each other in the last decade. My interviews highlighted the importance that beef producers place on trust in who they decide to work with, and it is necessary for conservationists to first understand the beef producer's perspective before encouraging changes in management. My research should help move conservation forward for two reasons. First, I have provided evidence that there is a lack of vegetation heterogeneity on a landscape managed with a variety of grazing strategies, which is an issue that conservationists have talked about but have not had sufficient evidence to support. Second, because working with private producers is so crucial, a solution to create more heterogeneity is to engage private producers in a way that makes sense to them: “seeing is believing.”

CHAPTER 7: Literature cited

Adler, P. B., D. A. Raff, and W. K. Lauenroth. 2001. The effect of grazing on the spatial heterogeneity of vegetation. Oecologia 128:465–479.

Ahlering, M. A., D. H. Johnson, and J. Faaborg. 2006. Conspecific attraction in a grassland bird, the Baird's Sparrow. Journal of Field Ornithology 77:365–371.

Ahlering, M. A., and C. L. Merkord. 2016. Cattle grazing and grassland birds in the northern tallgrass prairie. Journal of Wildlife Management 80:643–654.

Ajzen, I. 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50:179–211.

Ajzen, I., and M. Fishbein. 1970. The prediction of behavior from attitudinal and normative variables. Journal of Experimental Social Psychology 6:466–487.

Allouche, O., M. Kalyuzhny, G. Moreno-Rueda, M. Pizarro, and R. Kadmon. 2012. Area-heterogeneity tradeoff and the diversity of ecological communities. Proceedings of the National Academy of Sciences 109:17495–500.

Allred, B. W., S. D. Fuhlendorf, D. M. Engle, and R. D. Elmore. 2011. Ungulate preference for burned patches reveals strength of fire-grazing interaction. Ecology and Evolution 1:132–44.

Anderson, L. C., L. A. Powell, W. H. Schacht, J. J. Lusk, and W. L. Vodehnal. 2015. Greater prairie-chicken brood-site selection and survival in the Nebraska Sandhills. Journal of Wildlife Management 79:559–569.

Angell, R. F. 1997. Crested wheatgrass and shrub response to continuous or rotational grazing. Journal of Range Management 50:160–164.

Asah, S. T. 2008. Empirical social-ecological system analysis: From theoretical framework to latent variable structural equation model. Environmental Management 42:1077–1090.

Askins, R. A., F. Chávez-ramírez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knopf, and P. D. Vickery. 2007. Conservation of grassland birds in North America: Understanding ecological processes in different regions. Ornithological Monographs 64:1–46.

Audubon Society. 2016. Working Lands, Grassland Birds. <http://www.audubon.org/conservation/project/grassland-birds>. Accessed 28 Nov 2016.

Augustine, D. J., D. T. Booth, S. E. Cox, and J. D. Derner. 2012. Grazing intensity and spatial heterogeneity in bare soil in a grazing-resistant grassland. Rangeland Ecology & Management 65:39–46.

Augustine, D. J., and J. D. Derner. 2012. Disturbance regimes and mountain plover habitat in shortgrass steppe: Large herbivore grazing does not substitute for prairie dog grazing or fire. Journal of Wildlife Management 76:721–728.

Bailey, D. W., J. E. Gross, E. A. Laca, L. R. Rittenhouse, B. Michael, D. M. Swift, P. L. Sims, and M. B. Coughenour. 1996. Mechanisms that result in large herbivore grazing distribution patterns. Journal of Range Management 49:386–400.

Barnes, M., and A. Hild. 2013. Strategic grazing management for complex creative systems. Rangelands 35:3–5.

Baruch-Mordo, S., J. S. Evans, J. P. Severson, D. E. Naugle, J. D. Maestas, J. M. Kiesecker, M. J. Falkowski, C. A. Hagen, and K. P. Reese. 2013. Saving sage-grouse from the trees: A proactive solution to reducing a key threat to a candidate species. Biological Conservation 167:233–241.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67:1–48.

Baumgart-Getz, A., L. S. Prokopy, and K. Floress. 2012. Why farmers adopt best management practice in the United States: A meta-analysis of the adoption literature. Journal of environmental management 96:17–25.

Baumgartner, H., and J. B. E. M. Steenkamp. 1996. Exploratory consumer buying behavior: Conceptualization and measurement. International Journal of Research in Marketing 13:121–137.

Becerra, T. A., D. M. Engle, R. D. Elmore, and S. D. Fuhlendorf. 2013. Contrasting preference for grassland landscapes among population groups in the Central and Southern Great Plains. Rangeland Ecology & Management 66:529–538.

Belin, D. L., D. B. Kittredge, T. H. Stevens, D. C. Dennis, C. M. Schweik, B. J. Morzuch. 2005. Assessing private forest owner attitudes toward ecosystem-based management. Journal of Forestry 103:28–35.

Belton, L. R. 2008. Factors related to success and participants' psychological ownership in collaborative wildlife management : A survey of sage-grouse local working groups. [Dissertation] Utah State University. Logan, UT.

Best, L. B. 1979. Effects of fire on a field sparrow population. American Midland Naturalist 101:434–445.

Bhattacharyya, A., R. D. Harris, W. G. Kvasnicka, and G. M. Veserat. 1997. Factors influencing rates of adoption of *Trichomoniasis* vaccine by Nevada range cattle producers. Journal of Agricultural and Resource Economics 22:174–190.

Biondini, M. E., A. A. Steuter, and R. G. Hamilton. 1999. Bison use of fire-managed remnant prairies. Journal of Range Management 52:454–461.

Bleed, A. S., and C. A. Flowerday, editors. 1998. An atlas of the Sand Hills. 3rd edition. World Herald Foundation, Omaha, NE.

Borcard, D., F. Gillet, and P. Legendre. 2011. Numerical ecology with R. R. Gentleman, K. Hornik, and G. G. Parmigiani, editors. First edition. Springer, New York, NY.

Bragg, T. B., and A. A. Steuter. 1996. Prairie ecology-the mixed prairie. Pages 53–65 in F. Samson and F. Knopf, editors, Prairie conservation: Preserving North America's most endangered ecosystem. 1st edition. Island Press, Washington, D.C.

Brennan, L. A., and W. P. Kuvlesky. 2005. North American grassland birds: An unfolding conservation crisis? Journal of Wildlife Management 69:1–13.

Briske, D. D., J. D. Derner, J. R. Brown, S. D. Fuhlendorf, W. R. Teague, K. M. Havstad, R. L. Gillen, A. J. Ash, and W. D. Willms. 2008. Rotational grazing on rangelands: Reconciliation of perception and experimental evidence. Rangeland Ecology & Management 61:3–17.

Briske, D. D., S. D. Fuhlendorf, and F. E. Smeins. 2005. State-and-transition models, thresholds, and rangeland health: A synthesis of ecological concepts and perspectives. Rangeland Ecology & Management 58:1–10.

Briske, D. D., N. F. Sayre, L. Huntsinger, M. E. Fernández-Giménez, B. Budd, and J. D. Derner. 2011. Origin, persistence, and resolution of the rotational grazing debate: Integrating human dimensions into rangeland research. Rangeland Ecology & Management 64:325–334.

Brown, M. B., M. E. Burbach, J. J. Dinan, R. J. Held, R. J. Johnson, J. G. Jorgensen, J. Lackey, J. F. Marcus, G. S. Matkin, and C. M. Thody. 2010. Nebraska's Tern and Plover Conservation Partnership – a model for sustainable conservation of threatened and endangered species. Wader Study Group Bulletin 118:1–4.

Burton, R. J. F. 2004. Seeing through the "good farmer"s' eyes: towards developing an understanding of the social symbolic value of "productivist" behaviour. Sociologia Ruralis 44:195–215.

Caswell, H. A. L. 1976. Community structure : A neutral model analysis. Ecological Monographs 46:327–354.

Cho, Y. N., A. Thyroff, M. I. Rapert, S. Y. Park, and H. J. Lee. 2013. To be or not to be green: Exploring individualism and collectivism as antecedents of environmental behavior. Journal of Business Research 66:1052–1059.

Cinner, J. E., and R. B. Pollnac. 2004. Poverty, perceptions and planning: Why socioeconomics matter in the management of Mexican reefs. Ocean and Coastal Management 47:479–493.

Coughenour, M. B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching, and native ungulate ecosystems. Journal of Range Management 44:530–542.

Coulloudon, B. 1999. Sampling vegetation attributes. Technical Reference 1734-4. Denver, CO. <www.blm.gov/nstc/library/pdf/samplveg.pdf>.

Creswell, J. W. 2014. Research design: Qualitative, quantitative, and mixed methods approaches. 4th edition. Sage Publications, Inc., Thousand Oaks, CA.

Cross, J. E., C. M. Keske, M. G. Lacy, D. L. K. Hoag, and C. T. Bastian. 2011. Adoption of conservation easements among agricultural landowners in Colorado and Wyoming: The role of economic dependence and sense of place. Landscape and Urban Planning 101:75–83.

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Science 33:43–64.

Davidson, A. D., J. K. Detling, and J. Brown. 2012. Ecological roles and conservation challenges of social, burrowing, herbivorous mammals in the world’s grasslands. Frontiers in Ecology and the Environment 10:477-486.

Davis, S. K., B. C. Dale, T. O. M. Harrison, and D. C. Duncan. 2014. Response of grassland songbirds to grazing system type and range condition. Pages 110–119 in. Proceedings of the North American Prairie Conference.

Davis, S. K., and W. E. Lanyon. 2008. Western meadowlark (*Sturnella neglecta*). A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, NY, USA. <http://bna.birds.cornell.edu/bna/species/104>.

De Young, R. 1993. Changing behavior and making it stick: The conceptualization and management of conservation behavior. Environment and Behavior 25:485–505.

Derner, J. D., W. K. Lauenroth, P. Stapp, and D. J. Augustine. 2009. Livestock as ecosystem engineers for grassland bird habitat in western Great Plains of North America. Rangeland Ecology & Management 62:111–118.

Didier, E. A., and M. Brunson. 2004. Adoption of range management innovations by Utah ranchers. Journal of Range Management 57:330–336.

Dillman, D. A., J. D. Smyth, and L. M. Christian. 2009. Internet, mail, and mixed-mode surveys: the tailored design method. 3rd edition. John Wiley & Sons, Ltd, Hoboken, NJ.

Ditomaso, J. M. 2000. Invasive weeds in rangelands: species, impacts, and management. Weed Science 48:255–265.

Edwards, R. 2013. Can ecotourism save the Great Plains? Prairie Fire.

Elliot, A. J., and P. G. Devine. 1994. On the motivational nature of cognitive dissonance: Dissonance as psychological discomfort. Journal of Personality and Social Psychology 67:382-394.

Ellis, C. 2013. The symbiotic ideology: stewardship, husbandry, and dominion in beef production. Rural Sociology 78:429–449.

Elmendorf, C. S. 2003. Ideas, incentives, gifts, and governance: Toward conservation stewardship of private land, in cultural and psychological perspective. University of Illinois Law Review 2003:423–506.

Environmental Protection Agency. 2016. Ecoregions of North America. Washington, DC. <https://www.epa.gov/eco-research/ecoregions-north-america>. Accessed 9 Nov 2016.

Ervin, C. A., and D. Ervin. 1982. Factors affecting the use of soil conservation practices: hypotheses, evidence, and policy implications. Land Economics 58:277–292.

Festinger, L. 1962. A theory of cognitive dissonance. Stanford University Press.

Fishbein, M., and I. Ajzen. 2010. Predicting and changing behavior: The reasoned action approach. Psychology Press, New York, NY.

Fisher, R. J., and S. K. Davis. 2010. From Wiens to Robel: A review of grassland-bird habitat selection. Journal of Wildlife Management 74:265–273.

Fiske, I., and R. Chandler. 2011. Unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1–23.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8:629–644.

Freese, C. H., S. D. Fuhlendorf, and K. Kunkel. 2014. A management framework for the transition from livestock production toward biodiversity conservation on Great Plains rangelands. Ecological Restoration 32:358–368.

Freese, C. H., D. Montanye, and F. D. Fleischman. 2010. Proposed standards and guidelines for private nature reserves in the northern Great Plains. Great Plains Research 20:71–84.

Fuhlendorf, S. D., and D. M. Engle. 2001. Restoring heterogeneity on rangelands: Ecosystem management based on evolutionary grazing patterns. Bioscience 51:625–632.

Fuhlendorf, S. D., and D. M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. Journal of Applied Ecology 41:604–614.

Fuhlendorf, S. D., D. M. Engle, R. D. Elmore, R. F. Limb, and T. G. Bidwell. 2012. Conservation of pattern and process: Developing an alternative paradigm of rangeland management. Rangeland Ecology & Management 65:579–589.

Fuhlendorf, S. D., D. M. Engle, J. Kerby, and R. G. Hamilton. 2009. Pyric herbivory: Rewilding landscapes through the recoupling of fire and grazing. Conservation Biology 23:588–98.

Fuhlendorf, S. D., W. C. Harrell, D. M. Engle, R. G. Hamilton, C. A. Davis, and D. M. Leslie. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. Ecological Applications 16:1706–1716.

Fuhlendorf, S. D., T. J. Hovick, R. D. Elmore, A. M. Tanner, D. M. Engle, and C. A. Davis. 2017. A Hierarchical Perspective to Woody Plant Encroachment for Conservation of Prairie-Chickens. Rangeland Ecology & Management 70:9–14.

Gillen, R. L., J. A. Eckroat, and F. T. Mccollum. 2000. Vegetation response to stocking rate in southern mixed-grass prairie. Journal of Range Management 53:471–478.

Goldsmith, R. E., and G. R. Foxall. 2003. The Measurement of Innovativeness. Pages 321–330 in L. V. Shavinina, editor, The International Handbook on Innovation. Elsevier Science, Oxford, UK.

Greer, M. J., K. Bakker, and C. D. Dieter. 2016. Grassland bird response to recent loss and degradation of native prairie in central and western South Dakota. The Wilson Journal of Ornithology 128:278–289.

Gutwein, M., and J. H. Goldstein. 2013. Integrating conservation and financial objectives on private rangelands in northern Colorado: Rancher and practitioner perceptions. Rangeland Ecology & Management 66:330–338.

Hart, R. H., J. Bissio, M. J. Samuel, and J. W. Waggoner. 1993. Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. Journal of Range Management 46:81–87.

Hart, R. H., M. J. Samuel, P. S. Test, and M. Smith. 1988. Cattle, vegetation, and economic responses to grazing systems and grazing pressure. Journal of Range Management 41:282–286.

Hazen, H., and P. Anthamatten. 2004. Representation of ecological regions by protected areas at the global scale. Physical Geography 25:499–512.

Henderson, A. E., and S. K. Davis. 2014. Rangeland Health assessment: A useful tool for linking range management and grassland bird conservation? Rangeland Ecology & Management 67:88–98.

Henderson, A. E., M. Reed, and S. K. Davis. 2014. Voluntary stewardship and the Canadian Species at Risk Act: Exploring rancher willingness to support species at risk in the Canadian prairies. Human Dimensions of Wildlife 19:17–32.

Hobbs, N. T. 1996. Modification of ecosystems by ungulates. Journal of Wildlife Management 60:695–713.

Hoffman, C. M. 2013. Building upon common-pool resource theory to explore success in transitioning water management institutions. [Dissertation] University of Nebraska-Lincoln. Lincoln, NE.

Hovick, T. J., R. D. Elmore, and S. D. Fuhlendorf. 2014. Structural heterogeneity increases diversity of non-breeding grassland birds. Ecosphere 5:1–13.

Hutto, R., S. M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593–602.

Inman, K., and D. M. Mcleod. 2002. Property rights and public interests: A Wyoming agricultural lands study. Growth and Change 33:91–114.

Jacobo, E. J., A. M. Rodríguez, N. Bartoloni, and V. Deregibus. 2006. Rotational grazing effects on rangeland vegetation at a farm scale. Rangeland Ecology & Management 59:249–257.

Janssen, G. K. 1996. Encouraging conservation of endangered plants on private lands: A case study of Johnston’s frankenia (*Frankenia johnstonii*), an endangered south Texas subshrub. Pages 1–7 in Southwestern rare and endangered plants: proceedings of the second conference, September 11-14, 1995. Flagstaff, AZ.

Johnson, D. H., and L. D. Igl. 2001. Area requirements of grassland birds: A regional perspective. Auk 118:24–34.

Johnson, T., P. L. Kennedy, T. Delcurto, and R. V. Taylor. 2011. Bird community responses to cattle stocking rates in a Pacific Northwest bunchgrass prairie. Agriculture, Ecosystems & Environment 144:338–346.

Kahan, D. M., D. Braman, J. Monahan, L. Callahan, and E. Peters. 2010. Cultural cognition and public policy: The case of outpatient commitment laws. Law and Human Behavior 34:118–140.

Kantrud, H. A., and R. L. Kologiski. 1983. Avian associations of the Northern Great Plains grasslands. Journal of Biogeography 10:331–350.

Kembel, S. W., P. D. Cowan, M. R. Helmus, W. K. Cornwell, H. Morlon, D. D. Ackerly, S. P. Blomberg, and C. O. Webb. 2010. Picante: R tools for integrating phylogenies and ecology. Bioinformatics 26:1463–1464.

Kempema, S. 2007. The influence of grazing systems on grassland bird density, productivity, and species richness on private rangeland in the Nebraska Sandhills. [Thesis] University of Nebraska-Lincoln.

Kennedy, S. M., M. E. Burbach, and M. S. Sliwinski. 2016. Sustainable grassland management: an exploratory study of progressive ranchers in Nebraska. Sustainable Agriculture Research 5:103.

Knapp, C. N., and M. E. Fernández-Giménez. 2009. Knowledge in practice: Documenting rancher local knowledge in northwest Colorado. Rangeland Ecology & Management 62:500–509.

Knapp, C. N., F. Stuart Chapin, and J. O. Cochran. 2015. Ranch owner perceptions and planned actions in response to a proposed Endangered Species Act listing. Rangeland Ecology & Management 68:453–460.

Knight, K. B., T. P. Toombs, and J. D. Derner. 2011. Cross-fencing on private us rangelands: Financial costs and producer risks. Rangelands 33:41–44.

Koper, N., and F. K. A. Schmiegelow. 2006. Effects of habitat management for ducks on target and nontarget species. Journal of Wildlife Management 70:823–834.

Krannich, R., and M. Smith. 1998. Local perceptions of public lands natural resource management in the rural west: Toward improved understanding of the "revolt in the west." Society & Natural Resources 11:677–695.

Krausman, P. R., D. E. Naugle, M. R. Frisina, R. Northrup, V. C. Bleich, W. M. Block, M. C. Wallace, and J. D. Wright. 2009. Livestock grazing, wildlife habitat, and rangeland values. Rangelands 31:15–19.

Kreuter, U. P., H. E. Amestoy, M. M. Kothmann, D. N. Ueckert, A. Mcginty, and S. R. Cummings. 2005. The use of brush management methods: A Texas landowner survey. Rangeland Ecology & Management 58:284–291.

Lamb, B. L., and K. Cline. 2003. Public knowledge and perceptions of black-tailed prairie dogs. Human Dimensions of Wildlife 8:127–143.

Langpap, C. 2006. Conservation of endangered species: Can incentives work for private landowners? Ecological Economics 57:558–572.

Leeuw, A. De, P. Valois, I. Ajzen, and P. Schmidt. 2015. Using the theory of planned behavior to identify key beliefs underlying pro-environmental behavior in high-school students: Implications for educational interventions. Journal of Environmental Psychology 42:128–138.

Lesch, W. C., and C. J. Wachenheim. 2014. Factors influencing conservation practice adoption in agriculture: A review of the literature. Fargo, ND.

Liffmann, R. H., L. Huntsinger, and L. C. Forero. 2000. To ranch or not to ranch: Home on the urban range? Journal of Range Management 53:362–370.

Lindenmayer, D. B., R. J. Hobbs, R. Montague-Drake, J. Alexandra, A. Bennett, M. Burgman, P. Cale, A. Calhoun, V. Cramer, P. Cullen, D. Driscoll, L. Fahrig, J. Fischer, J. Franklin, Y. Haila, M. Hunter, P. Gibbons, S. Lake, G. Luck, C. Macgregor, S. Mcintyre, R. C. Mac Nally, A. Manning, J. R. Miller, H. Mooney, R. F. Noss, H. P. Possingham, D. Saunders, F. K. A. Schmiegelow, M. Scott, D. Simberloff, T. Sisk, G. Tabor, B. H. Walker, J. A. Wiens, J. Woinarski, and E. S. Zavaleta. 2008. A checklist for ecological management of landscapes for conservation. Ecology letters 11:78–91.

Lipsey, M. K. 2015. Cows and Plows : Science-based Conservation for Grassland Songbirds in Agricultural Landscapes. [Dissertation] University of Montana. Missoula, MT.

Lipsey, M. K., K. E. Doherty, D. E. Naugle, S. Fields, J. S. Evans, S. K. Davis, and N. Koper. 2015. One step ahead of the plow: Using cropland conversion risk to guide Sprague's Pipit conservation in the northern Great Plains. Biological Conservation 191:739–749.

Lumley, T. 2004. Analysis of complex survey samples. Journal of Statistical Software 9:1:19.

Lwiwski, T. C., N. Koper, and D. C. Henderson. 2015. Stocking rates and vegetation structure, heterogeneity, and community in a northern mixed-grass prairie. Rangeland Ecology & Management 68:322–331.

Lybecker, D., B. L. Lamb, and P. D. Ponds. 2002. Public attitudes and knowledge of the black-tailed prairie dog: A common and controversial species. Bioscience 52:607.

Macarthur, R. H., and J. W. Macarthur. 1961. On bird species diversity. Ecology 42:594–598.

Maccallum, R. C., M. W. Browne, and H. M. Sugawara. 1996. Power analysis and determination of sample size for covariance structure modeling. Psychological Methods 1:130–149.

Marchini, S., and D. W. Macdonald. 2012. Predicting ranchers' intention to kill jaguars: Case studies in Amazonia and Pantanal. Biological Conservation 147:213–221.

Marshall, C., and G. B. Rossman. 2010. Designing Qualitative Methods. 5th edition. Sage Publications, Inc., Thousand Oaks, CA.

Maslow, A. H. 1954. Motivation and Personality. Harper and Row, New York, NY.

Mcgranahan, D. A., P. W. Brown, L. A. Schulte, and J. C. Tyndall. 2013. A historical primer on the US farm bill: Supply management and conservation policy. Journal of Soil and Water Conservation 68:67A–73A.

Mcgranahan, D. A., and K. Kirkman. 2013. Multifunctional rangeland in Southern Africa: Managing for production, conservation, and resilience with fire and grazing. Land 2:176–193.

Mengel, R. M. 1970. The North American central plains as an isolating agent in bird speciation. Pages 280–340 in W. Dort and J. K. Jones, editors, Pleistocene and Recent Environments of the Central Great Plains. University of Kansas Press, Lawrence, Kansas.

Minchin, P. R. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Vegetatio 69:89–107.

Müller, J., J. Stadler, and R. Brandl. 2010. Composition versus physiognomy of vegetation as predictors of bird assemblages: The role of LIDAR. Remote Sensing of Environment 114:490–495.

Mac Nally, R. C. 1990. The roles of floristics and physiognomy in avian community composition. Australian Journal of Ecology 15:321–327.

Neilly, H., J. Vanderwal, and L. Schwarzkopf. 2016. Balancing biodiversity and food production: A better understanding of wildlife response to grazing will inform off-reserve conservation on rangelands. Rangeland Ecology & Management 69:430–436.

Newbold, T., L. N. Hudson, A. P. Arnell, S. Contu, A. De Palma, S. Ferrier, S. L. L. Hill, A. J. Hoskins, I. Lysenko, H. R. P. Phillips, V. J. Burton, C. W. T. Chng, S. Emerson, D. Gao, G. Pask-hale, J. Hutton, M. Jung, K. Sanchez-ortiz, B. I. Simmons, S. Whitmee, H. Zhang, J. P. W. Scharlemann, and A. Purvis. 2016. Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science 353:288–291.

Norton, B. E., M. Barnes, and W. R. Teague. 2013. Grazing management can improve livestock distribution. Rangelands 35:45–51.

Oksanen, A. J., F. G. Blanchet, R. Kindt, P. R. Minchin, R. B. O. Hara, G. L. Simpson, P. Soly-, M. H. H. Stevens, and H. Wagner. 2016. Package "vegan".

Pannell, D. J., G. R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. Australian Journal of Experimental Agriculture 46:1407–1424.

Pärtel, M., R. Szava-Kovats, and M. Zobel. 2011. Dark diversity: Shedding light on absent species. Trends in Ecology & Evolution 26:124–8.

Pascual, U., and C. Perrings. 2007. Developing incentives and economic mechanisms for in situ biodiversity conservation in agricultural landscapes. Agriculture, Ecosystems & Environment 121:256–268.

Pasquini, L., R. M. Cowling, C. Twyman, and J. Wainwright. 2010. Devising appropriate policies and instruments in support of private conservation areas: Lessons learned from the Klein Karoo, South Africa. Conservation Biology 24:470–8.

Paul W. Mielke, J., K. J. Berry, and E. S. Johnson. 1976. Multi-response permutation procedures for *a priori* classifications. Communications in Statistics 5:1409–1424.

Pickett, S. T. A., and J. N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biological Conservation 13:27–36.

Potvin, M. A., and A. T. Harrison. 1984. Vegetation and litter changes of a nebraska sandhills prairie protected from grazing. Journal of Range Management 37:55–58.

Powell, L. A. 2012. Common-interest community agreements on private lands provide opportunity and scale for wildlife management. Animal Biodiversity and Conservation 35:295–306.

Powell, L. A. 2015. Periodic corrections to agricultural land values provide opportunity for conservation. Journal of Soil and Water Conservation 70:39–44.

Prokopy, L. S., K. Floress, D. Klotthor-Weinkauf, and A. Baumgart-Getz. 2008. Determinants of agricultural best management practice adoption: Evidence from the literature. Journal of Soil and Water Conservation 63:300–311.

Qualtrics. 2015. Qualtrics, Provo, Utah. <http://www.qualtrics.com>.

Rahm, M. R., and W. E. Huffman. 1984. Adoption of reduced tillage: The role of human capital and other variables. American Journal of Agricultural Economics 66:405–413.

Ranellucci, C. L., N. Koper, and D. C. Henderson. 2012. Twice-over rotational grazing and its impacts on grassland songbird abundance and habitat structure. Rangeland Ecology & Management 65:109–118.

Reece, P. E., T. L. Holman, and K. J. Moore. 1999. Late-summer forage on prairie sandreed dominated range-land after spring defoliation. Journal of Range Management 52:228–234.

Reece, P. E., W. H. Schacht, and J. D. Volesky. 2007. Skillful grazing management on semiarid rangelands. Lincoln, NE.

Reece, P. E., J. D. Volesky, and W. H. Schacht. 2008. Integrating management objectives and grazing strategies on semi-arid rangeland. Lincoln, NE.

Reimer, A. P., and L. S. Prokopy. 2014. Farmer participation in U.S. Farm Bill conservation programs. Environmental management 53:318–32.

Ribic, C. A., R. R. Koford, J. R. Herkert, D. H. Johnson, N. Niemuth, D. E. Naugle, K. Bakker, D. W. Sample, and R. B. Renfrew. 2009. Area sensitivity in North American grassland birds: Patterns and processes. Auk 126:233–244.

Richards, R. T., and M. R. George. 1996. Evaluating changes in ranch management practices through extension education. Journal of Range Management 49:76–80.

Rickenbach, M. G., D. B. Kittredge, D. M. Dennis, and T. H. Stevens. 1998. Ecosystem management: Capturing the concept for woodland owners. Journal of Forestry 96:18–24.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Roehrich, G. 2004. Consumer innovativeness. Journal of Business Research 57:671–677.

Rohrmann, B. 1997. Risk orientation questionnaire: Attitudes towards risk decisions. 1997. University of Melbourne. Melbourne, Australia. Retrieved from < http://www.rohrmannresearch.net/pdfs/rohrmann-rac-roq.pdf>.

Rosseel, Y. 2012. Lavaan: An R package for structural equation modeling. Journal of Statistical Software 48:1–36.

Rotenberry, J. T., and J. A. Wiens. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: A multivariate analysis. Ecology 61:1228–1250.

Rowe, H. I., E. T. Bartlett, and L. E. Swanson. 2001. Ranching motivations in 2 Colorado counties. Journal of Range Management 54:314–321.

Royle, J. A. 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108–15.

Samson, F. B., and F. L. Knopf. 1994. Prairie conservation in North America. Bioscience 44:418–421.

Samson, F. B., F. L. Knopf, and W. R. Ostlie. 2004. Great Plains ecosystems: past, present, and future. Wildlife Society Bulletin 32:6–15.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, J. D. J. Ziolkowski, and W. A. Link. 2014. The North American Breeding Bird Survey, results and analysis 1966–2013. Laurel, MD.

Sauer, J. R., W. A. Link, J. E. Fallon, K. L. Pardieck, and D. J. Ziolkowski. 2013. The North American Breeding Bird Survey 1966–2011: Summary analysis and species accounts. North American Fauna 79:1–32.

Savory, A. 1983. The Savory grazing method or holistic resource management. Rangelands 5:155–159.

Savory Institute. 2016. Savory Institute. <http://savory.global/institute>. Accessed 28 Nov 2016.

Sayre, N. F. 2004. Viewpoint: The need for qualitative research to understand ranch management. Journal of Range Management 57:668–674.

Scasta, J. D., E. T. Thacker, T. J. Hovick, D. M. Engle, B. W. Allred, S. D. Fuhlendorf, and J. R. Weir. 2015. Patch-burn grazing (PBG) as a livestock management alternative for fire-prone ecosystems of North America. Renewable Agriculture and Food Systems 31:550-567.

Schacht, W. H., J. D. Volesky, D. Bauer, and M. B. Stephenson. 2011. Grazing systems for Nebraska Sandhills rangeland. Lincoln, NE.

Schumacher, K. W. 2016. Prairie dog legislation and burrowing owls in Nebraska. Lincoln, NE.

Schutz, A. B. 2010. Grassland governance and common-interest communities. Sustainability 2:2320–2348.

Schwartz, S. H., and J. A. Howard. 1981. A normative decision-making model of altruism. In J. P. Rushton and R. M. Sorrentino, editors, Altruism and helping behavior (pp. 189-211). Hillsdale, NJ: Lawrence Erlbaum.

Serbruyns, I., and S. Luyssaert. 2006. Acceptance of sticks, carrots and sermons as policy instruments for directing private forest management. Forest Policy and Economics 9:285–296.

Sheeder, R. J., and G. D. Lynne. 2011. Empathy-conditioned conservation: "Walking in the shoes of others" as a conservation farmer. Land Economics 87:433–452.

Sivadas, E., N. T. Bruvold, and M. R. Nelson. 2008. A reduced version of the horizontal and vertical individualism and collectivism scale: A four-country assessment. Journal of Business Research 61:201–210.

Skagen, S. K., and A. A. Yackel Adams. 2010. Are there optimal densities for prairie birds? Condor 112:8–14.

Sliwinski, M. S., and N. Koper. 2015. Managing mixed-grass prairies for songbirds using variable cattle stocking rates. Rangeland Ecology & Management 68:470–475.

Smith, H. F., and C. A. Sullivan. 2014. Ecosystem services within agricultural landscapes: Farmers' perceptions. Ecological Economics 98:72–80.

Smith, J. R., W. R. Louis, D. J. Terry, K. H. Greenaway, M. R. Clarke, and X. Cheng. 2012. Congruent or conflicted? The impact of injunctive and descriptive norms on environmental intentions. Journal of Environmental Psychology 32:353–361.

Steg, L., and J. De Groot. 2010. Explaining prosocial intentions: Testing causal relationships in the norm activation model. The British journal of social psychology 49:725–743.

Stephenson, M. B. 2010. Effect of grazing system on livestock performance, botanical composition, and standing crop in the Nebraska Sandhills. University of Nebraska-Lincoln.

Stephenson, M. B., W. H. Schacht, J. D. Volesky, K. M. Eskridge, E. M. Mousel, and D. Bauer. 2013. Grazing method effect on topographical vegetation characteristics and livestock performance in the Nebraska Sandhills. Rangeland Ecology & Management 66:561–569.

Symstad, A. J., and J. L. Jonas. 2011. Incorporating biodiversity into rangeland health: Plant species richness and diversity in Great Plains grasslands. Rangeland Ecology & Management 64:555–572.

Tanaka, J. A., M. Brunson, and L. A. Torell. 2011. A social and economic assessment of rangeland conservation practices. Pages 371–422 in D. D. Briske, editor, Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps. United States Department of Agriculture, Natural Resources Conservation Service.

Teague, W. R., and S. L. Dowhower. 2003. Patch dynamics under rotational and continuous grazing management in large, heterogeneous paddocks. Journal of Arid Environments 53:211–229.

Temple, S. A., B. M. Fevold, L. K. Paine, D. L. Undersander, and D. W. Sample. 1999. Nesting birds and grazing cattle: Accommodating both on Midwestern pastures. Studies in Avian Biology 19:196–202.

Tews, J., U. Brose, V. Grimm, K. Tielbörger, M. C. Wichmann, M. Schwager, and F. Jeltsch. 2004. Animal species diversity driven by habitat heterogeneity/diversity: The importance of keystone structures. Journal of Biogeography 31:79–92.

The Associated Press. 2012. South Dakota ranchers seek state action on prairie dogs. Rapid City Journal. <http://rapidcityjournal.com/news/south-dakota-ranchers-seek-state-action-on-prairie-dogs/article_990808f4-4aa2-11e1-aa6a-001871e3ce6c.html>. Accessed 24 Jan 2017.

The Nature Conservancy. 2015. Fire Learning Network. <https://www.conservationgateway.org/conservationpractices/firelandscapes/firelearningnetwork/Pages/fire-learning-network.aspx>. Accessed 19 Jan 2017.

Toledo, D., M. G. Sorice, and U. P. Kreuter. 2013. Social and ecological factors influencing attitudes toward the application of high-intensity prescribed burns to restore fire adapted grassland ecosystems. Ecology and Society 18(4):9.

Toombs, T. P., J. D. Derner, D. J. Augustine, B. Krueger, and S. Gallagher. 2010. Managing for biodiversity and livestock. Rangelands 32:10–15.

Toombs, T. P., and M. G. Roberts. 2009. Are natural resources conservation service range management investments working at cross-purposes with wildlife habitat goals on western United States rangelands? Rangeland Ecology & Management 62:351–355.

Towne, E. G., D. C. Hartnett, and R. C. Cochran. 2005. Vegetation trends in tallgrass prairie from bison and cattle grazing. Ecological Applications 15:1550–1559.

Truett, J. C., M. Phillips, K. Kunkel, and R. Miller. 2001. Managing bison to restore biodiversity. Great Plains Research 11:123–144.

Turner Enterprises, Inc. 2017. Turner Ranches. < http://www.tedturner.com/turner-ranches/>. Accessed 20 February 2017.

Twidwell, D., W. E. Rogers, S. D. Fuhlendorf, C. L. Wonkka, D. M. Engle, J. R. Weir, U. P. Kreuter, and C. A. Taylor. 2013. The rising Great Plains fire campaign: Citizens' response to woody plant encroachment. Frontiers in Ecology and the Environment 11:64–71.

Twidwell, D., A. S. West, W. B. Hiatt, A. L. Ramirez, J. Taylor Winter, D. M. Engle, S. D. Fuhlendorf, and J. D. Carlson. 2016. Plant invasions or fire policy: Which has altered fire behavior more in tallgrass prairie? Ecosystems 19:356–368.

U.S. Department of Agriculture. 2015. Summary report: 2012 National Resources Inventory. Washington, D.C. <www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcseprd396218.pdf>.

Underwood, A. J. 1994. On beyond BACI: Sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:4–15.

United States Department of Agriculture. 2015. 2012 Census of Agriculture Highlights: Cattle Industry.

USGS. 2013. Effects of grazing regimes on distribution and abundance of grassland birds at Valentine National Wildlife Refuge. Jamestown, ND.

Vallentine, J. F. 2001. Grazing Management. 2nd edition. Academic Press, San Diego, CA.

Van Gossum, P., S. Luyssaert, I. Serbruyns, and F. Mortier. 2005. Forest groups as support to private forest owners in developing close-to-nature management. Forest Policy and Economics 7:589–601.

Vavra, M. 2005. Livestock grazing and wildlife: Developing compatibilities. Rangeland Ecology & Management 58:128–134.

VERBI Software. 2014. MAXQDA. VERBI Software, Berlin, Germany.

Vermeire, L. T., R. K. Heitschmidt, and M. R. Haferkamp. 2008. Vegetation response to seven grazing treatments in the Northern Great Plains. Agriculture, Ecosystems & Environment 125:111–119.

Vickery, P. D., P. L. Tubaro, J. Silva, B. G. Peterjohn, J. R. Herkert, and R. B. Cavalcanti. 1999. Ecology and conservation of grassland birds of the western hemisphere. Studies in Avian Biology 19:2–26.

Walk, J. W., and R. E. Warner. 2000. Grassland management for the conservation of songbirds in the Midwestern USA. Biological Conservation 94:165–172.

Wiens, J. A. 1974. Habitat heterogeneity and avian community structure in North American grasslands. American Midland Naturalist 91:195–213.

Wiens, J. A. 1976. Population responses to patchy environments. Annual Review of Ecology and Systematics 7:81–120.

Willcox, A. S., W. M. Giuliano, and M. C. Monroe. 2012. Predicting cattle rancher wildlife management activities: An application of the theory of planned behavior. Human Dimensions of Wildlife 17:159–173.

Winter, M., D. H. Johnson, and J. A. Shaffer. 2005. Variability in vegetation effects on density and nesting success of grassland birds. Journal of Wildlife Management 69:185–197.

Winter, S. L., S. D. Fuhlendorf, C. L. Goad, C. A. Davis, K. R. Hickman, and D. M. Leslie. 2012. Restoration of the fire-grazing interaction in *Artemisia filifolia* shrubland. Journal of Applied Ecology 49:242–250.

With, K. A., A. W. King, and W. E. Jensen. 2008. Remaining large grasslands may not be sufficient to prevent grassland bird declines. Biological Conservation 141:3152–3167.

World Wildlife Fund. 2015. Sustainable Ranching Initiative. <http://www.worldwildlife.org/projects/sustainable-ranching-initiative>. Accessed 24 Jan 2017.

Wright, C. K., and M. C. Wimberly. 2013. Recent land use change in the western corn belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences 2013:1–6.

Yung, L., and J. M. Belsky. 2007. Private property rights and community goods: Negotiating landowner cooperation amid changing ownership on the Rocky Mountain Front. Society & Natural Resources 20:689–703.

APPENDIX A: **May vegetation structure datasheet.**

Sandhills Grazing System and Landscape Bird Habitat Assessment			
Ranch:	Plot #:	Date (MM/DD/YY):	
		Observer:	

	QUADRAT							
	50m N	100m N	50m E	100m E	50m S	100m S	50m W	100m W
Grass height (cm)*								
Forb height (cm)*								
Shrub height (cm)*								
Litter depth (cm), center								
Litter density (N/L/M/H)								
Canopy height (cm)								
Litter cover								
DSV cover**								
Bare ground cover								
Moss/lichen cover								
Animal dung cover								
Grass cover (live)								
Forb cover (live)								
Cactus cover (live)								
Shrub cover (live)								
Slope (flat/low/med/steep)								
Slope faces								
Ecological site***								
VOR (100%)								

Running water in plot?	Y N
Standing water in plot?	Y N
Blowout in plot?	Y N
Description: (e.g. pond/still water versus creek; approximate size and location of blowout)	
Additional comments:	

COVER CLASSES			
0 = 0%	2 = >1 to 5%	4 = 26 to 50%	6 = 75 to 95%
1 = >0 and 1%	3 = 6 to 25%	5 = 51 to 75%	7 = 95 to 100%

*Grass, forb, and shrub height is maximum height of dead or alive (or dormant) plants; put X if none in frame
**DSV = Dead Standing Vegetation (DSV is still standing but dead, whereas litter is lying <45° angle)
***Sands (rolling dunes), Choppy sands (steep dunes, cat steps), Sandy (broad, flat expanse), Blowout

Vegetation structure Instructions

Measurements:

1. Grass height (dead or alive)
2. Forb height (dead or alive)
3. Shrub height (dead or alive)
4. Litter depth (center of frame)
5. Litter density (where measured, None, Low, Medium, High)
6. Canopy height (Styrofoam and meter stick)

Cover classes (of whole frame, see bottom of datasheet for cover classes):

7. Litter cover (dead plant material lying at <45 degree angle)
8. DSV cover (standing dead vegetation, normally fairly low because it is standing and not laying, a dead standing shrub may increase this cover)
9. Bare ground cover (includes rocks)
10. Moss/lichen cover
11. Animal dung cover
12. Grass cover (live)
13. Forb cover (live)
14. Cactus cover (live)
15. Shrub cover (live)

Ecological site information:

16. Slope (Flat, Low, Medium, Steep)
17. Slope faces (to nearest 45 (e.g., N, NE, S, SE, W, SW, E, NE, etc.)
18. Ecological site (Blowout, Sandy, Sands, or Choppy Sands)

Visual Obstruction Readings:

19. Robel pole measurements (pole in center of frame, one from each side of frame, write in decimeters; can remove frame if in the way, stand at 4m (length of string) and look from height of 1m—use meter stick)

Running water, standing water, and blowout should be filled at end once the plot has been covered.

Description can include any notes you feel are relevant.

APPENDIX B: **Vegetation structure model selection tables**

Table B-1. Model selection table for visual obstruction reading in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Stocking rate + Season of use	13	25881.19	0.00	0.68	-12927.6
Season of use	12	25883.04	1.85	0.27	-12929.5
Dormant-season stocking rate	7	25888.70	7.50	0.02	-12937.3
Seasonal stocking rates	9	25889.20	8.01	0.01	-12935.6
Disturbance intensity	11	25890.62	9.43	0.01	-12934.3
Stocking rate + Grazing strategy	11	25891.08	9.89	0.00	-12934.5
Stocking rate	7	25891.67	10.47	0.00	-12938.8
Stocking rate (categorical)	7	25892.64	11.45	0.00	-12939.3
Management intensity (categorical)	8	25898.79	17.60	0.00	-12941.4
Null	6	25899.64	18.45	0.00	-12943.8
Ownership	7	25900.25	19.05	0.00	-12943.1
Warm-season stocking rate	7	25900.38	19.19	0.00	-12943.2
Cool-season stocking rate	7	25900.92	19.73	0.00	-12943.5
Grazing strategy	10	25901.52	20.33	0.00	-12940.7

Table B-2. Model selection table for variability (SD) in visual obstruction reading in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
(quadratic) Warm-season stocking rate	7	2813.07	0.00	0.86	-1399.4
(quadratic) Seasonal stocking rates	11	2818.40	5.33	0.06	-1397.9
Grazing strategy	9	2820.07	7.00	0.03	-1400.9
(quadratic) Stocking rate + Grazing strategy	11	2821.39	8.33	0.01	-1399.4
Management intensity (categorical)	7	2822.19	9.12	0.01	-1404.0
Null	5	2822.44	9.38	0.01	-1406.2
Stocking rate (categorical)	6	2823.55	10.48	0.00	-1405.7
Dormant-season stocking rate	6	2823.96	10.89	0.00	-1405.9
Stocking rate	6	2824.08	11.01	0.00	-1406.0
Ownership	6	2824.22	11.15	0.00	-1406.0
Warm-season stocking rate	6	2824.41	11.34	0.00	-1406.1
Cool-season stocking rate	6	2824.48	11.42	0.00	-1406.2
Disturbance intensity	10	2825.28	12.21	0.00	-1402.4
(quadratic) Dormant-season stocking rate	7	2825.50	12.43	0.00	-1405.6
(quadratic) Stocking rate	7	2825.83	12.76	0.00	-1405.8
(quadratic) Cool-season stocking rate	7	2826.17	13.11	0.00	-1406.0
Seasonal stocking rates	8	2827.93	14.87	0.00	-1405.8
Season of use	11	2829.15	16.08	0.00	-1403.3
(quadratic) Stocking rate + Season of use	13	2831.67	18.61	0.00	-1402.5

Table B-3. Model selection table for litter depth in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Season of use	12	20920.91	0.00	0.73	-10448.4
Stocking rate + Season of use	13	20922.92	2.01	0.27	-10448.4
Stocking rate (categorical)	7	20989.63	68.72	0.00	-10487.8
Disturbance intensity	11	20990.27	69.36	0.00	-10484.1
Stocking rate	7	20990.74	69.83	0.00	-10488.4
Null	6	20990.98	70.07	0.00	-10489.5
Dormant-season stocking rate	7	20991.40	70.49	0.00	-10488.7
Ownership	7	20991.68	70.77	0.00	-10488.8
Cool-season stocking rate	7	20992.49	71.58	0.00	-10489.2
Warm-season stocking rate	7	20992.86	71.96	0.00	-10489.4
Management intensity (categorical)	8	20993.78	72.87	0.00	-10488.9
Seasonal stocking rates	9	20994.56	73.65	0.00	-10488.3
Stocking rate + Grazing strategy	11	20995.32	74.42	0.00	-10486.6
Grazing strategy	10	20996.66	75.75	0.00	-10488.3

Table B-4. Model selection table for variability (SD) in litter depth in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Ownership	6	1894.82	0.00	0.47	-941.3
(quadratic) Stocking rate	7	1897.00	2.18	0.16	-941.4
Stocking rate	6	1898.89	4.07	0.06	-943.4
Null	5	1899.20	4.37	0.05	-944.5
Stocking rate (categorical)	6	1899.84	5.02	0.04	-943.8
Cool-season stocking rate	6	1900.11	5.29	0.03	-944.0
Warm-season stocking rate	6	1900.15	5.32	0.03	-944.0
(quadratic) Stocking rate + Grazing strategy	11	1900.24	5.41	0.03	-938.9
Dormant-season stocking rate	6	1901.07	6.25	0.02	-944.5
(quadratic) Warm-season stocking rate	7	1901.13	6.30	0.02	-943.5
Seasonal stocking rates	8	1901.41	6.58	0.02	-942.6
(quadratic) Cool-season stocking rate	7	1901.87	7.05	0.01	-943.8
(quadratic) Stocking rate + Season of use	13	1901.94	7.11	0.01	-937.6
(quadratic) Dormant-season stocking rate	7	1902.94	8.11	0.01	-944.4
(quadratic) Seasonal stocking rates	11	1902.98	8.16	0.01	-940.2
Management intensity (categorical)	7	1903.06	8.23	0.01	-944.4
Season of use	11	1903.34	8.51	0.01	-940.4
Disturbance intensity	10	1905.39	10.57	0.00	-942.5
Grazing strategy	9	1906.18	11.36	0.00	-943.9

Table B-5. Model selection table for litter cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Stocking rate + Season of use	13	38272.10	0.00	0.81	-19123
Season of use	12	38274.98	2.88	0.19	-19125.5
Stocking rate + Grazing strategy	11	38341.76	69.66	0.00	-19159.9
Stocking rate	7	38344.34	72.23	0.00	-19165.2
Dormant-season stocking rate	9	38346.25	74.15	0.00	-19164.1
Cool-season stocking rate	7	38354.23	82.12	0.00	-19170.1
Disturbance intensity	11	38358.24	86.14	0.00	-19168.1
Warm-season stocking rate	7	38358.77	86.66	0.00	-19172.4
Stocking rate (categorical)	7	38358.96	86.85	0.00	-19172.5
Null	6	38360.20	88.09	0.00	-19174.1
Grazing strategy	10	38360.54	88.43	0.00	-19170.2
Seasonal stocking rates	7	38360.80	88.70	0.00	-19173.4
Ownership	7	38362.10	90.00	0.00	-19174
Management intensity (categorical)	8	38363.71	91.61	0.00	-19173.8

Table B-6. Model selection table for variability (SD) in litter cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
(quadratic) Stocking rate + Grazing strategy	11	3599.99	0.00	0.96	-1788.7
(quadratic) Stocking rate	7	3607.11	7.11	0.03	-1796.5
(quadratic) Stocking rate + Season of use	13	3610.82	10.83	0.00	-1792.1
Stocking rate	6	3611.64	11.65	0.00	-1799.7
Disturbance intensity	10	3613.73	13.74	0.00	-1796.7
Stocking rate (categorical)	6	3614.33	14.34	0.00	-1801.1
Seasonal stocking rates	8	3614.47	14.47	0.00	-1799.1
Warm-season stocking rate	6	3614.63	14.64	0.00	-1801.2
Null	5	3615.47	15.48	0.00	-1802.7
Cool-season stocking rate	6	3615.77	15.78	0.00	-1801.8
(quadratic) Dormant-season stocking rate	7	3616.40	16.40	0.00	-1801.1
Ownership	6	3616.59	16.60	0.00	-1802.2
(quadratic) Warm-season stocking rate	7	3616.68	16.68	0.00	-1801.2
Dormant-season stocking rate	6	3616.91	16.92	0.00	-1802.4
Season of use	11	3617.03	17.03	0.00	-1797.3
(quadratic) Cool-season stocking rate	7	3617.81	17.82	0.00	-1801.8
(quadratic) Seasonal stocking rates	11	3618.90	18.90	0.00	-1798.2
Management intensity (categorical)	7	3618.97	18.97	0.00	-1802.4
Grazing strategy	9	3620.47	20.48	0.00	-1801.1

Table B-7. Model selection table for bare ground in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Stocking rate + Season of use	13	39220.01	0.00	0.77	-19597
Season of use	12	39222.39	2.37	0.23	-19599.2
Stocking rate	7	39285.19	65.18	0.00	-19635.6
Disturbance intensity	11	39286.32	66.31	0.00	-19632.1
Null	6	39286.54	66.53	0.00	-19637.3
Stocking rate (categorical)	7	39286.82	66.81	0.00	-19636.4
Warm-season stocking rate	7	39287.05	67.04	0.00	-19636.5
Cool-season stocking rate	7	39287.32	67.31	0.00	-19636.7
Seasonal stocking rates	9	39287.61	67.60	0.00	-19634.8
Ownership	7	39287.70	67.69	0.00	-19636.8
Management intensity (categorical)	8	39288.33	68.32	0.00	-19636.2
Dormant-season stocking rate	7	39288.38	68.37	0.00	-19637.2
Grazing strategy	10	39289.21	69.20	0.00	-19634.6
Stocking rate + Grazing strategy	11	39289.82	69.80	0.00	-19633.9

Table B-8. Model selection table for variability (SD) in bare ground in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Season of use	11	3602.80	0.00	0.22	-1790.1
Dormant-season stocking rate	6	3603.16	0.36	0.18	-1795.5
(quadratic) Seasonal stocking rates	11	3604.26	1.47	0.10	-1790.9
Stocking rate (categorical)	6	3604.37	1.57	0.10	-1796.1
(quadratic) Dormant-season stocking rate	7	3605.17	2.37	0.07	-1795.5
(quadratic) Cool-season stocking rate	7	3605.45	2.65	0.06	-1795.6
Null	5	3605.72	2.92	0.05	-1797.8
Seasonal stocking rates	8	3606.32	3.52	0.04	-1795.0
(quadratic) Stocking rate + Season of use	13	3606.83	4.03	0.03	-1790.1
Stocking rate	6	3606.88	4.08	0.03	-1797.4
Warm-season stocking rate	6	3607.04	4.24	0.03	-1797.4
Disturbance intensity	10	3607.27	4.48	0.02	-1793.4
Ownership	6	3607.29	4.49	0.02	-1797.6
Cool-season stocking rate	6	3607.37	4.58	0.02	-1797.6
(quadratic) Stocking rate	7	3608.84	6.04	0.01	-1797.3
(quadratic) Warm-season stocking rate	7	3609.07	6.27	0.01	-1797.4
Management intensity (categorical)	7	3609.75	6.96	0.01	-1797.8
Grazing strategy	9	3611.64	8.84	0.00	-1796.7
(quadratic) Stocking rate + Grazing strategy	11	3615.41	12.61	0.00	-1796.5

Table B-9. Model selection table for standing dead vegetation cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Disturbance intensity	11	33141.36	0.00	0.60	-16559.7
Stocking rate + Season of use	13	33142.78	1.42	0.29	-16558.3
Season of use	12	33145.26	3.90	0.09	-16560.6
Stocking rate (categorical)	7	33148.05	6.69	0.02	-16567
Ownership	7	33154.01	12.66	0.00	-16570
Stocking rate	7	33158.41	17.06	0.00	-16572.2
Warm-season stocking rate	7	33158.41	17.06	0.00	-16572.2
Null	6	33159.41	18.05	0.00	-16573.7
Management intensity (categorical)	8	33160.67	19.31	0.00	-16572.3
Dormant-season stocking rate	7	33160.70	19.34	0.00	-16573.3
Seasonal stocking rates	9	33160.89	19.54	0.00	-16571.4
Cool-season stocking rate	7	33161.02	19.67	0.00	-16573.5
Stocking rate + Grazing strategy	11	33165.26	23.91	0.00	-16571.6
Grazing strategy	10	33165.64	24.28	0.00	-16572.8

Table B-10. Model selection table for variability (SD) of standing dead vegetation cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Ownership	6	3351.65	0.00	0.50	-1669.7
Season of use	11	3354.81	3.17	0.10	-1666.2
Null	5	3355.57	3.92	0.07	-1672.7
Warm-season stocking rate	6	3356.04	4.39	0.06	-1671.9
Dormant-season stocking rate	6	3356.82	5.17	0.04	-1672.3
(quadratic) Stocking rate + Season of use	6	3357.11	5.46	0.03	-1672.5
Cool-season stocking rate	13	3357.12	5.47	0.03	-1665.2
Stocking rate (categorical)	6	3357.27	5.62	0.03	-1672.6
Management intensity (categorical)	7	3357.30	5.65	0.03	-1671.5
Stocking rate	6	3357.57	5.93	0.03	-1672.7
(quadratic) Warm-season stocking rate	7	3358.06	6.42	0.02	-1671.9
(quadratic) Stocking rate	7	3358.68	7.03	0.01	-1672.2
(quadratic) Dormant-season stocking rate	7	3358.68	7.04	0.01	-1672.2
(quadratic) Cool-season stocking rate	7	3358.74	7.10	0.01	-1672.3
Seasonal stocking rates	8	3359.63	7.98	0.01	-1671.7
Grazing strategy	9	3360.03	8.38	0.01	-1670.8
Disturbance intensity	10	3360.17	8.53	0.01	-1669.9
(quadratic) Stocking rate + Grazing strategy	11	3363.42	11.78	0.00	-1670.5
(quadratic) Seasonal stocking rates	11	3365.57	13.92	0.00	-1671.5

Table B-11. Model selection table for live grass cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Stocking rate + Season of use	13	36303.60	0.00	0.81	-18138.8
Season of use	12	36307.78	4.18	0.10	-18141.9
Disturbance intensity	11	36308.09	4.49	0.09	-18143.0
Seasonal stocking rates	9	36316.56	12.96	0.00	-18149.3
Stocking rate (categorical)	7	36320.27	16.67	0.00	-18153.1
Dormant-season stocking rate	7	36327.94	24.34	0.00	-18157.0
Warm-season stocking rate	7	36328.65	25.06	0.00	-18157.3
Grazing strategy	10	36345.15	41.55	0.00	-18162.6
Stocking rate + Grazing strategy	11	36347.12	43.52	0.00	-18162.5
Null	6	36347.28	43.68	0.00	-18167.6
Cool-season stocking rate	7	36347.42	43.83	0.00	-18166.7
Ownership	7	36347.45	43.85	0.00	-18166.7
Management intensity (categorical)	8	36348.00	44.41	0.00	-18166.0
Stocking rate	7	36348.97	45.37	0.00	-18167.5

Table B-12. Model selection table for variability (SD) in live grass cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	Δ	*w*	LL
Grazing strategy	9	3510.96	0.00	0.55	-1746.3
(quadratic) Stocking rate + Grazing strategy	11	3513.33	2.37	0.17	-1745.4
Disturbance intensity	10	3513.65	2.69	0.14	-1746.6
Intensity	7	3516.86	5.89	0.03	-1751.3
Stocking rate (categorical)	6	3517.05	6.09	0.03	-1752.5
Warm-season stocking rate	6	3517.89	6.93	0.02	-1752.9
(quadratic) Dormant-season stocking rate	7	3518.14	7.18	0.02	-1752.0
Ownership	6	3518.42	7.46	0.01	-1753.1
Null	5	3518.62	7.65	0.01	-1754.3
(quadratic) Warm-season stocking rate	7	3519.69	8.73	0.01	-1752.7
Stocking rate	6	3519.93	8.96	0.01	-1753.9
Dormant-season stocking rate	6	3520.15	9.19	0.01	-1754.0
Cool-season stocking rate	6	3520.62	9.65	0.00	-1754.2
Seasonal stocking rates	8	3520.65	9.68	0.00	-1752.2
(quadratic) Stocking rate	7	3521.94	10.98	0.00	-1753.9
(quadratic) Cool-season stocking rate	7	3522.67	11.70	0.00	-1754.2
(quadratic) Seasonal stocking rates	11	3525.20	14.24	0.00	-1751.4
Season of use	11	3526.23	15.26	0.00	-1751.9
(quadratic) Stocking rate + Season of use	13	3527.39	16.42	0.00	-1750.3

Table B-13. Model selection table for shrub cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Stocking rate + Grazing strategy	11	31985.97	0.00	0.97	-15982.0
Seasonal stocking rates	9	31994.79	8.82	0.01	-15988.4
Dormant-season stocking rate	7	31995.88	9.91	0.01	-15990.9
Stocking rate	7	31996.01	10.05	0.01	-15991.0
Disturbance intensity	11	31996.87	10.90	0.00	-15987.4
Grazing strategy	10	31997.33	11.36	0.00	-15988.6
Stocking rate + Season of use	13	31999.24	13.27	0.00	-15986.6
Intensity (low, moderate, or high)	8	32002.45	16.48	0.00	-15993.2
Previous warm-season stocking rate	7	32004.27	18.30	0.00	-15995.1
Season of use	12	32004.85	18.88	0.00	-15990.4
Null	6	32004.87	18.90	0.00	-15996.4
Stocking rate (low or high)	7	32005.34	19.37	0.00	-15995.7
Previous cool-season stocking rate	7	32005.97	20.00	0.00	-15996.0
Ownership	7	32006.47	20.50	0.00	-15996.2

Table B-14. Model selection table for variability (SD) in shrub cover in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. All stocking rates are from the previous year. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	Δ	*w*	LL
(quadratic) Stocking rate + Grazing strategy	11	3505.28	0.00	0.88	-1741.4
(quadratic) Warm-season stocking rate	7	3510.79	5.51	0.06	-1748.3
Grazing strategy	9	3510.94	5.66	0.05	-1746.3
Stocking rate	6	3516.97	11.69	0.00	-1752.4
(quadratic) Seasonal stocking rates	11	3517.90	12.62	0.00	-1747.7
Dormant-season stocking rate	6	3518.07	12.78	0.00	-1753.0
(quadratic) Stocking rate	7	3519.02	13.74	0.00	-1752.4
(quadratic) Dormant-season stocking rate	7	3519.53	14.25	0.00	-1752.7
Intensity (low, moderate, or high)	7	3520.34	15.06	0.00	-1753.1
Seasonal stocking rates	8	3520.50	15.22	0.00	-1752.1
Disturbance intensity	10	3520.97	15.69	0.00	-1750.3
Null	5	3521.12	15.84	0.00	-1755.5
Stocking rate (low or high)	6	3521.45	16.17	0.00	-1754.7
Warm-season stocking rate	6	3522.45	17.17	0.00	-1755.2
Cool-season stocking rate	6	3522.86	17.58	0.00	-1755.4
Ownership	6	3522.99	17.71	0.00	-1755.4
(quadratic) Cool-season stocking rate	7	3524.70	19.42	0.00	-1755.2
(quadratic) Stocking rate + Season of use	13	3529.05	23.77	0.00	-1751.2
Season of use	11	3531.01	25.73	0.00	-1754.3

APPENDIX C: **Bird responses to vegetation structure variables**

Table C-1. Model selection table for relationship of grasshopper sparrow abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Management unit means	19	4143.06	0	1	-2051.78
Pasture means	19	4165.58	22.52	0	-2063.04
Management unit SD	19	4172.49	29.44	0	-2066.50
Plot means	19	4183.15	40.1	0	-2071.83
Pasture SD	19	4227.29	84.23	0	-2093.90
Plot SD	19	4262.50	119.45	0	-2111.50
Ecological site	13	4263.55	120.5	0	-2118.42
Null	10	4313.28	170.22	0	-2146.43

Table C-2. Model selection table for relationship of western meadowlark abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	Δ AIC	*w*	LL
Null	10	3778.66	0	0.37	-1879.12
Pasture SD	19	3779.07	0.41	0.30	-1869.79
Management unit SD	19	3779.64	0.98	0.23	-1870.07
Ecological site	13	3781.55	2.88	0.09	-1877.42
Plot means	19	3786.29	7.62	0.01	-1873.39
Plot SD	19	3787.18	8.52	0.01	-1873.84
Pasture means	19	3787.97	9.30	0	-1874.23
Management unit means	19	3793.20	14.54	0	-1876.85

Table C-3. Model selection table for relationship of lark sparrow abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AICc	ΔAIC	*w*	LL
Management unit means	19	3059.16	0	0.48	-1509.83
Plot means	19	3059.81	0.65	0.35	-1510.16
Pasture means	19	3062.52	3.36	0.09	-1511.51
Management unit SD	19	3062.63	3.47	0.08	-1511.57
Ecological site	13	3085.49	26.33	0	-1529.39
Pasture SD	19	3088.34	29.18	0	-1524.42
Plot SD	19	3100.55	41.39	0	-1530.53
Null	10	3110.89	51.73	0	-1545.23

Table C-4. Model selection table for relationship of horned lark abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AICc	ΔAIC	*w*	LL
Management unit SD	20	3034.71	0	0.7	-1496.52
Pasture SD	20	3036.36	1.65	0.3	-1497.35
Management unit means	20	3059.25	24.54	0	-1508.80
Plot means	20	3069.46	34.75	0	-1513.90
Pasture means	20	3081.08	46.37	0	-1519.71
Plot SD	20	3092.03	57.32	0	-1525.19
Ecological site	14	3115.17	80.46	0	-1543.17
Null	10	3121.55	86.86	0	-1549.52

Table C-5. Model selection table for relationship of dickcissel abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AICc	ΔAIC	*w*	LL
Plot means	20	1670.05	0	0.61	-814.20
Management unit SD	20	1671.17	1.12	0.35	-814.76
Management unit means	20	1675.64	5.59	0.04	-816.99
Pasture means	20	1686.76	16.72	0	-822.55
Plot SD	20	1716.02	45.97	0	-837.18
Pasture SD	20	1720.44	50.40	0	-839.39
Ecological site	14	1758.56	88.51	0	-864.87
Null	10	1838.37	168.33	0	-908.97

Table C-6. Model selection table for relationship of field sparrow abundance to vegetation structure measures at three scales (plot, pasture, and management unit), in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

	K	AICc	ΔAIC	*w*	LL
Management unit means	20	1479.41	0	0.93	-718.88
Pasture means	20	1484.66	5.25	0.07	-721.50
Management unit SD	20	1491.78	12.37	0	-725.06
Plot means	20	1536.93	57.52	0	-747.64
Pasture SD	20	1538.62	59.21	0	-748.48
Plot SD	20	1573.11	93.69	0	-765.72
Ecological site	14	1598.33	118.92	0	-784.76
Null	10	1608.91	129.50	0	-794.24

APPENDIX D: **Bird response to management**

Table D-1. Model selection table for relationship of grasshopper sparrow abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Ownership	11	4184.67	0.00	1.00	-2081.1
Seasonal stocking rates	13	4226.63	41.96	0.00	-2100.0
Grazing strategy + Stocking rate	15	4233.02	48.35	0.00	-2101.0
Warm-season stocking rate	11	4240.57	55.90	0.00	-2109.0
Season of use + Stocking rate	12	4243.88	59.21	0.00	-2109.6
Disturbance intensity	15	4256.54	71.87	0.00	-2112.8
Stocking rate	11	4260.85	76.19	0.00	-2119.2
Ecological site	13	4263.55	78.88	0.00	-2118.4
Stocking rate (categorical)	11	4270.60	85.93	0.00	-2124.0
Grazing strategy	14	4302.19	117.52	0.00	-2136.7
Dormant-season stocking rate	11	4307.16	122.49	0.00	-2142.3
Season of use	11	4309.24	124.57	0.00	-2143.4
Management intensity	12	4310.60	125.93	0.00	-2143.0
Cool-season stocking rate	11	4313.12	128.45	0.00	-2145.3
Null (abundance)	10	4313.28	128.61	0.00	-2146.4
Null (abundance + detection)	2	4487.07	302.41	0.00	-2241.5

Table D-2. Model selection table for relationship of western meadowlark abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Warm-season stocking rate	11	3778.30	0.00	0.18	-1877.9
Null (abundance)	10	3778.66	0.36	0.15	-1879.1
Dormant-season stocking rate	11	3779.17	0.87	0.12	-1878.3
Management intensity	12	3779.48	1.17	0.10	-1877.4
Seasonal stocking rates	13	3780.54	2.24	0.06	-1876.9
Stocking rate (categorical)	11	3780.61	2.30	0.06	-1879.1
Ownership	11	3780.63	2.33	0.06	-1879.1
Cool-season stocking rate	11	3780.66	2.35	0.06	-1879.1
Stocking rate	11	3780.76	2.46	0.05	-1879.1
Season of use	11	3780.81	2.51	0.05	-1879.2
Grazing strategy	14	3781.44	3.14	0.04	-1876.3
Ecological site	13	3781.55	3.24	0.04	-1877.4
Grazing strategy + Stocking rate	15	3782.52	4.22	0.02	-1875.8
Season of use + Stocking rate	12	3782.84	4.54	0.02	-1879.1
Disturbance intensity	15	3784.04	5.74	0.01	-1876.6
Null (abundance + detection)	2	4388.17	609.87	0.00	-2192.1

Table D-3. Model selection table for relationship of lark sparrow abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Ecological site	13	3085.49	0.00	0.96	-1529.4
Seasonal stocking rates	13	3093.35	7.87	0.02	-1533.3
Season of use + Stocking rate	12	3094.40	8.91	0.01	-1534.9
Grazing strategy + Stocking rate	15	3095.13	9.64	0.01	-1532.1
Warm-season stocking rate	11	3097.45	11.96	0.00	-1537.5
Ownership	11	3100.42	14.93	0.00	-1539.0
Disturbance intensity	15	3101.78	16.29	0.00	-1535.4
Management intensity (categorical)	12	3104.08	18.59	0.00	-1539.7
Season of use	11	3104.28	18.79	0.00	-1540.9
Cool-season stocking rate	11	3105.88	20.39	0.00	-1541.7
Grazing strategy	14	3106.01	20.52	0.00	-1538.6
Stocking rate	11	3106.70	21.21	0.00	-1542.1
Dormant-season stocking rate	11	3110.50	25.01	0.00	-1544.0
Null (abundance)	10	3110.89	25.40	0.00	-1545.2
Stocking rate (categorical)	11	3111.58	26.09	0.00	-1544.5
Null (abundance + detection)	2	3209.72	124.23	0.00	-1602.9

Table D-4. Model selection table for relationship of horned lark abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Disturbance intensity	16	3068.86	0.00	1.00	-1517.9
Grazing strategy	15	3082.60	13.74	0.00	-1525.8
Grazing strategy + Stocking rate	16	3084.49	15.63	0.00	-1525.7
Ownership	12	3085.90	17.04	0.00	-1530.7
Stocking rate (categorical)	12	3099.97	31.10	0.00	-1537.7
Season of use + Stocking rate	13	3113.89	45.03	0.00	-1543.6
Management intensity	13	3114.91	46.04	0.00	-1544.1
Ecological site	14	3115.17	46.31	0.00	-1543.2
Stocking rate	12	3117.07	48.21	0.00	-1546.2
Warm-season stocking rate	12	3117.31	48.45	0.00	-1546.4
Seasonal stocking rates	14	3118.45	49.59	0.00	-1544.8
Null (abundance)	11	3121.55	52.68	0.00	-1549.5
Dormant-season stocking rate	12	3121.57	52.71	0.00	-1548.5
Season of use	12	3121.88	53.02	0.00	-1548.6
Cool-season stocking rate	12	3123.65	54.78	0.00	-1549.5
Null (abundance + detection)	3	3243.51	174.64	0.00	-1618.7

Table D-5. Model selection table for relationship of dickcissel abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Disturbance intensity	16	1716.59	0.00	0.99	-841.8
Management intensity	13	1725.53	8.94	0.01	-849.4
Grazing strategy + Stocking rate	16	1740.65	24.06	0.00	-853.8
Grazing strategy	15	1743.97	27.38	0.00	-856.5
Season of use + Stocking rate	13	1757.77	41.18	0.00	-865.5
Ecological site	14	1758.56	41.96	0.00	-864.9
Season of use	12	1758.81	42.22	0.00	-867.1
Dormant-season stocking rate	12	1759.79	43.20	0.00	-867.6
Seasonal stocking rates	14	1761.01	44.42	0.00	-866.1
Null (abundance)	11	1762.96	46.37	0.00	-870.2
Stocking rate	12	1763.81	47.22	0.00	-869.6
Ownership	12	1764.76	48.17	0.00	-870.1
Cool-season stocking rate	12	1764.81	48.22	0.00	-870.1
Stocking rate (categorical)	12	1765.04	48.44	0.00	-870.2
Warm-season stocking rate	12	1765.05	48.46	0.00	-870.2
Null (abundance + detection)	3	1839.58	122.98	0.00	-916.8

Table D-6. Model selection table for relationship of field sparrow abundance to management variables in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Grazing strategy + Stocking rate	16	1506.64	0.00	1.00	-736.8
Grazing strategy	15	1534.68	28.04	0.00	-751.9
Disturbance intensity	16	1543.80	37.16	0.00	-755.4
Management intensity	13	1565.30	58.66	0.00	-769.3
Seasonal stocking rates	14	1578.62	71.98	0.00	-774.9
Stocking rate	12	1582.36	75.72	0.00	-778.9
Season of use + Stocking rate	13	1583.02	76.38	0.00	-778.2
Stocking rate (categorical)	12	1585.54	78.91	0.00	-780.5
Dormant-season stocking rate	12	1585.71	79.07	0.00	-780.6
Cool-season stocking rate	12	1586.71	80.07	0.00	-781.1
Ownership	12	1590.98	84.34	0.00	-783.2
Ecological site	14	1598.33	91.70	0.00	-784.8
Season of use	12	1599.07	92.44	0.00	-787.2
Null (abundance)	11	1601.81	95.17	0.00	-789.7
Warm-season stocking rate	12	1603.51	96.88	0.00	-789.5
Null (abundance + detection)	3	1669.21	162.58	0.00	-831.6

APPENDIX E: Avian diversity model selection tables

Table E-1. Model selection table for Shannon diversity index for songbirds in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Dormant-season stocking rate	6	81.71	0	0.72	-34.77
Seasonal stocking rates	8	83.79	2.08	0.26	-33.76
Season of use + stocking rate	7	91.87	10.16	0.00	-38.83
Warm-season stocking rate	6	92.23	10.52	0.00	-40.04
Total stocking rate	6	92.45	10.73	0.00	-40.14
Season of use	6	92.45	10.74	0.00	-40.14
Null	5	93.79	12.08	0.00	-41.84
Cool-season stocking rate	6	93.99	12.28	0.00	-40.92
Ownership	6	95.06	13.35	0.00	-41.45
Stocking rate (categorical)	6	95.60	13.89	0.00	-41.72
Grazing strategy + stocking rate	10	97.37	15.66	0.00	-38.47
Management intensity (categorical)	7	97.40	15.68	0.00	-41.59
Grazing strategy	9	98.11	16.40	0.00	-39.88
Disturbance intensity	10	99.85	18.14	0.00	-39.71

Table E-2. Model selection table for Simpson diversity index for songbirds in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Dormant-season stocking rate	6	-1147.30	0.00	0.53	579.73
Seasonal stocking rates	8	-1146.82	0.48	0.42	581.55
Warm-season stocking rate	6	-1139.91	7.39	0.01	576.03
Season of use	6	-1139.76	7.53	0.01	575.96
Season of use + stocking rate	7	-1139.30	7.99	0.01	576.76
Cool-season stocking rate	6	-1138.15	9.14	0.01	575.16
Total stocking rate	6	-1137.43	9.86	0.00	574.80
Null	5	-1137.24	10.05	0.00	573.68
Stocking rate (categorical)	6	-1136.30	11.00	0.00	574.23
Ownership	6	-1135.74	11.56	0.00	573.95
Grazing strategy	9	-1135.49	11.81	0.00	576.92
Grazing strategy + stocking rate	10	-1134.83	12.47	0.00	577.63
Management intensity (categorical)	7	-1134.29	13.01	0.00	574.25
Disturbance intensity	10	-1131.52	15.78	0.00	575.97

Table E-3. Model selection table for songbird richness in the Nebraska Sandhills, 2014-2015. Models are in order of best fit to worst fit. Values reported include number of parameters (K), Akaike's Information Criterion corrected for small sample sizes (AIC_c), difference in AIC_c from the best fitting model (ΔAIC), model weight (*w*), and the log-likelihood (LL).

Model	K	AIC_c	ΔAIC	*w*	LL
Dormant-season stocking rate	6	1831.02	0.00	0.79	-909.43
Seasonal stocking rates	8	1834.48	3.45	0.14	-909.10
Total stocking rate	6	1839.05	8.03	0.01	-913.44
Season of use + stocking rate	7	1839.54	8.51	0.01	-912.66
Season of use	6	1839.83	8.81	0.01	-913.84
Warm-season stocking rate	6	1839.98	8.96	0.01	-913.91
Null	5	1840.06	9.04	0.01	-914.97
Ownership	6	1840.75	9.73	0.01	-914.29
Cool-season stocking rate	6	1841.44	10.42	0.00	-914.64
Stocking rate (categorical)	6	1842.09	11.07	0.00	-914.97
Management intensity (categorical)	7	1843.83	12.81	0.00	-914.81
Disturbance intensity	10	1844.12	13.10	0.00	-911.85
Grazing strategy + stocking rate	10	1845.63	14.61	0.00	-912.60
Grazing strategy	9	1846.36	15.34	0.00	-914.01

APPENDIX F: **Interview informed consent**

University of Nebraska Lincoln

SCHOOL OF NATURAL RESOURCES

IRB# 20141114643 EX
Date Approved: 11/25/2014
Valid Until: 11/24/2019

Dear Study Participant,

My name is Maggi Sliwinski. I am conducting a study exploring the ways ranchers view landscapes and ranch management.

Participation in this study will require you to participate in one face to face interview of up to 60 minutes. Participation in an interview will take place at your home or another location that is convenient to you. This interview will be audio recorded for future reference.

There are no direct benefits to you as a research participant. Indirect benefits may include future collaborations with organizations interested in rural development and the sustainability of the ranching industry. There are no known risks or discomforts associated with this research.

The results of this study will be utilized for a PhD dissertation and potential for inclusion in conference presentations and scientific articles, as well as extension bulletins.

Your responses to this interview will be kept confidential. Your name will not be associated with any publication of the study results, and your ranch will not be identifiable.

You may ask any questions concerning this research at any time by contacting me 716-704-3058, maggi.sliwinski@gmail.com. You may also contact Dr. Mark Burbach, 402-472-8210, mburbach1@unl.edu. If you would like to speak to someone else, please call the Research Compliance Services Office at University of Nebraska-Lincoln at 402-472-6965 or irb@unl.edu.

Participation in this study is voluntary. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled.

You are voluntarily making a decision whether or not to participate in this research study. By agreeing to participate in the interview and signing this form, you have given your consent to participate in this research.

Sincerely,

Maggi Sliwinski

_____________________________ _______________
Signature of Research Participant Date

☐ I agree to be audio recorded during this interview.

234 Hardin Hall / P.O. 830982 / Lincoln, NE 68583-0982 / (716) 704-3058 / FAX (402) 472-2946 / http://snr.unl.edu

APPENDIX G: **Interview guide**

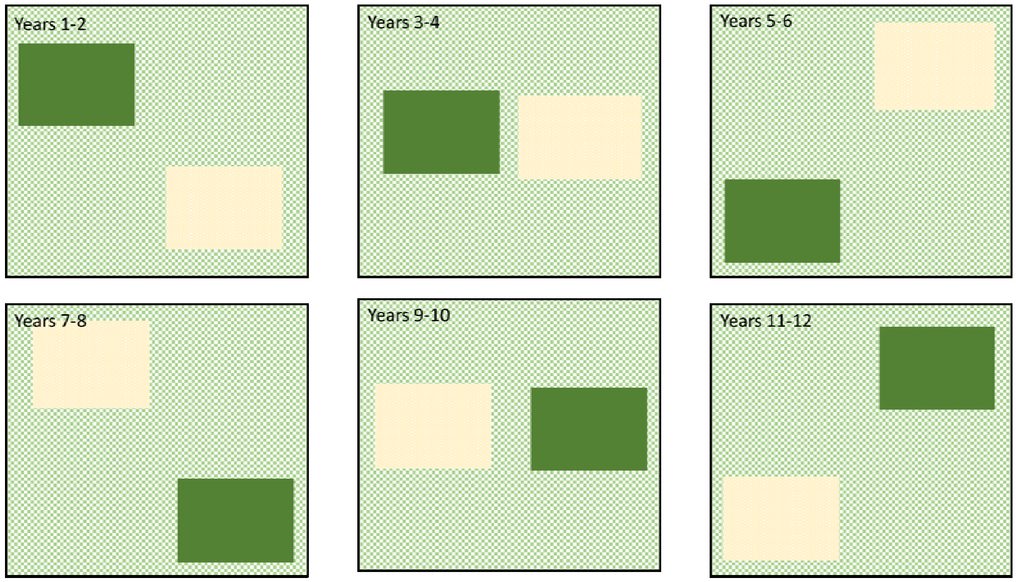
Interviewee: ____________________________ Location: ________________________

Date: _____________________ Time: ____________________

I am conducting a study exploring the ways in which ranchers view landscapes and different types of wildlife habitat. I will ask you some questions, you can take your time to think about your responses. I will be taking notes while you're speaking, and you have previously indicated that it's ok to audio record. So, we'll go ahead and get started.

1. What do you value about the grassland landscape? [ice breaker]
2. What do you think about the different types of grassland shown in the photos (Fig. B1)?
3. What would you think about each of these types of grassland if they were on your own land (Fig. B2)?
4. If you had each of these on your own land, what would you think if the different areas shifted over time (Fig. B3)?
5. What would you think about each of these if they were on your neighbor's land?
6. Consider that certain wildlife prefer these atypical areas. What do you think about these different types of habitat knowing this (Fig. B4)?
7. If you wanted to provide each of these types of habitat on your land, how would you do so?
    a. Would burning be an option?
    b. What influences your interest in creating these different habitats?
8. What do you think about having these habitats shifted among neighboring ranches in an area (Fig. B5)? For example, you would lump your cattle in with your neighbor's for a couple years to rest your pastures and grazing the neighbor's a little harder. Then you would switch.
    a. What influences your interest in this strategy?
9. How would you respond if an agency was interested in helping you manage the landscape for these different types of habitat? What about a group of ranchers?

APPENDIX H: **Interview graphics**



Figure_Apx H-1. Diagram showing the rotation of heavily grazes areas (tan), normal grazing (light green), and under-grazed areas (dark green).

Figure H-2. Diagram showing what types of birds might prefer each of the habitats that would be created by grazing some areas heavily and leaving other areas under-grazed.

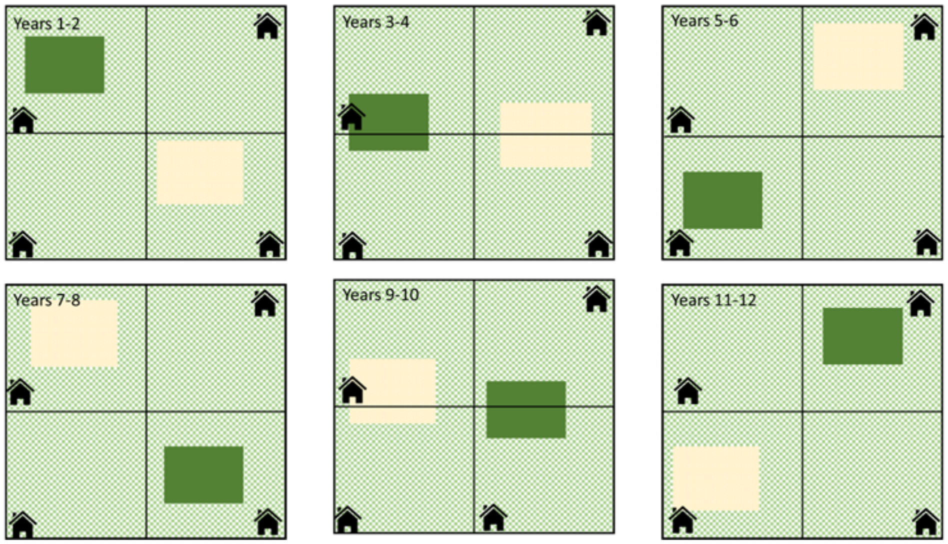


Figure H-3. Diagram showing how a group of ranches might coordinate to create the different types of habitat that are required by the various bird species in the Great Plains.

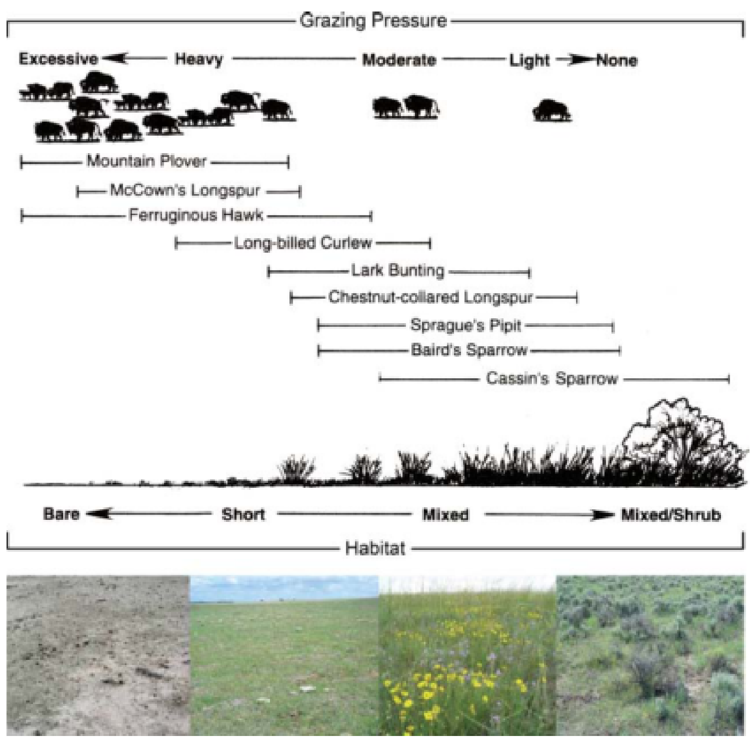


Figure 1. Bird response to grazing pressures (modified from Knopf 1996).

Figure H-4. Figure used to show participants the different types of habitats that are required by different bird species.

APPENDIX I: **Pre-notice postcard**

Figure I-1. Postcard that was sent to survey mailing list prior to sending the first survey mailing. This was done to alert the landowners that a survey would be coming.

APPENDIX J: First survey mailing cover letter

University of Nebraska Lincoln

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
SCHOOL OF NATURAL RESOURCES

Maggi Sliwinski
244 Hardin Hall
3310 Holdrege Street
Lincoln, NE 68583-0982

IRB Approval
IRB# 20141114643 EX
Date Approved: 02/01/2016
Valid Until: 11/24/2019

February 5, 2016

Dear Ranch Manager,

I am a graduate research student at the University of Nebraska-Lincoln and I am writing to ask for your help with a research project that is striving to understand the viewpoints of ranchers regarding management techniques that support grassland ecosystems and conservation.

Ranchers, especially in the Great Plains, steward most of the remaining native grasslands. The health of privately-owned grasslands in the Great Plains demonstrates that ranchers are excellent stewards of grazing lands; we want to learn from ranchers about their conservation concerns, the management strategies used by ranchers to ensure conservation of their ranch resources, and ranchers' views of potential approaches for maintaining grassland ecosystems. The results of the survey will be shared with participating ranchers through supporting organizations. We will also report the results in extension and research publications. Your responses will remain completely anonymous.

Completion of the enclosed survey should take no longer than 20 minutes. It should be completed by the main decision maker on the ranch, who is at least 19 years old. Your participation in this research is completely voluntary and is completely confidential. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled. By completing and returning this survey, your consent to participate is implied. You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study by contacting me or my supervisor at the phone numbers below. If you have any concerns about the research or questions about your rights as a participant, please contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965.

I would like to thank you in advance for completing this survey, I know that your time is valuable. Once you have finished the survey, please return it in the postage-paid envelope we have provided. If you have any questions please do not hesitate to contact me or my supervisor (contact information below). I would appreciate receiving your completed survey within 3 weeks.

Sincerely,

Maggi Sliwinski
(402) 327-1647
maggi.sliwinski@gmail.com

Mark Burbach
(402) 472-8210

APPENDIX K**: Survey**

Survey of range managers in the Northern Great Plains: Ranch and landscape management

Your opinions are important! Thank you in advance for completing this survey.

IMPORTANT: If you are not the main decision maker for your ranch/farm, please give this survey to the person who is. Remember, you must be 19+ years old to complete the survey.

Instructions: Most of the questions in this survey use a rating scale with 5 options. Please circle the number that best represents your opinion about each statement. A "1" indicates strong disagreement, whereas a "5" indicates strong agreement with the statement.

Strongly disagree . . . . Strongly agree
1 2 3 4 5

Landscapes					
My land is part of a much bigger natural system.	1	2	3	4	5
My land is not important to other people.	1	2	3	4	5
What I do on my land affects others' land.	1	2	3	4	5
My land provides important habitat for wildlife.	1	2	3	4	5
My land provides benefits for society.	1	2	3	4	5
My property is insignificant in the big picture of all land in the region.	1	2	3	4	5
What my neighbors do on their land does not affect me or my land.	1	2	3	4	5
I would consider working with others, if it meant the rangeland would be better off.	1	2	3	4	5

Management Over Time					
What I do on my land will not matter in the long run.	1	2	3	4	5
My land does not need to provide for future generations.	1	2	3	4	5
My land should provide for the needs of future plant and wildlife populations.	1	2	3	4	5
I have a responsibility to leave my land in at least as good a condition as I found it.	1	2	3	4	5
The health of the land today is not a result of past activity.	1	2	3	4	5
Land is a testament to the previous owners.	1	2	3	4	5
Actions of current land owners do not affect future owners.	1	2	3	4	5

Rangeland Management					
Converting native rangeland to any other use, such as cropland, is not valuable to me.	1	2	3	4	5
Increasing rangeland productivity by interseeding tame grasses or through herbicide application are good practices on native rangeland.	1	2	3	4	5
I benefit from the diversity of plants and soil types in native rangeland.	1	2	3	4	5
Restricting livestock grazing to a level that is sustainable (e.g., "take half, leave half") is a good grazing strategy.	1	2	3	4	5
Good management results in patchiness of grazing patterns (e.g., a variety of grass heights and densities).	1	2	3	4	5
Patches of bare ground, resulting from cattle grazing certain areas more, are a natural result of any grazing management.	1	2	3	4	5

Strongly disagree . . . . Strongly agree

1 2 3 4 5

Rangeland Management					
Periodic fire is vital in managing rangeland vegetation.	1	2	3	4	5
Fire provides outcomes that cannot be reached with livestock.	1	2	3	4	5
Areas that have had fires should be left alone until they heal.	1	2	3	4	5
Subdividing pastures using fencing is a good management strategy.	1	2	3	4	5
Planting trees (e.g., for wind breaks or shelter belts) is bad for rangeland wildlife.	1	2	3	4	5
The best use of a small stream is to dam it for a stock pond.	1	2	3	4	5
Livestock access to streams and surrounding riparian areas should be limited.	1	2	3	4	5

Rangeland Management					
Eliminating prairie dogs would be in the best interests of a ranch.	1	2	3	4	5
I would be fine with a neighbor having a prairie dog colony.	1	2	3	4	5
I would be unhappy if there were more deer, antelope, and/or elk on my ranch because they would compete with my livestock for forage.	1	2	3	4	5
It is important to leave dead cattle in the pasture because the carcass provides a nutrient boost to the area.	1	2	3	4	5
Nutrient removal through annual sale of livestock is harmful for my native rangeland.	1	2	3	4	5
Predators are important components of the rangeland ecosystem.	1	2	3	4	5
I am worried about society's interest in increasing predator populations.	1	2	3	4	5

Landscapes					
How I treat my land affects the overall environment in my county.	1	2	3	4	5
I am able to manage my land to achieve desired outcomes.	1	2	3	4	5
If I want to change my management, I have the resources to be able to do so.	1	2	3	4	5
What I do on my land effects the services (e.g., aquifer recharge, clean air, carbon storage) provided by the rangeland ecosystem to society.	1	2	3	4	5
I can change my management strategy if a newer, better option becomes available.	1	2	3	4	5
Wildlife populations in the Great Plains are not affected by management on my ranch.	1	2	3	4	5

Worldview					
People have the right to modify the natural environment to suit their needs.	1	2	3	4	5
When people interfere with nature it often produces disastrous consequences.	1	2	3	4	5
Human ingenuity will insure that we keep the Earth livable.	1	2	3	4	5
The Earth has plenty of natural resources if we just learn how to develop them.	1	2	3	4	5
Plants and wildlife have as much right as people to exist.	1	2	3	4	5
Despite our special abilities, people are still subject to the laws of nature.	1	2	3	4	5

Strongly disagree . . . . Strongly agree

1	**2**	**3**	**4**	**5**

Land Relations

The diversity of plants and wildlife in an area is a sign of the quality of the environment.	1	2	3	4	5
Because farmers and ranchers' livelihoods depend on the land, they are the best stewards of the land.	1	2	3	4	5
Farmers and ranchers have an obligation to protect the soil, water, plants, habitat, and fish and wildlife on their land.	1	2	3	4	5
The best use of land should be determined by the amount of profit that can be earned annually.	1	2	3	4	5
Large-scale restoration, across the entire landscape, is required to improve the condition of the land.	1	2	3	4	5
Farmers/ranchers should focus on optimizing production on their farm/ranch regardless of environmental costs.	1	2	3	4	5
Farmers and ranchers have the right to use the soil, water, plants, and wildlife on land they own in any way they see fit.	1	2	3	4	5

Management/Business Practices

I am usually among the first to try new management strategies.	1	2	3	4	5
I know more than other people about the latest new ranching products.	1	2	3	4	5
I try new products before my friends and neighbors.	1	2	3	4	5
I would rather stick with a product I usually buy than try something I am not sure of.	1	2	3	4	5
I'm very cautious in trying new or different products.	1	2	3	4	5
I rarely buy products if I am uncertain about their performance.	1	2	3	4	5
Reading advertisements to find out what's new is a waste of time.	1	2	3	4	5
I like to shop around and look at product displays.	1	2	3	4	5
I like to browse through catalogs even when I don't plan to buy anything.	1	2	3	4	5

Individualism/Collectivism

My happiness depends very much on the happiness of those around me.	1	2	3	4	5
I would do what would please my family, even if I hated the activity.	1	2	3	4	5
I am a unique individual.	1	2	3	4	5
I enjoy working in situations involving competition with others.	1	2	3	4	5
I often "do my own thing."	1	2	3	4	5
Children should feel honored if their parents receive a distinguished award.	1	2	3	4	5
Without competition it is not possible to have a good society.	1	2	3	4	5
I feel good when I cooperate with others.	1	2	3	4	5

Expectations

Most ranchers in my community act in the best interests of the rangeland.	1	2	3	4	5
I feel guilty if I do not act in the best interest of my rangeland.	1	2	3	4	5
My neighbors expect me to act in the best interest of my rangeland.	1	2	3	4	5
My neighbors act in the best interests of their rangeland.	1	2	3	4	5
I feel proud when I manage my rangeland properly.	1	2	3	4	5

Strongly disagree . . . . Strongly agree

1	**2**	**3**	**4**	**5**

Land Relations

All parts of the ecosystem, down to the microorganisms in the soil, are important for proper functioning of the landscape.	1	2	3	4	5
If you take care of the land, it will take care of you.	1	2	3	4	5
Restored lands maximize both productivity and ecosystem function.	1	2	3	4	5
The quality of the land is positively influenced by the diversity of native plants and wildlife that live on or around it.	1	2	3	4	5
The needs of farmers and ranchers should take priority over the conservation of land.	1	2	3	4	5
Farmers and ranchers are masters of the land.	1	2	3	4	5
We should restore the landscape to the way it was when the pioneers first arrived.	1	2	3	4	5
Farmers and ranchers are only temporary trustees of the land and it is their responsibility to take good care of it for future generations.	1	2	3	4	5
I would be pleased if a rare or threatened species was found on my land.	1	2	3	4	5
Rare or threatened species should be protected.	1	2	3	4	5

Risk

I'm quite cautious when I make plans and when I act on them.	1	2	3	4	5
I follow the motto, "nothing ventured, nothing gained."	1	2	3	4	5
I don't like to put something at stake, I would rather be on the safe side.	1	2	3	4	5
Even when I know that my chances are limited, I try my luck.	1	2	3	4	5
I only set small work goals so that I can achieve them without difficulty.	1	2	3	4	5
I express my opinion even if most people have opposite views.	1	2	3	4	5
My decisions are always made carefully and accurately.	1	2	3	4	5
I tend to imagine the unfavorable outcomes of my actions.	1	2	3	4	5

Please indicate how likely or unlikely you are to do the following activities in the next five years by circling the appropriate number following each statement below. (1 = very unlikely, 5 = very likely)

Very unlikely . . . . Very likely

1	**2**	**3**	**4**	**5**

Future Activities

Alter management to provide habitat for threatened or endangered species.	1	2	3	4	5
Work with a neighbor on invasive species control.	1	2	3	4	5
Temporarily overgraze some of my pastures to create wildlife habitat.	1	2	3	4	5
Work with a neighbor on brush encroachment control.	1	2	3	4	5
Manage the threat of wildfires by using prescribed fires.	1	2	3	4	5
Change management practices to increase carbon sequestration on my ranch.	1	2	3	4	5
Be prepared for adverse weather, such as droughts.	1	2	3	4	5
Modify management to increase wildlife populations on my ranch.	1	2	3	4	5

DEMOGRAPHICS (skip any questions that you feel are intrusive)

1. Which of the following grazing systems do you <u>primarily</u> use? (Check one.)

- O Rest-rotation (at least one pasture is rested for a full year each year)
- O Deferred-rotation (grazing in one pasture is deferred until the dormant season)
- O Continuous, season long (pasture is grazed by a single herd through the growing season)
- O Management intensive grazing (many small pasture, rotate through each once)
- O Short-duration grazing (many small pastures, rotate through each at least twice)
- O Other (please describe)____

2a. How many acres of rangeland do you manage? ___________acres

2b. How many acres of farmland do you manage? ___________acres

3. What is the greatest number of pastures you have devoted to a single herd? ________pastures

4. How many acres is the largest native rangeland pasture that you manage? ___________acres

5. How many acres is the smallest native rangeland pasture that you manage? ___________acres

6. What generation rancher/farmer are you (e.g., 1st, 2nd, 3rd, 4th, ...)? __________

7. How many years' experience do you have managing a ranch/farm? ________years

8. What is the highest level of formal education you have completed? (Check one.)

- O Primary school
- O High school
- O Some college
- O Associate's degree
- O Four-year college degree (Bachelor's degree)
- O Advanced degree (MS, MBA, etc.)

9. Are you (circle one): Male Female

10. In what year were you born? _______

11. What percentage of your family's income comes from off-ranch/off-farm employment? _________%

12. Are you a member of a Native American tribe? No Yes

13. Please feel free to write any comments you have below.

Thank you for completing this survey, your participation is very valuable to us. Please return the survey in the postage-paid envelope we provided. **Thank you!**

APPENDIX L: **Reminder postcard**

Figure L-1. Postcard that was sent to all those on the survey mailing list who had not yet returned the survey. This was done to encourage participants to complete and return the survey, or to call if they had any questions or lost their survey.

APPENDIX M: **Final survey mailing (cover letter)**

Nebraska
Lincoln

INSTITUTE OF AGRICULTURE AND NATURAL RESOURCES
SCHOOL OF NATURAL RESOURCES

Maggi Sliwinski
244 Hardin Hall
3310 Holdrege Street
Lincoln, NE 68583-0982

Sandhills Task Force
"Where People and Land are One"

March 4, 2016

Dear Ranch or Farm Manager,

A couple of weeks ago I sent you a request to fill out and return a survey. To the best of our knowledge, we have not yet received the survey. I am writing a second time to ask for your help with this project, which is striving to understand the viewpoints of rangeland managers regarding management techniques that support rangeland systems. Ranchers from across the Northern Great Plains have already returned the survey, and I'd like to ensure that your opinions are included. The Nebraska Cattlemen's Association, Sandhills Task Force, South Dakota Cattlemen's Association, and North Dakota Grazing Lands Coalition support this research.

Range managers, especially in the Great Plains, steward most of the remaining native grasslands. The health of privately-owned grasslands in the Great Plains demonstrates that managers are excellent stewards of grazing lands; we want to learn from managers about their conservation concerns, the management strategies used to ensure conservation of their range resources, and managers' views of potential approaches for maintaining grassland systems. The results of the survey will be shared with participants through supporting organizations. We will also report the results in extension and research publications. Your responses will remain completely anonymous.

Completion of the enclosed survey should take no longer than 20 minutes. It should be completed by the main decision maker on the ranch/farm, who is at least 19 years old. Your participation in this research is completely voluntary and confidential. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled. By completing and returning this survey, your consent to participate is implied. You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study by contacting me or my supervisor at the phone numbers below. If you have any concerns about the research or questions about your rights as a participant, please contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965.

I am urging you to complete this survey because I would like the results of this study to reflect the opinions and experiences of as many land managers as possible. I know that your time is valuable, so thank you in advance for completing the survey. Once you have finished, please return the survey in the postage-paid envelope we have provided. If you have any questions please do not hesitate to contact me or my supervisor (contact information below). I would appreciate receiving your completed survey within 3 weeks.

Sincerely,

Maggi Sliwinski, phone: (402) 327-1647, e-mail: maggi.sliwinski@gmail.com
Mark Burbach, phone: (402) 472-8210

APPENDIX N: Scales used in the analysis of survey data

Items included in the latent variables for each scale included in the analysis.
* Reverse coded

Landscape management scale (Belin et al. 2005)
X1 My land is part of a much bigger natural system.
X2 My land is not important to other people. *
X3 What I do on my land affects others' land.
X4 My land provides important habitat for wildlife.
X5 My land provides benefits for society.
X6 My property is insignificant in the big picture of all land in the region. *
X7 What my neighbors do on their land does not affect me or my land. *
X8 I would consider working with others, if it meant the rangeland would be better off.

Temporal vision scale (Belin et al. 2005)
X9 What I do on my land will not matter in the long run. *
X10 My land does not need to provide for future generations. *
X11 My land should provide for the needs of future plant and wildlife populations.
X12 I have a responsibility to leave my land in at least as good a condition as I found it.
X13 The health of the land today is not a result of past activity. *
X14 Land is a testament to the previous owners.
X15 Actions of current land owners do not affect future owners. *

Heterogeneity management attitudes scale (Freese et al. 2014)
X22 Periodic fire is vital in managing rangeland vegetation.
X23 Fire provides outcomes that cannot be reached with livestock.
X24 Areas that have had fires should be left alone until they heal. *
X26 Planting trees (e.g., for wind breaks or shelter belts) is bad for rangeland wildlife.
X29 Eliminating prairie dogs would be in the best interests of a ranch. *
X30 I would be fine with a neighbor having a prairie dog colony.
X32 It is important to leave dead cattle in the pasture because this provides a nutrient boost to the area.
X33 Nutrient removal through annual sale of livestock is harmful for my native rangeland.
X35 I am worried about society's interest in increasing predator populations. *

Herbivorous mammals attitudes scale
X29 Eliminating prairie dogs would be in the best interests of a ranch. *
X30 I would be fine with a neighbor having a prairie dog colony.

Fire attitudes scale
X22 Periodic fire is vital in managing rangeland vegetation.
X23 Fire provides outcomes that cannot be reached with livestock.

Perceived Behavioral Control scale
X36 How I treat my land affects the overall environment in my county.
X37 I am able to manage my land to achieve desired outcomes.
X38 If I want to change my management, I have the resources to be able to do so.
X39 What I do on my land effects the services (e.g., aquifer recharge, clean air, carbon storage) provided by the rangeland ecosystem to society.
X40 I can change my management strategy if a newer, better option becomes available.

Land Use Values, human scale (Sweikert 2017, in review)
X49 Because farmers and ranchers' livelihoods depend on the land; they are the best stewards of the land.
X51 The best use of land should be determined by the amount of profit that can be earned annually.
X53 Farmers/ranchers should focus on optimizing production on their farm/ranch regardless of environmental costs.
X54 Farmers and ranchers have the right to use the soil, water, plants, and wildlife on land they own in any way they see fit.
X81 The needs of farmers and ranchers should take priority over the conservation of land.
X82 Farmers and ranchers are masters of the land.

Land Use Values, nature scale (Sweikert 2017, in review)
X48 The diversity of plants and wildlife in an area is a sign of the quality of the environment.
X50 Farmers and ranchers have an obligation to protect the soil, water, plants, habitat, and fish and wildlife on their land.
X77 All parts of the ecosystem, down to the microorganisms in the soil, are important for proper functioning of the landscape.
X78 If you take care of the land, it will take care of you.
X79 Restored lands maximize both productivity and ecosystem function.
X80 The quality of the land is positively influenced by the diversity of native plants and wildlife that live on or around it.
X84 Farmers and ranchers are only temporary trustees of the land; it is their responsibility to take care of it for future generations.

Innovativeness scale: Social (Roehrich 2004)
X55 I am usually among the first to try new management strategies.
X56 I know more than other people about the latest new ranching products.
X57 I try new products before my friends and neighbors.

Innovativeness scale: Exploratory acquisition of products (Baumgartner and Steenkamp 1996)
X58 I would rather stick with a product I usually buy than try one I'm not sure of. *

X59 I’m very cautious in trying new or different products. *
X60 I rarely buy products if I am uncertain about their performance. *

Innovativeness scale: Exploratory information seeking (Baumgartner and Steenkamp 1996)
X62 I like to shop around and look at product displays.
X63 I like to browse through catalogs even when I don’t plan to buy anything.

Individualism scale (Sivadas et al. 2008)
X66 I am a unique individual.
X67 I enjoy working in situations involving competition with others.
X68 I often “do my own thing.”
X70 Without competition it is not possible to have a good society.

Collectivism scale (Sivadas et al. 2008)
X64 My happiness depends very much on the happiness of those around me.
X65 I would do what would please my family, even if I hated the activity.
X69 Children should feel honored if their parents receive a distinguished award.
X71 I feel good when I cooperate with others.

Norms scale (Steg and de Groot 2010)
X72 Most ranchers in my community act in the best interests of the rangeland.
X73 I feel guilty if I do not act in the best interest of my rangeland.
X74 My neighbors expect me to act in the best interest of my rangeland.
X75 My neighbors act in the best interests of their rangeland.
X76 I feel proud when I manage my rangeland properly.

Threatened and Endangered Species scale (Belin et al. 2005)
X85 I would be pleased if a rare or threatened species was found on my land.
X86 Rare or threatened species should be protected.

Risk aversion scale (Rohrmann 1997)
X87 I’m quite cautious when I make plans and when I act on them. *
X89 I don’t like to put something at stake, I would rather be on the safe side. *
X91 I only set small work goals so that I can achieve them without difficulty. *
X93 My decisions are always made carefully and accurately. *
X94 I tend to imagine the unfavorable outcomes of my actions. *

Future Activities scale
X95 Alter management to provide habitat for threatened or endangered species.
X96 Work with a neighbor on invasive species control.
X97 Temporarily overgraze some of my pastures to create wildlife habitat.
X98 Work with a neighbor on brush encroachment control.
X99 Manage the threat of wildfires by using prescribed fires.

X100 Change management practices to increase carbon sequestration on my ranch.
X101 Be prepared for adverse weather, such as droughts.
X102 Modify management to increase wildlife populations on my ranch.