COMMUNITY DYNAMICS OF GRASSLAND BIRDS, RANGELAND VEGETATION, AND BLACK-TAILED PRAIRIE DOGS ON GRAZED MIXED-GRASS PRAIRIE

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department:
Range Science

May 2014

Fargo, North Dakota

North Dakota State University
Graduate School

Title

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MASTER OF SCIENCE

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ABSTRACT

Investigators surveyed vegetation and grassland bird communities on and off black-tailed prairie dog (*Cynomys ludovicianus*) towns to investigate community drivers, interactions, and species associations. This study was conducted within the Standing Rock Indian Reservation, near McLaughlin, South Dakota, USA, on grazed mixed-grass prairie. Sampling of birds and vegetation communities in 2012 and 2013 using fixed-width belt transects revealed community differences relative to prairie dog presence or absence ($p<0.01$) with percent cover bare ground being most strongly correlated ($r^2 \geq 0.93$) with the principal NMS axis in both years. All bird species, excluding Lark Sparrows, nested exclusively on or off prairie dog towns. After PCA, nests and random locations sampled for vegetation were not significantly different (MANOVA $p>0.05$) within their habitat type (town or off-town), except for Brewer's blackbird nests ($p<0.01$). Lack of significance may be due to limitations in sample sizes and the homogeneous nature of habitat at the scale sampled.

ACKNOWLEDGEMENTS

Sincere gratitude is hereby extended to both my co-advisors. Dr. Benjamin Geaumont provided invaluable guidance, professional experience, and insight on conducting thorough research with real management and conservation applications. Furthermore, he opened the door of opportunity which allowed me to gain critical early experience in the field and eventually led to my pursuit of graduate studies at North Dakota State University. I feel fortunate to have worked with an advisor who encourages independence and self-sufficiency and who mentors with such unwavering patience. Dr. Kevin Sedivec contributed to my growth as a communicator of science. His willingness to give of himself and his regard for every student's individual goals speaks of his dedication as an advisor.

In addition to my advisors, my thesis committee members are particularly deserving of thanks. The sharing of their expertise and precious time was truly critical in the completion of this academic endeavor. Dr. Ryan Limb should be commended for his ability to assist in PC-ORD analyses from memory while successfully operating a vehicle and offered much advice and guidance during many crucial stages of this degree and thesis. Dr. Megan Orr was invaluable in assisting with meaningful statistical content and providing new perspective.

Many thanks are also extended to the faculty and staff of the NDSU School of Natural Resource Sciences. Particular gratitude is given to Dr. Gary Clambey for many valued discussions about ecology, agriculture, and North Dakota. These casual graduate student discussion meetings often touched on topics which resonated at a much deeper level and truly enriched my on-campus experience.

Sincere thanks to all who assisted with data collection, particularly field technicians Alyssa DeRubeis and Jennifer Chancey, for perseverance and maintaining positivity in the face of heat, chiggers, early mornings, and long days.

Finally, I must mention Aldo Leopold, who inspired me through his writings and philosophies to pursue the study of ecology and whom I still recognize as a shaping and motivating influence on myself as an aspiring scientist.

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1. GENERAL INTRODUCTION

There is growing concern for both declining numbers of grassland birds and black-tailed prairie dogs (*Cynomys ludovicianus*). Prairie dog populations currently exist in only a small percent of their historic range (Burroughs et al. 1995). Many commonly-held opinions of prairie dogs are negative, which has led to widespread eradication efforts across all North American prairie dog range (Miller et al. 2007). Loss of suitable habitat and disease compound the effects of eradication efforts, leading to dramatic population decreases. The sudden loss or removal of prairie dogs from the landscape results in dramatic shifts in community dynamics. From an ecological standpoint, prairie dogs are considered keystone species in terms of being keystone modifiers (Mills et al. 1993). Modifiers are species that have a disproportionately large effect on the landscape relative to their body mass (Mills et al. 1993). Other species that are accustomed to inhabiting or utilizing prairie dog towns may be negatively impacted if the specific habitats prairie dogs create disappear. Many grassland bird species use prairie dog towns in some capacity, making the utility of cohesive study of birds and prairie dog associations clear.

There is value in the educated management of both prairie dogs and grassland birds. Hunting black-tailed prairie dogs is a sport many travel to partake in, supporting local economies in the Great Plains. This makes sustainable management necessary in order to maintain prairie dogs and other species in the community. Grassland birds are an integral part of a healthy prairie ecosystem and loved by prairie and avian enthusiasts alike. Understanding the intricate interactions between these two groups will shed light on management issues for both and may help provide solutions.

Livestock production is an important industry and grazing has impacts on both wildlife and plant communities in its own right. Examining biological communities in a grazed context allows for applications to a wider range of private landowners and managers who have operations that coincide with prairie dog range. The results of this study will inform any individuals or organizations who may be interested in the natural communities present on grazed land. Prairie dogs in particular are a controversial and political topic in the context of livestock production. In the face of this challenge, understanding community drivers, species associations, and interactions becomes even more important.

The following chapters discuss two studies, which are part of a much larger overarching project aimed at establishing a sustainable beef herd on the Standing Rock Indian Reservation in north-central South Dakota. The people of Standing Rock would benefit socially and economically from having a local, nutritious food source. Additionally, the tribal people wish to establish this beef operation in a sustainable manner. Concern for degraded rangelands and interest in the maintenance of robust bird and plant communities is largely responsible for shaping the goals of this research. We investigated the biological communities to inform management efforts and to provide information to the local people. This will aid in the establishment of a sustainable beef operation on the Standing Rock Indian Reservation. This was done in the context of both plant and avifauna species abundance and diversity, and from an avifauna reproductive standpoint, focused on habitat selection.

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An Explanation of Thesis Organization

This thesis follows the format required for submission into Rangeland Ecology & Management. The literature review is contained within Chapter Two. Chapters Three and Four represent separate portions of the completed study. Although this thesis follows the general formatting guidelines for submission, the length of individual sections often exceeds that of the journal limits. Due to the continuance of this study for three more years under a new graduate student, I have provided a level of detail greater than is required for submission to a journal in order to aid future researchers and ensure that methods remain consistent.

The pronoun "we" is used to give credit to the co-authors who provided their professional experience and guidance throughout the writing, analysis, and review processes. Each chapter is denoted with a footnote marker that explains the co-authors' contributions to each section.

2. LITERATURE REVIEW

Black-tailed Prairie Dogs

Species Description. Prairie dogs are burrowing, social rodents native to North American grasslands (Hoogland 1995). There are five separate species of prairie dogs recognized in North America and all five reside in the same genus, which they share with other ground squirrels. These species include the white-tailed prairie dog (*Cynomys leucurus*), Gunnison's prairie dog (*Cynomys gunnisoni*), Mexican prairie dog (*Cynomys mexicanus*), Utah prairie dog (*Cynomys parvidens*), and the black-tailed prairie dog (*Cynomys ludovicianus*).

Like other prairie dog species, black-tailed prairie dogs are social rodents that excavate their own burrows and live in social family groups called coteries. Active during the day, they often exhibit territorial displays toward adjacent coteries and issue barks as alarm signals in the presence of perceived danger. Groups of coteries aggregate together into large expanses of occupied area known as towns, villages, or colonies (Hoogland 1995). Black-tailed prairie dogs weigh between 900-1350 grams with males generally being larger in size than females. The last one-third of the tail is black, which distinguishes them from the white-tailed species, which instead has a tail ending in a white tip. Coat color can vary slightly between individuals but is always yellowish on the dorsal side with white or buff colored hair on the ventral side. Prairie dogs have small ears, little more than flaps of skin on the sides of their skull. Their eyes are placed laterally on the sides of the head, which provides excellent peripheral vision. This eye placement enables a wide field of vision ideal for watching for predators but sacrifices somewhat in terms of depth of field (Burt and Grossenheider 2006).

Prairie dogs are susceptible to sylvatic plague (*Yersinia pestis*), a bacterial disease spread by fleas that also affects other species of mammals and humans. Once this bacterium occurs in a colony, mortality rates can be as high as 90%. The social arrangement of prairie dogs, family groups living in close proximity, aids in the transmission of infected fleas, spreading the infection rapidly.

Distribution and Abundance. Black-tailed prairie dogs are extant in a belt stretching from southern Canada to northern Mexico (Hoogland 1995). Historically this included portions of Montana, North Dakota, South Dakota, Wyoming, Colorado, Nebraska, Kansas, Oklahoma, Texas, Arizona, and New Mexico. Black-tailed prairie dogs had an estimated population of over five billion within the last century (Hoogland 1995). Current black-tailed prairie dog range extends throughout much of the historic geographic area, excluding Arizona, but actual occupied acreage is much different. There is disagreement within the scientific literature about the magnitude of the decline in black-tailed prairie dog populations. Sources concerned with conservation interests or with an ecological perspective cite numbers as high as a 98% decline while other sources aligned with agricultural or livestock production interests give much lower decline estimates (Proctor et al. 2006). One source concludes that the current number of prairie dogs is less than 2% of the "infinite" numbers described by Meriwether Lewis (Burroughs et al. 1995). Recent typical densities within a colony are greater than ten individuals (adults and yearlings) per hectare (Hoogland 2006). Black-tailed prairie dog colonies have the largest known minimum colony size of any prairie dog species with a minimum town size generally greater than 1,000 individuals (Hoogland 2006).

Diet. Analysis of feces and stomach contents indicates that prairie dogs are herbivorous (Stockard 1930; Kelso 1939; King 1955; Summers and Linder 1978). Documentation shows occasional consumption of insects (Kelso 1939; O'Meilia et al. 1982). Prairie dogs are selective about plant species consumption depending on the time of year (King 1955; Koford 1958; Costello 1970). During the summer they graze primarily on wheatgrasses, buffalo grass (*Bouteloua dactyloides*), scarlet globemallow (*Sphaeralcea coccinea*), and rabbitbrush species (*Chrysothamnus* spp.). When more time is spent underground during the winter, eating of underground roots is more common. Prairie dogs also select prickly pear cactus (*Opuntia macroriza*) and thistle (*Cirsium* spp.) during the winter. Evidence suggests that prairie dogs avoid sagebrush (*Artemisia* spp.), threeawn (*Aristida* spp.), and horseweed (*Conyza* spp.). Grasses are preferred over forbs, comprising more than 75% of their diets (Detling 1998). Consumption of fresh or old bison (*Bison bison*) scat has also been documented (Hoogland 1995).

Hoogland (1995) saw rare evidence of cannibalism in black-tailed prairie dogs. After killing unweaned juveniles belonging to other females, lactating females occasionally consumed parts of the carcass. He also observed cannibalism on four occasions where an adult or juvenile died aboveground.

Habitat. Black-tailed prairie dogs inhabit mostly short-grass and mixed-grass prairie, which make up the vast majority of their geographic range. They can be found to a more limited extent in sagebrush steppe and desert grassland areas. Specific habitat preferences are a combination of vegetative cover, precipitation, topography, slope, aspect, and soil type (Hoogland 2006). Evidence suggests that short-grass prairie dominated by buffalo grass, blue grama (*Bouteloua gracilis*), and western wheatgrass (*Pascopyrum smithii*) and grazed mixed-grass prairie are preferred (King 1955). Vegetation heights between 7 and 13 cm and gentle slopes (2% to 5%) are ideal for scanning for predators and facilitating communication (King 1955; Koford 1958). Physical topographic barriers may divide towns into sub-colonies called wards (Hoogland 1995). Many towns occur on south aspects, presumably because of the dominance of grasses over forbs and the opportunity for increased thermal energy during the winter. Research suggests that black-tailed prairie dogs are generally not limited by soil type. Colonies occur in a wide variety of soil types from silty clay loams to sandy loams and deep, alluvial soils. Soils not prone to collapsing or flooding are favored to aid in tunnel and burrow excavation (Koford 1958). Once a suitable area is found and prairie dogs begin to occupy it, their continuous burrowing, foraging, and vegetation clipping activities begin to influence the landscape in a variety of ways.

Ecosystem Influences. Evidence shows that prairie dog activities influence nutrient cycling, increase nitrogen content of vegetation and soil, change vegetation structure and community dynamics, aerate soil, deepen water penetration, and provide prey and shelter for other species, including species of concern like burrowing owls (*Athene cunicularia*) and many diurnal raptor species (Detling 1998; Miller et al. 2007). Prairie dog grazing decreases mulch cover, live plant canopy cover, maximum vegetation height and plant species richness (Agnew et al. 1986). Miller et al. (2007) argue that due to the extensive reduction of prairie dog populations, prairie dogs are now functionally extinct. In other words, prairie dogs do not exist in high enough population levels to allow them to fulfill their functional ecological and evolutionary roles. The loss of prairie dogs certainly impacts the ecosystem. Mills et al. (1993) assert that removal or loss of these modifiers can result in "changes in energy flow, loss of structure or materials that affect habitat flow and trophic interactions, and disappearance of other species that rely on specific successional habitats and resources."

A recent study by Baker et al. (2013) tested the commonly accepted paradigm that prairie dogs always decrease vegetation volume, grass cover, and tall shrub cover while simultaneously increasing bare ground and forb cover. The authors explained that the origin of this paradigm is a collection of studies in northern mixed-grass prairie occupied by black-tailed prairie dogs, but the assumptions are commonly applied to other regions and prairie dog species. Results revealed that the paradigm was consistent for the seven complexes examined in the northern mixed-grass prairie. Other prairie dog species did also decrease vegetation volume but their overall impact on the cover of plant functional groups varied. White-tailed prairie dogs did not suppress tall shrub cover whereas black-tailed prairie dogs suppressed shrub growth at all complexes where tall shrubs existed in the surrounding habitat matrix. Due to the dominance of higher grazing-tolerance grasses in short grass steppe, both black-tailed prairie dogs and Gunnison's prairie dogs had little impact on grass cover.

Interactions with Livestock. The topic of prairie dogs and their interaction with livestock is controversial. A large volume of work has been done on the subject, but divisions based on varied perspectives and the inherent subtleties associated with complex ecosystem interactions have made a single conclusion seemingly impossible (Curtin 2006; Derner et al. 2006; Detling 2006).

The growth of cattle ranching in the West came with widespread prairie dog eradication efforts (Miller et al. 2007). These efforts stem largely from two main assumptions about prairie dogs; 1) prairie dogs compete with livestock for forage and 2) prairie dog burrowing activities pose a hazard to the health of livestock range and the animals themselves.

Many ranchers are concerned with decreased cattle production due to forage competition with prairie dogs. According to classic diet research, cattle and black-tailed prairie dogs do significantly overlap in their diets, up to 60% in a mixed-grass prairie and 64% in a short-grass prairie (Hansen and Gold 1977; Uresk 1984, 1986). However, diet overlap does not mean that competition is occurring. Competition implies that both of the competing entities is worse off due to the use of shared and limiting resources. Proving that competition is present can be challenging (Ricklefs and Miller 2000). Debate remains partially because prairie dog activities often increase forage quality despite reducing overall plant biomass (Miller et al. 2007). Additionally, competition levels can be highly situational depending on the examined scale and stocking rates as well as geographical location and moisture status of a region. Generalizing about the presence of competition in this situation is dangerous but widespread beliefs about negative impacts on cattle production has led in part to the practice of excluding prairie dogs via poisoning.

O'Meilia et al. (1982) investigated competition between steers and prairie dogs in Oklahoma, USA, and found that there was no difference in weight gain between steers raised on and off prairie dog towns over the entire year. A later study re-analyzed the data and concluded that there is no difference over an entire year, but when analysis is limited to only the winter a difference does exist

(Vermeire et al. 2004). Management implications based on these results are minimal, as most western ranchers do not allow cattle to free-range graze during the winter or typically supplement their diets with stored feed (Miller et al. 2007). One study that is particularly relevant to the content of this thesis evaluated competition between livestock and prairie dogs in South Dakota, USA. Investigators used data and linear programming to estimate that competition is between 4% and 7% between prairie dogs and cattle based on diets, consumption rates, plant production and seral stage, stocking rates, and densities of prairie dogs (Uresk and Paulson 1988).

Although a ubiquitous rule about competition between livestock and prairie dogs is not appropriate, it may be useful to provide landowners with some general guidelines on the issue. Competition between livestock and prairie dogs is more likely to occur in areas of low biomass productivity (Detling 2006). Higher stocking levels and areas with greater prairie dog densities also increase the likelihood of competition.

Results of investigations into grazing preferences vary based on region. In New Mexico, USA cattle walked miles away from water sources in order to preferentially graze on prairie dog towns (Curtin 2006). However, in short-grass steppe in Colorado, USA, cows exhibited no preference for grazing either on or off prairie dog towns (Guenther and Detling 2003). This further supports the danger of generalizing about livestock competition and preferences over the entirety of prairie dog range.

Many landowners also choose to eradicate prairie dogs due to their tunneling activities. Mounds are often considered unsightly and many landowners see them as degradation and hazards. However, studies show that mounds account for a very small percent of the area in a prairie dog colony. Farrar (2002) gave estimates of 2.5% and Detling (2006) of 6% of the colony area. It has also been shown that vegetation biomass associated with mounds increases as a result of increased nutrient and water runoff from the mounds (Severe 1977). Therefore, any vegetation biomass lost from the actual mound may be offset with increased growth in the surrounding areas (Severe 1977). In addition, if eradication of prairie dogs is carried out purely on the grounds of lost vegetation biomass, it is important to note that prairie dogs are more likely to colonize areas that were already overgrazed by livestock (Hoogland 1995). This means a colony may have been founded in an area with already low vegetation biomass due to overstocking of domestic grazing animal. Subsequent assumptions that prairie dogs are the sole cause of decreased forage production are erroneous and may lead to poisoning of entire colonies based on incorrect conclusions.

Another concern regarding the activities of prairie dogs is livestock injury from stepping in excavated burrows. There is little evidence to support these claims as being significant enough to justify wide scale eradication. Evidence suggests that leg fractures from prairie dog holes are rare (Hoogland 1995).

Grassland Birds

Declines. Researchers have documented population declines of grassland birds for approximately the past five decades. However, it is suspected that the declines started well before scientists began monitoring populations (Peterjohn and Sauer 1999; Vickery and Herkert 1999; Askins 2000). Strong evidence supports scientists' assertions that these declines are driven by anthropogenic changes, in many cases on a continental scale. Estimates place the beginning of grassland bird population declines with the advent of the first steel plow (Brennan and Kuvlesky 2005). Our ability to break hard prairie soil and the efficiency of new technology allowed the spread of agriculture to previously untouched areas. This led to the subsequent conversion of prairie habitat across the Great Plains and the West into agricultural landscapes and urbanization. Reasonably conservative estimates place the percentage of lost grassland ecosystems around 80% since the mid-1800s (Knopf 1994; Noss et al. 1995). Samson and Knopf (1994) also estimate that less than 0.1% of native tallgrass prairie remains in areas that are suitable for crop farming. Much of the remaining intact grassland has been fragmented, rendering it unsuitable for birds that require large, contiguous grasslands for foraging and/or nesting (Samson and Knopf 1994).

In addition to dramatic prairie habitat reductions, the conversion of open natural pine forests and southern grasslands in the southeast United States to dense, closed-canopy pine plantations has caused problems for grassland and grass-shrub dependent bird species (Brennan and Kuvlesky 2005). Historically these forests were maintained by natural wildfire disturbance but human fire suppression and timber planting has greatly altered the landscape. Rangeland deterioration by way of exotic grass invasions, fire suppression, altered hydrology, overgrazing, erosion increases, and woody plant encroachment poses a substantial threat to critical grassland habitat across the Great Plains and throughout the western United States (Brennan and Kuvlesky 2005). The extirpation of bison, an important native grazer, and improper grazing management and on-going prairie dog eradication efforts further threaten critical grassland bird habitat that was historically maintained by these modifiers.

More recent research also cites urbanization as a threat to grassland ecosystems (McDonnell and Pickett 1990; Knight et al. 1995). Jones and Bock (2002) confirmed these findings when they analyzed long-term data and identified significant declines in the majority of grassland species since 1909 near Boulder, Colorado. Several species disappeared from the region as the urban area expanded and encroached on nearby habitat. This study revealed that the main cause of some species declines, such as the Brewer's blackbird (*Euphagus cyanocephalus*), is urbanization through indirect effects. In the case of the Brewer's blackbird, urbanization has increased numbers of common grackles (*Quiscalus quiscula*), another icterid now outcompeting with the Brewer's blackbird (Jones and Bock 2002). With cities encroaching on historic grassland ranges, the remaining fragments become even more precious for native prairie species.

The International Union for the Conservation of Nature and Natural Resources (IUCN) lists many grassland bird species as species of "least concern" for conservation despite documented declines occurring over decades. This is often due to having large ranges or high populations which prevents these species from meeting listing criteria. Many grassland birds currently considered common are declining at higher than expected rates. Identifying and mitigating declines for these species early can help prevent conservation crises down the road. This is why investigating how birds use the landscape and the dynamics of grassland bird communities is crucial.

Interactions with Prairie Dogs. Considering the connections between grassland birds and black-tailed prairie dogs is important in the face of population declines of both groups. Historically, continuous grazing maintained by prairie dog colonies occupying hundreds of thousands of hectares of rangeland provided essential habitat for many grassland bird species and were an integral part of native prairie dynamics (Miller et al. 2007).

The presence of prairie dogs increases densities of other associated grassland species, including birds. Many members of the grassland bird community are considered closely connected to prairie dog towns, using burrows for dens or refuges and colonized areas as important foraging sites. Smith and Lomolino (2004) cite burrowing owls, mountain plover (*Charadrius montanus*), golden eagle (*Aquila chrysaetos*), ferruginous hawk (*Buteo rega*lis), prairie falcon (*Falco mexicanus*), Swainson's hawk (*Buteo swainsoni*), lesser prairie chicken (*Tympanuchus pallidicinctus*), and long-billed curlew (*Numenius americanus*) as examples. Prairie dog towns often result in increased diversity of avian species in comparison to adjacent uncolonized areas (Bonham and Lerwick 1976; Hansen and Gold 1977; Coppock et al. 1983; Agnew et al. 1986).

Smith and Lomolino (2004) investigated avian communities associated with black-tailed prairie dogs in short-grass prairie ecosystems and found that unique avian communities were present on prairie dog towns compared to four other studied treatments (open rangeland, conservation reserve program grasslands, scrub habitats, and fallowed crop fields) in the Oklahoma panhandle. Relative densities of all observed avian species were higher on prairie dog towns compared to other sites in summer and fall. Mean species richness was higher on prairie dog towns during the summer (with no differences for mean species richness in the fall). Species positively and significantly associated with prairie dog towns during the summer included burrowing owls, meadowlarks (*Sturnella magna, S. neglecta*), horned larks (*Eremophila alpestris*), and killdeer (*Charadrius vociferus*). Horned larks and ferruginous hawks were highly associated with prairie dog towns during the fall. Individual species tended to strongly prefer prairie dog towns or avoid them, supporting the idea that a heterogeneous landscape is needed for a healthy, robust community.

Despite a large volume of research investigating bird abundances relative to prairie dogs, few studies have examined nesting grassland birds in relation to prairie dog colonies. The majority of nest studies considering the scope of nesting grassland birds and prairie dog habitat focus on the near threatened mountain plover (*Charadrius montanus*) whose range does not overlap with this study's geographic location. Other research focuses mainly on differential nesting success. Nest predation is frequently cited as being the chief cause of nest failure for grassland birds (Martin 1993). Predation rates may be higher on prairie dog colonies because nests may be easier to locate and predators are more abundant, attracted by the amount of prey associated with these areas (O'Meilia 1982, Agnew et al. 1986).

Baker et al. (2000) conducted a study using artificial nests stocked with quail eggs in order to evaluate nest predation on prairie dog towns and paired off-town locations. They found that predation rates on the colonies were 29.5% higher than off-town sites. Further analysis revealed that there were correlations between differences in nest predation rates and estimates of the mean nesting cover, which supports the pattern found in previous studies (Martin 1993). Nesting cover on prairie dog towns was less dense and more homogeneous in structure. Avian species associated with prairie dog colonies had smaller clutches and more broods per year compared with species associated with off-town sites, suggesting underlying mechanisms to compensate for an increase in the risk of nest failure. In addition, Baker et al. (2000) suggest that birds may choose to nest on colonies because the risk of nest predation is offset by an increase in foraging success. The literature support for this conclusion is mixed. Some studies found higher abundances of insects on prairie dog towns whereas others looking at total herbivorous insect biomass found greater biomass on off-colony locations (O'Meilia 1982; Olson 1985). It is possible that predator-prey dynamics shifted after associations between certain bird species and prairie dogs evolved, which may explain why birds nest on prairie dog towns despite an increased risk of nest predation.

Today prairie dog colonies exist as smaller and more fragmented patches compared to the historic expanses of prairie dog range. These isolated and condensed habitats may aid predators in locating nests by decreasing the area that must be searched, concentrating nests in greater densities, and increasing predator abundance via greater influence of edge effects. If this is true, then this pattern suggests that eradication of prairie dogs is also indirectly impacting the nesting success of grassland birds and makes a strong argument for coordinated efforts to conserve large, contiguous colonies as opposed to smaller, isolated ones.

Although this study does pose some interesting questions, the utility of application to grassland birds is debatable. Artificial nests have an inherently "human" influence. There is a lack of natural nesting behavior exhibited by a breeding pair. Researchers selected the nesting sites and constructed the nests. The limitations of this study make further research necessary to either validate or reject these conclusions when applied to naturally occurring nests. There is a sizeable knowledge gap in the scientific literature relating to grassland bird reproductive ecology associated with prairie dog towns. We hope that our research will begin to fill this gap and spur future studies.

Interactions with Livestock. Historically many individuals within the natural resource and conservation fields have been very critical of grazing, particularly in relation to cattle on public lands. This was led in part by scientific studies with stacks of shortcomings in terms of design and bias that were not subjected to critical peer reviews (Knopf 1996). As interest in declines of grassland birds has grown, a re-evaluation of rangeland management and more recent research has led to new conclusions relating to interactions of grassland birds and livestock. Mengel (1970) identified 26 endemic birds that evolved on North American grassland habitats in a landscape dominated by grazers, including bison and prairie dogs. Without maintenance by natural fire regimes and large herds of unconfined native grazers the habitats these species evolved in are undergoing changes that lead to habitats that are greatly different from historic states (Knopf 1996).

Birds generally respond to livestock grazing based on the modifications to vegetation associated with livestock activity, as opposed to simply the presence of the cattle themselves (Bock and Webb 1984). In addition, research indicates that habitat selection by ground-nesting birds is focused less on individual plants and more on the vegetative structure as a whole (Knopf 1996). Cattle can have a major and immediate impact on shrub and ground vegetation (Sedgwick and Knopf 1991). In areas with a history of overstocking, the shrub layer is often completely removed or at least structurally altered (Klebenow and Oakleaf 1984). Browsing of lateral branches by cattle is common in arid regions and leads to changes in shrub growth form. This is detrimental to any birds that nest in or beneath shrub species. The opposite can also be true for shrub species that grazing animals avoid consuming. This leads to an increase of woody growth which can encroach on the open grassland some bird species require.

Herbaceous vegetation is also directly altered by grazing, whether by native grazers or livestock. Overstocking can cause massive decreases in biomass leaving birds dependent on taller grass species for nests without suitable habitat for reproduction (Knopf 1996). However, research suggests that appropriately stocked pastures frequently increase heterogeneity vertically and horizontally across the landscape. This can be beneficial to grassland birds by providing them with a variety of habitats to select from and by increasing bird species richness and diversity.

Rangeland Vegetation

Mixed-grass Prairie. The mixed-grass prairie bridges the gap between the arid shortgrass prairie of the western United States and the tallgrass prairie to the east. The region was first recognized by Clements (1920). Aptly named, many plant species found in either the shortgrass or tallgrass prairie can be found together in the mixed-grass prairie. This combination makes the mixed-grass prairie more diverse than either of the neighboring eco-regions. Dominant grasses include blue grama, little bluestem (*Schizachyrium scoparium*), needleandthread (*Hesterostipa comata*), green needlegrass (*Nassella viridula*), junegrass (*Koeleria macrantha*), and western wheatgrass.

The mixed-grass prairie has fared better than the tallgrass prairie in terms of conservation. Largely due to the continued dominance of ranching in the region, some contiguous grassland pieces still exist in the northern United States and southern Canada, although arguably none of them is unchanged from human influence. Prominent topographical features such as the Dakota Badlands and rolling hills and buttes combined with a more arid climate make much of the area unsuitable for farming. This unsuitability for crop agriculture has helped to preserve much of the native mixed-grass prairie in North America.

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3. COMMUNITY INTERACTIONS AND ASSOCIATIONS OF BLACK-TAILED PRAIRIE DOGS, GRASSLAND BIRDS, AND RANGELAND VEGETATION ON GRAZED RANGELAND

Abstract

Investigators surveyed vegetation and grassland bird communities on and off black-tailed prairie dog (*Cynomys ludovicianus*) towns to investigate community drivers, interactions, and species associations. This study was conducted within the Standing Rock Indian Reservation, near McLaughlin, South Dakota, USA, on grazed mixed-grass prairie. Sampling of birds and vegetation communities in 2012 and 2013 using fixed-width belt transects revealed community differences relative to prairie dog presence or absence (PerMANOVA, $p<0.01$) with percent basal cover bare ground being most strongly correlated ($r^2 \geq 0.93$) with the principal NMS axis in both years. Diversity and evenness relative to prairie dog presence was similar between both habitat types and years, although the suites of species were different. Although some species of birds and plants were recorded on exclusively one habitat type, many utilized both on and off prairie dog town locations, making an argument for maintenance of both habitat types to support a diversity of plant and animals in mixed-grass prairie systems.

Introduction

Herbivores often play an important role in community dynamics in grassland ecosystems by exerting change on the landscape. In the northern Great Plains, black-tailed prairie dogs (*Cynomys ludovicianus*) are considered by many biologists and ecologists to be a keystone modifier species and ecosystem engineers because of the large impact they have on the landscape relative to their body size (Mills et al. 1993; Detling 1998; Proctor et al. 2006; Miller 2007). Continuous burrowing and grazing activities create a specific successional habitat by changing soil characteristics, nutrient cycling, plant communities, and vegetative characteristics (Mills et al. 1993; Knopf 1996). These changes may then cascade through other trophic levels and influence the community composition, including grassland bird assemblages (Knopf 1996; Smith and Lomolino 2004). Understanding species associations and shaping influences on the composition of these communities becomes important for informing management decisions as grassland birds and prairie dogs experience continuing population declines. Utilizing rangeland for livestock production is an important economic influence in the North American Great Plains. Therefore, examining biological communities of birds, prairie dogs, and vegetation in a grazed context is important for wider applicability of results and enhancing standing knowledge of the community dynamics of a large proportion of remaining grasslands.

Black-tailed prairie dogs are often the targets of widespread eradication efforts (Proctor et al. 2006). This is largely due to common views of this species as a pest and nuisance. Eradicating prairie dogs causes a shift in the biological community as their influence on the landscape disappears. This change affects the abiotic components of an ecosystem (i.e. soil and nutrient cycles; Barth et al. 2014) but it also may affect any biotic species associated with these burrowing herbivores (Bonham and Lerwick 1976; Hansen and Gold 1977; Coppock et al. 1983; Agnew et al. 1986). These biotic species include predators that rely on prairie dogs as a prey base, such as many diurnal raptors and black-footed ferret (*Mustela nigripes*) (Smith and Lomolino 2004). Black-footed ferrets rely on prairie dogs for more than 90% of their diet and utilize burrows as dens to raise their young (Hillman 1968). Despite some recovery success through reintroductions and breeding programs, black-footed ferrets are still considered to be one of the most endangered animals in the world. As black-footed ferrets rely heavily on prairie dogs for prey and habitat, they are extremely sensitive to prairie dog declines and losses in prairie dog habitat (U.S. Fish and Wildlife Service 1988). In addition to species that use prairie dogs as a prey base, other species associated with the specific habitats prairie dogs engineer may also suffer. This includes invertebrate species, plant communities, and grassland birds such as Burrowing Owls (*Athene cunicularia*), a conservation species of concern (Smith and Lomolino 2004). Researchers presume that impacts follow eradication of prairie dogs based on current knowledge of ecological communities, but few studies have investigated these associations and sought to quantify and assess them.

Black-tailed prairie dogs are extant in a belt stretching from southern Canada to northern Mexico (Hoogland 1995). Estimates of population declines vary depending on source, but are cited as being somewhere between 90-98% declines in distribution and abundance (Proctor et al. 2006). Eradication efforts stem from a general dislike for prairie dog burrowing activities and the assumption that prairie dogs compete with livestock for forage. Concerns about sylvatic plague (*Yersinia pestis*) also motivate landowners and managers to eradicate prairie dogs. Research suggests that competition between livestock and prairie dogs for forage is highly situational (Detling 2006). Whether or not competition occurs and the magnitude is dependent on geographic location, time of grazing, health of the rangeland, average production, moisture status, stocking rates, and the examined scale (Uresk and Paulson 1988). Even in the presence of competition with livestock grazing, ecologists argue it does not occur at a magnitude which justifies widespread poisoning considering the impacts eradication has on a suite of other species and ecosystem functions (Hoogland 1995). Many studies conducted in the northern Great Plains show that small mammals utilize burrows as refuges (Cully et al. 2010). Furthermore, as stated above, other species rely on prairie dogs as their main source of prey or require the specific habitats they create for foraging or reproduction. Prairie dog presence has also been shown to increase landscape heterogeneity and influence plant community structure (Ceballos et al. 1999).

Grassland bird communities respond to heterogeneity of vegetation both in terms of structural variation and habitat patches across space (Knopf 1996; Davis 2004; Fuhlendorf et al.

2006). Many species of North American grassland birds are experiencing significant declines on a continental scale (Knopf 1996; Brennan and Kuvleskey 2005). These declines are suspected to be due to loss of suitable habitat through loss of native grassland and habitat degradation from a variety of factors. The majority of remaining grasslands in the western United States are used for livestock production. Few studies have aimed to examine the communities of grassland birds, vegetation, and prairie dogs in a completely grazed context. Doing so will allow for more widely applicable results and translate to better information for managers of livestock, rangelands, and wildlife.

There is a general lack of scientific research focused on identifying the major influences shaping grassland bird communities in the presence of both prairie dogs and cattle. Augustine and Baker (2013) examined grassland bird communities relative to prairie dog presence in the northern Great Plains. Some of their plots were grazed by either bison or cattle with no particular focus given to these plots compared to those not grazed. This study took place on a large scale across Montana, western South Dakota, and eastern Wyoming and examined how prairie dogs affect the composition and abundance of breeding birds using vegetative characteristics for describing habitat. They reported differences on and off colony sites with six breeding bird species having significantly greater densities on prairie dog towns when compared with off-colony sites. This was similar to what Smith and Lomolino (2004) found in their study on shortgrass prairie. Percent cover of bare ground, visual obstruction, percent cover of shrubs, and percent cover of grasses were important vegetative characteristics for describing differences in habitat correlates with variation in bird communities.

Concerns about conserving wildlife species and maintaining productive rangelands, both in terms of livestock and vegetation, coalesced into some fundamentally important questions that we aimed to answer with this study. Study objectives included examining community associations among grassland birds, rangeland vegetation, and black-tailed prairie dogs presence on grazed mixed grass prairie. We aimed to identify the strongest variables correlated with both on and off colony locations in terms of habitat characteristics, plant species, and grassland bird species to provide a complete picture of community dynamics. Vegetation surveys were completed in order to investigate the abundance and diversity of plant communities both on and off prairie dog towns and to connect habitat to the presence and absence of bird species.

Study Area

The study was conducted on leased land on the Standing Rock Indian Reservation near McLaughlin, South Dakota, USA (45°43'42.11"N, 100°38'41.60"W). McLaughlin is in Corson County, South Dakota, centrally located along the northern border with North Dakota (Figure 3.1).

Figure 3.1. Relative location of the research study site (represented by the star) in Corson County, South Dakota, USA.

The surrounding landscape is a mixture of rangeland and agricultural fields where topography is rolling to flat. This region consists of mixed-grass prairie dominated by mid-height cool season (C3) grasses. Dominant species of grasses include western wheatgrass (*Pascopyrum smithii*

(Rydb.) A. Löve), needle and thread (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), green needlegrass (*Nassella viridula* (Trin.) Barkworth), and prairie dropseed (*Sporobolus heterolepis* A. Gray) on native upland sites. Localized grass dominated areas on prairie dog towns consist of shorter warm season (C4) grasses including buffalo grass (*Bouteloua dactyloides* (Nutt.) J.T. Columbus) and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths). Forbs commonly encountered include blacksamson echinacea (*Echinacea angustifolia* DC.), scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.), and sagewort species (*Artemisia* spp). Woody vegetation is found in areas of concentrated moisture such as draws between slopes and bottomlands. Patches of western snowberry (*Symphoricarpos occidentalis* Hook.) can also be found interspersed with graminoid species. The majority of prairie dog towns are dominated by forbs including scarlet globemallow, fetid marigold (*Dyssodia papposa* (Vent.) Hitchc.), and woolly plantain (*Plantago patagonica* Jacq.). Area topography is a combination of rolling hills with relatively flat lowlands. These lowlands lie mostly along the northern edge of the field site nearest to a riparian area north of the study area and coincide with the majority of the area occupied by prairie dogs.

Web Soil Survey (NRCS USDA 2014) maps the dominant soil types on the study as Cabba-Reeder loams (6-25% slopes), Reeder-Cabba loams (6-9% slopes), Wayden-Cabba complexes (9 to 40% slopes), and similar soils with parent materials of clayey residuum weathered from shale. Other major soil map units include Dupree-Rock outcrop complexes (6-30% slopes), Regent-Wayden silty clay loams (6-15% slopes), and Sansarc-Opal-Dupree clays (9-25% slopes). The study area is dominated by shallow loamy and dense clay ecological sites which constitute approximately one-third of the overall site area. Smaller areas are occupied by loamy, shallow sandy, loamy terrace, thin claypan, clayey, shallow clay, and loamy overflow ecological sites.

Vegetative production based on soil type for this region typically ranges between 915-2492 kg•ha-1 per year (weights are air-dried vegetation; NRCS USDA 2014). The major soil map units have production estimates in the middle of this range (Cabba-Reeder loams approximately 1566 kg•ha-1 per year and Dupree-Rock outcrop complexes around 1059 kg•ha-1 per year).

The study site was delineated into four pastures of comparable size with varying degrees of prairie dog occurrence (Figure 3.2). Each pasture represented a different level (treatment) of percent occurrence of prairie dogs, with four levels studied including 1) 0 percent, 2) 18 percent, 3) 40 percent, and 4) 75 percent (Table 3.1). This stratification of percent prairie dog colony by pasture was done for livestock research that was conducted on this study site during the same time frame.

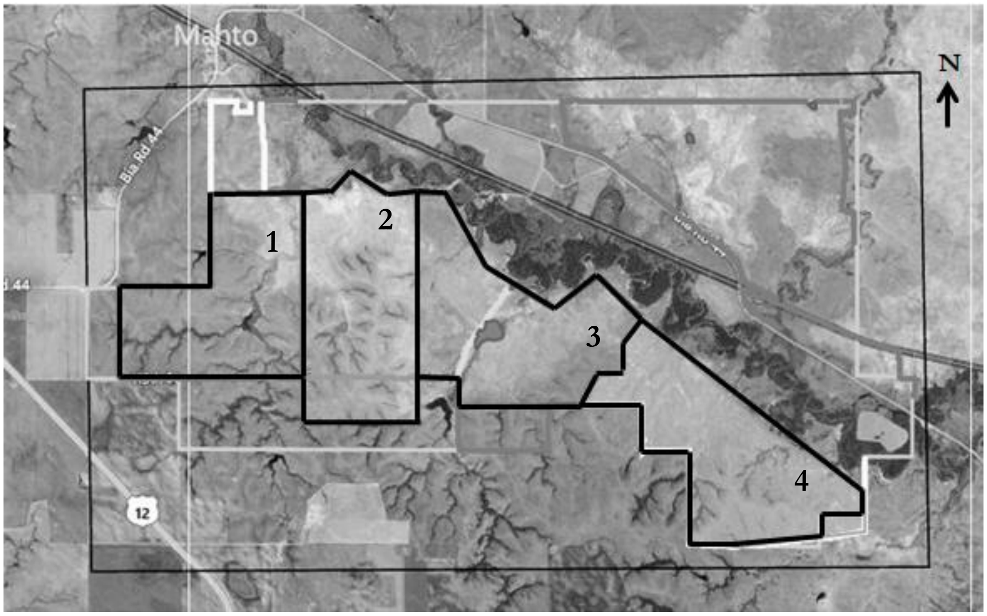

Figure 3.2. Aerial photograph of the field site near McLaughlin, South Dakota, USA with labeling of relevant boundaries and roads. Fence lines of the main research area are outlined in bold black. Numbers refer to pastures with 1) 18% 2) 40% 3) 75% and 4) 0% of pasture area colonized by prairie dogs. Imagery courtesy of USGS.

Each pasture treatment was stocked with Angus steers with a goal of achieving 50% degree of disappearance. Cattle were placed in their respective pastures 6 June 2012 and removed 9 October 2012. In 2013, cattle were placed on pasture 5 June and removed 22 October. See Table 3.2 for details regarding cattle numbers, and mean start and finishing weights. Since the stocking rates of the cattle were the same (achieve 50 percent disappearance of current years herbage produced) for all treatments (occurrence of prairie dogs) in this study, all pastures were considered to be the same in terms of livestock use. The focus of this investigation was comparing the off-town locations with areas colonized by prairie dogs.

Table 3.1. Total pasture area in hectares and extent of each pasture occupied by prairie dogs on study site near McLaughlin, South Dakota, USA.

Pasture	Pasture area (hectares)	Area occupied by prairie dogs (%)
1	193	18
2	207	40
3	208	75
4	204	0

Table 3.2. Number of cattle and starting and ending average weights of the four study pastures on rangeland near McLaughlin, SD, USA. Cattle grazed from 6 June 2012 to 9 October 2012, and 5 June 2013 to 22 October 2013. Standard deviations of mean weights are shown in parentheses. Pastures were stocked for a goal of 50% degree of disappearance.

Year	Pasture	No. of cattle	Beginning mean weight	Final mean weight
2012	1	53	661 (84)	870 (59)
2012	2	44	653 (71)	867 (64)
2012	3	16	655 (74)	869 (68)
2012	4	72	657 (74)	844 (57)
2013	1	53	672 (34)	975 (42)
2013	2	44	672 (38)	966 (43)
2013	3	16	680 (32)	962 (46)
2013	4	72	673 (36)	915 (46)

This region is considered to be semi-arid. McLaughlin receives 44 centimeters of precipitation on average with approximately 75 percent occurring during the growing season (South Dakota Weather and Climate 2014). The 29-year average reports a mean annual winter (December-March) temperature of -8 ˚C and a mean annual summer (June-August) temperature of 20 ˚C (South Dakota Weather and Climate 2014). Figures 3.3 and 3.4 illustrate average precipitation and temperatures by month for McLaughlin, South Dakota. Precipitation in July of 2012 was slightly below average in north central South Dakota, similar to the majority of the United States, which was suffering from a significant drought. In 2013, McLaughlin received approximately 14.5 cm above average precipitation in late spring and throughout the growing season.

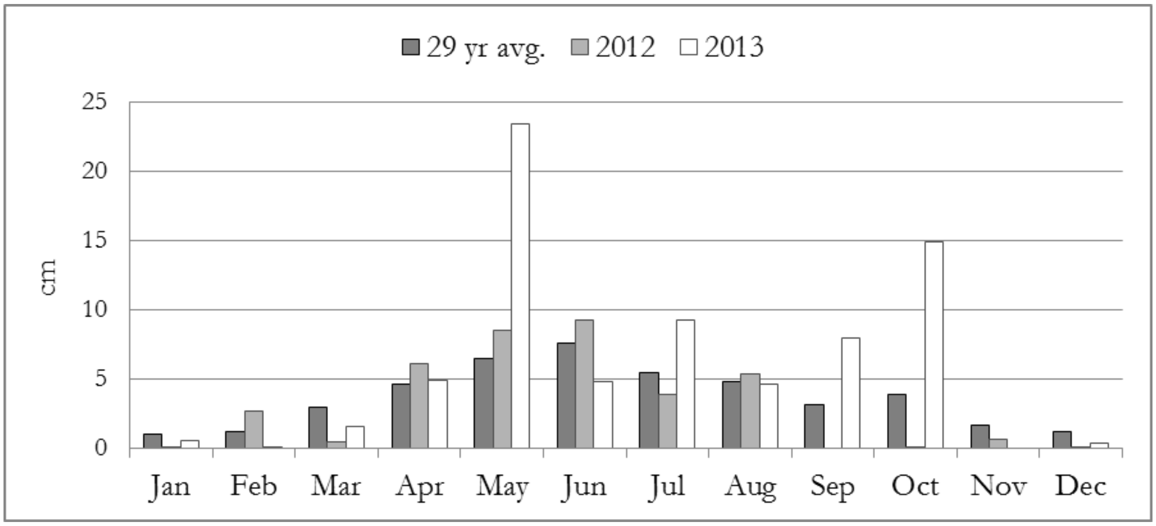

Figure 3.3. Average monthly precipitation for McLaughlin, South Dakota, USA, for 2012, 2013, and a 29-year average (1971-2000). Data for the 29-year average was provided by the South Dakota State Climate and Weather database (2014). Individual year data was provided by NOAA (2014).

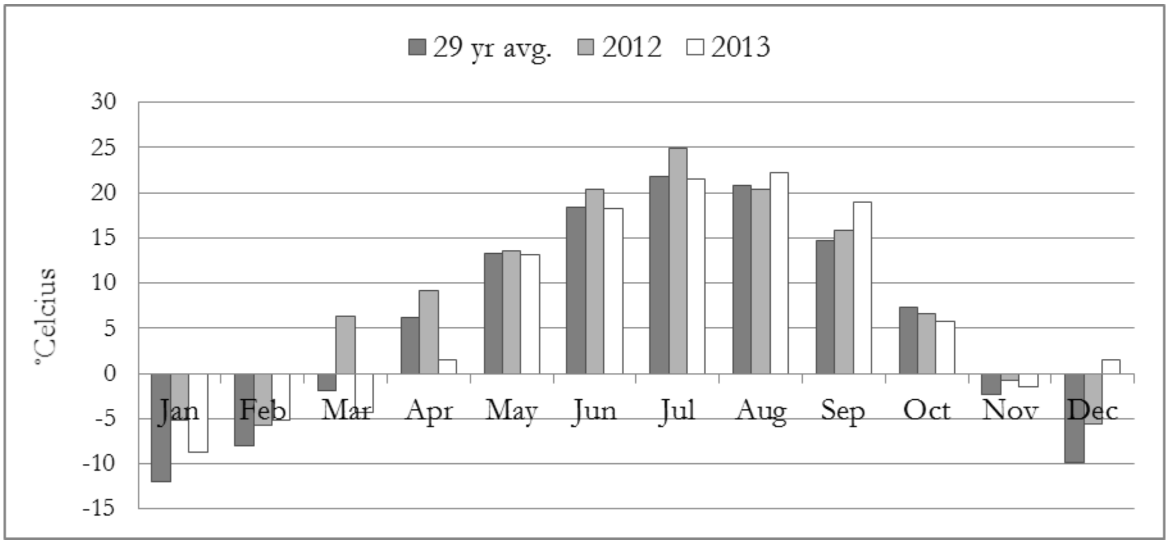

Figure 3.4. Average monthly temperatures for McLaughlin, South Dakota, USA, for 2012, 2013, and a 29-year average (1971-2000). Data for the 29-year average was provided by the South Dakota State Climate and Weather database (2014). Data for 2012 and 2013 were provided by NOAA (2014).

Prior to leasing, the study site was grazed by horses (approximately 100 individuals). Some impacts from the presence of these horses may include localized soil erosion and compaction, grazing effects, and the introduction of invasive weeds through hay fed on the study site, particularly in the pasture with 75% of its area occupied by prairie dogs. These weeds include absinth wormwood (*Artemisia absinthium* L.), western dock (*Rumex aquaticus* L.), and Canada thistle (*Cirsium arvense* (L.) Scop.).

Methods

Bird Surveys. Sampling of bird populations for abundance and diversity was completed using fixed width belt transects following standard distance sampling protocols (Hill et al. 2005; Buckland et al. 2001). Thirty-six transects, 300 meters in length, were placed across all four study pastures, nine in each pasture. Figure 3.5 shows the locations of each transect in the study site area. These transects were placed using a randomly selected start point. The other end was physically walked out 300 meters and placed in an appropriate location based on topography, woody draws, and the location of other transects. This allowed investigators to establish buffer zones between transects and fence lines as well as avoid placing a transect entirely in a wooded area, shrubby ravine, or water feature. Transect ends were marked via a handheld Garmin global positioning system (GPS) unit and flagged with a rebar stake and neon flagging tape to increase visibility from a distance.

Bird surveys were conducted beginning one half hour before sunrise until 0900 hours each day when winds were less than or equal to 15 km/hr and there was no precipitation. Three survey periods were completed each year during the breeding season (May-August) resulting in each transect being surveyed three times in both 2012 and 2013. Transects were surveyed in a randomly generated order and observers alternated which end of the transect they began the survey during each round.

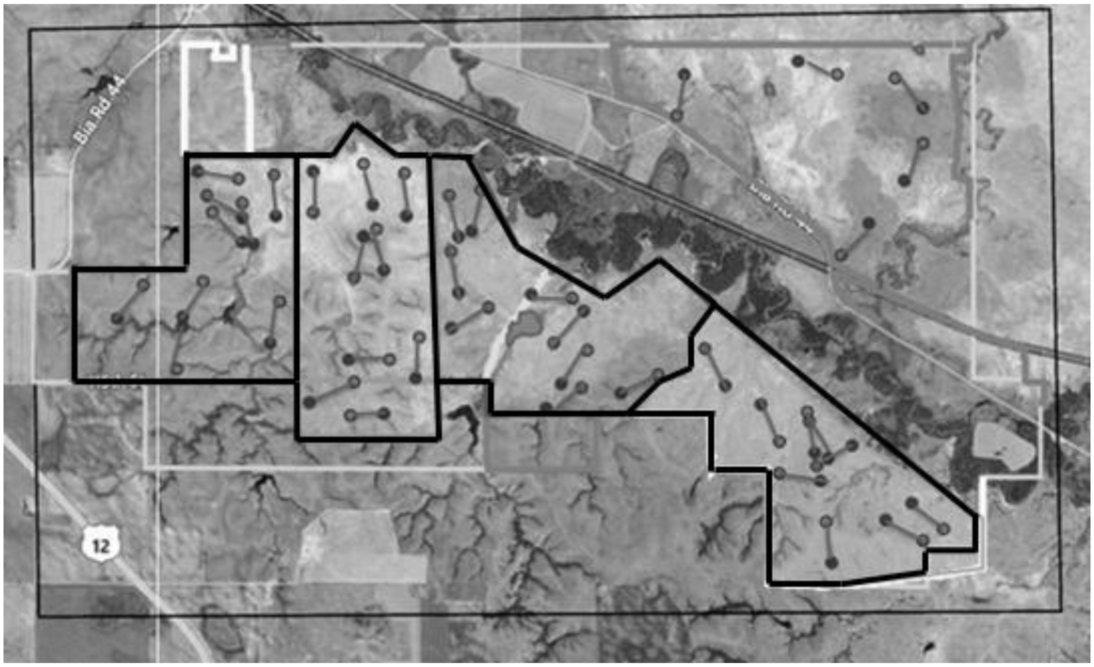

Figure 3.5. Aerial photograph of the field site located near McLaughlin, South Dakota, USA. Thirty-six belt transects surveyed for vegetation and bird communities are depicted by two end points and a connecting line. Imagery courtesy of USGS.

When beginning a survey, two observers started at one end of a transect and waited three to five minutes on arrival to allow birds to return to normal activities after the initial disturbance of the observers' approach. Two observers walked together from one end of the transect to the other at a steady pace in 15 minutes, recording all birds detected by sight or sound within a distance less than or equal to 100 meters on either side of the center line of the transect. Observers used binoculars to assist in visual detection.

Upon detecting a bird or cluster of birds, the observers identified the species and sex (if possible), recorded the number of individuals of each sex or unknown sex, compass bearing to the cluster, distance from the observer to the bird using a laser rangefinder (Leupold RX-1000 TBR), and any other notes of importance.

We found that it was most useful to divide the needed information into separate roles for the best efficiency and accuracy. One observer records detection information and navigates to the other endpoint using a handheld GPS while the other observer measures compass bearings and rangefinder readings to detected birds or clusters. Both observers were responsible for making bird observations at all times. This increases the likelihood that a bird will be detected and also prevents double counting of birds. Each bird should only be recorded once, at its initial detection location.

Detected birds must be using the survey area to be recorded as an observed individual or cluster. This eliminated the possibility of over estimating bird species due to flyovers that were simply moving through the area during the time of the survey. Flyovers of the belt transect area during the time of the survey by raptors were all recorded because they were most likely actively foraging (i.e. using the site) while engaged in soaring behavior. In this case the raptor's compass bearing and distance reading were taken at the position where it was first detected within the survey area.

Vegetation Surveys. Vegetation surveys were done on a subset of the same belt transects used to survey bird communities. Due to time limitation, 24 of 36 bird survey transects were sampled for vegetation. Twelve of the sampled transects were located on prairie dog towns and twelve off-town locations. Vegetation sampling was done when plant communities had reached peak production stage. In 2012, surveys began on 28 June and concluded on 25 July. In 2013, vegetation surveys began on 23 July and concluded on 15 August. The temporal difference in vegetation surveys between years can be largely attributed to the moisture differences in the region between years. Peak production and seasonal senescence were both earlier in the drier year of 2012. In 2013, a longer growing season with ample moisture and later peak production occurred, delaying senescence and promoting late summer regrowth.

Vegetation surveys used a combination of systematic design and randomization. Along the length of a transect, 21 - 10x10 m sample plots were completed. The corner of each plot was placed at a randomized distance out from the center line of the transect on alternating sides at 15 meter intervals, beginning at zero meters and concluding at 300 m. These randomized distances were less than or equal to 100 m from the transect center line so that the same area sampled for birds was also sampled for vegetation. At each sample plot, investigators counted and recorded the number of active and inactive prairie dog holes, recorded slope, aspect, and landscape position. Slope readings were done using an inclinometer on a compass and following methods suggested in the Breeding Biology Research and Monitoring Database (BBIRD) protocol from University of Montana (Martin et al. 1997). Figure 3.6 gives an example of a potential sampling scheme within a survey belt transect.

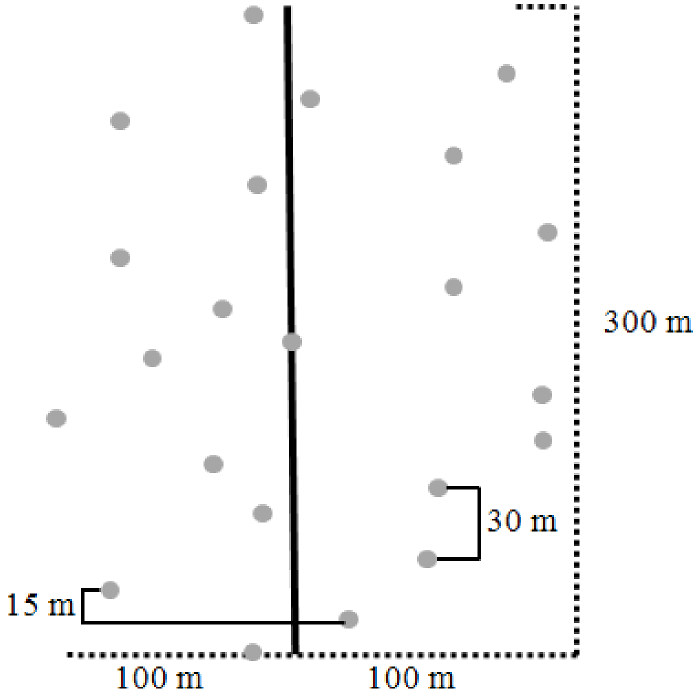

Figure 3.6. An example of a vegetative sampling scheme on belt transects for ecological research completed near McLaughlin, South Dakota, USA. Each gray point represents the location of a sampling plot.

Within the 10x10 meter plot, vegetative sampling was completed at six systematic sample points. Figure 3.7 diagrams the location of each sample point within the 10x10 m sample plot. At each of these six points, investigators completed vegetative sampling. This included recording the maximum live vegetation height (cm), maximum standing dead vegetation height (cm), visual obstruction reading using a modified Robel pole (cm) (Robel et al.1970), ten-pin point frames for basal cover by functional groups (Evans 1957), and 50x20 cm frames for percent canopy cover by species (Martin et al. 1997; Daubenmire 1959).

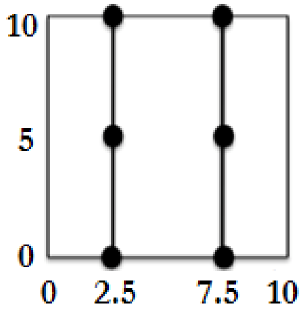

Figure 3.7. Location of sample point within 10x10 meter sample plots used during vegetation surveys for ecological research near McLaughlin, South Dakota, USA. Numbers are meters away from the main corner of the plot.

Maximum vegetation heights were collected using the tallest vegetation within a one meter diameter of the Robel pole. Visual obstruction readings and measurements of vegetation height were recorded in centimeters to allow for fine scale measurements that better capture small variations in the short vegetation typical of prairie dog towns (this change in length of increment was the modification to Robel et al. (1970) protocol). Ten-pin point frame functional groups included bare ground, litter, grasses, forbs, sedges, and shrubs. Bare ground (both basal and canopy cover) was considered to be mineral soil absent of any other cover. Basal litter was defined as dead plant material no longer rooted in the soil, detached from the live plant, and laying on mineral soil. Litter as canopy cover was dead plant material suspended in live plant matter as a canopy or multiple canopy layers and attached to the live plant. All plant species plus additional percentages of bare ground and/or litter must add up to at least 100%. Totals slightly over 100% are permissible if overlapping canopies occur in the frame. Two different observers sampled frames in 2012 and one observer conducted surveys in 2013 in order to maintain consistency in cover estimates. This greatly reduces any variation that may be introduced due to differences between observer readings.

Statistical Analysis. Analysis of complex community data was conducted using PC-ORD version 6 and applying non-metric multi-dimensional scaling (NMS; McCune and Mefford 2011).

Data processing was done before importing data into PC-ORD for NMS analysis. This included identifying and removing rare and ubiquitous species of plants and birds from the dataset. Analyzing with overly abundant or rare species can skew NMS analysis (McCune and Mefford 2011). To be considered appropriate for addition to the ordination, a bird or plant species must have been detected more than once. A species was considered to be overly abundant species if detected in consistently dominant levels (greater than 50% canopy cover for plant species). No bird or plant species were considered to be overly abundant under this criteria.

For the NMS ordination, the "slow and thorough" setting of the autopilot procedure was selected, with random starting configurations, a maximum of 500 iterations, and 250 real runs of data. Euclidean distance measurement was chosen due to the combination of taxonomic and non-taxonomic data in the dataset. The main matrix consisted of all quantitative data for both birds and vegetation. This included relative abundances of bird species (average number by transect) and averages of maximum live vegetation height, visual obstruction readings, percent basal bare ground, and canopy cover by species including litter. The secondary matrix grouped transects by pasture using categorical variables so investigators could see if significant differences between pastures existed. Due to climatic variation from year to year, both years were analyzed separately. Background data collected (slope, aspect, landscape position, and number of prairie dog holes) was not utilized in these analyses.

After running the ordination, investigators' examined the main matrix Pearson correlation coefficient values with the axes to determine directionality and which variables were strongly correlated. A strong correlation was considered to be r greater than or equal to 0.5. This is a conservative value chosen due to small sample sizes for some species. McCune (2011) states that even a small correlation coefficient will be statistically significant (provided appropriate data processing and methods have been followed) and other studies using NMS use values of 0.3

(McCune 2011). After receiving results of the analysis, we examined the overlay of the main matrix with individual variables to determine whether using the Pearson correlation coefficients is appropriate. If a variable has a non-linear correlation with the axis then using Pearson's correlations is inappropriate.

PerMANOVA was conducted to determine if bird and plant communities were different relative to the presence or absence of prairie dogs.

Results

2012 NMS Ordination. The NMS ordination for the community data from the 2012 field season consisted of 31 bird species and 86 plant species (complete site bird and plant lists can be found in Appendix A). The solution returned was 1-dimensional (Fig 3.8A and Fig 3.8B) and had a stress value of 8.47. The axis explains 97% of the variation in the data. Vegetative characteristics, bird species, and plant species were strongly correlated with the principal axis in both directions. Percent cover of bare ground is the most strongly correlated variable (r=0.99) and proportionally accounts for 0.98 of the location of any given transect along the axis. Tables 3.3-3.5 show variables strongly correlated with the axis and their corresponding Pearson correlation coefficient values.

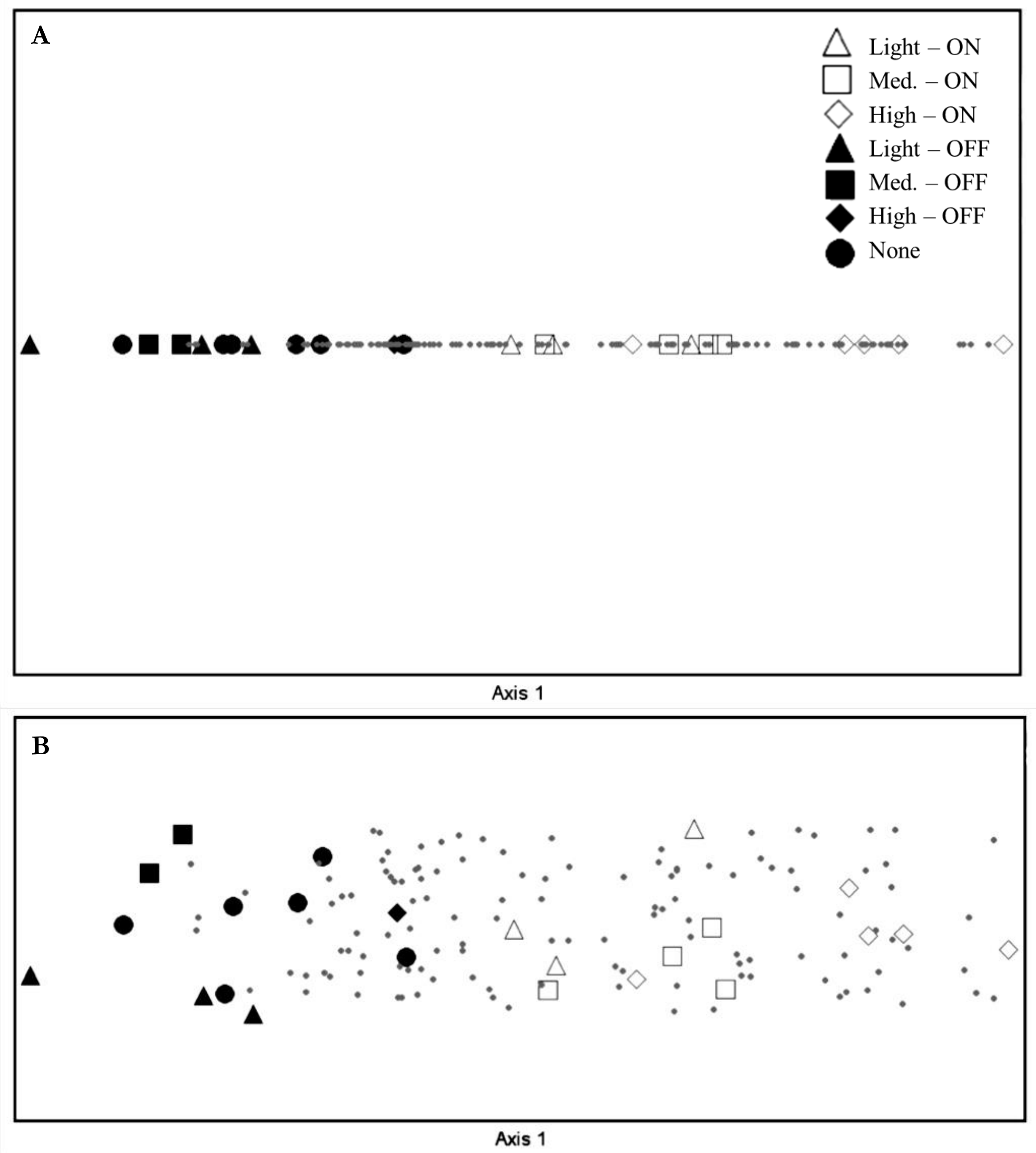

Figure 3.8. Non-metric multidimensional scaling results from an ordination examining differences in bird and plant communities on and off prairie dog towns (May-August 2012) on mixed-grass prairie near McLaughlin, SD, USA. Each shape represents a sampled belt transect and gray background points are individual variable scores. The terms light, medium, high, or none refer to the extent of prairie dog occupancy in the pasture. The label “ON” refers to transects which are on the prairie dog town and “OFF” refers to transects located in areas not occupied by prairie dogs. Graph A shows the one-dimensional solution with all points as they are along a line. Graph B shows the same ordination but with points and vertices jittered away from the line for visibility. Stress value=8.47 and ordination accounts for 97% percent of variance in dataset.

Table 3.3. Bird species strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Bird surveys were completed in 2012 (May-August) in grazed mixed-grass prairie in north central South Dakota, USA.

Bird Species	***r***	***r*²**
Grasshopper Sparrow	-0.90	0.81
Horned Lark	0.73	0.54
Vesper Sparrow	0.61	0.37
Dickcissel	-0.51	0.26

Table 3.4. Vegetative characteristics strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Surveys were completed in 2012 in grazed mixed-grass prairie in north central South Dakota, USA.

Variable	***r***	***r*²**
% BG[1]	0.99	0.98
MaxLv[2]	-0.96	0.91
VOR[3]	-0.87	0.76
Litter depth	-0.75	0.57
% Litter[4]	-0.66	0.44

[1]Percent bare ground, [2]Maximum live vegetation height, [3]Visual obstruction reading, [4]Percent canopy cover litter

2013 NMS Ordination. In 2013, 29 bird species and 82 plant species had sufficient sample sizes to be included in the NMS ordination (complete species lists can be found in Appendix A). The solution returned was 2-dimensional (Fig 3.9) and had a stress value of 7.33. The principal axis explains 79% of the variation in the data and the secondary vertical axis accounts for 17%, for a total of 96% of the variation in the dataset accounted for by the ordination. Vegetative characteristics, bird species, and plant species were strongly correlated with the principal axis in both directions. Percent cover of bare ground was again the most strongly correlated variable with the principal axis (r=0.96) and proportionally accounts for 0.93 of the location of any given transect along the axis. Suckling clover (*Trifolium dubium* Sibth.) was most strongly correlated with the secondary axis. Tables 3.6-3.8 show the variables strongly correlated with the principal axis and their corresponding

Pearson correlation coefficient values. Tables 3.9 and 3.10 display strongly correlated variables and their corresponding Pearson correlation coefficients with the secondary axis.

Table 3.5. Plant species strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Surveys were completed in 2012 in grazed mixed-grass prairie in north central South Dakota, USA.

Species	***r***	***r*^{2}**
Poa pratensis	-0.86	0.74
Artemisia ludoviciana	-0.71	0.50
Artemisia frigida	-0.70	0.49
Carex spp	-0.68	0.46
Artemisia dracunculoides	-0.63	0.40
Aristida purpurea	-0.61	0.40
Koeleria macrantha	-0.60	0.36
Echinacea angustifolia	-0.57	0.33
Hesperostipa comata	-0.56	0.32
Bromus inermis	-0.56	0.32
Symphoricarpos occidentalis	-0.56	0.32
Latuca tatarica	-0.50	0.22
Dyssodia papposa	0.83	0.69
Amaranthus albus	0.59	0.35
Schedonnardus paniculatus	0.54	0.30
Solidago missouriensis	0.52	0.27

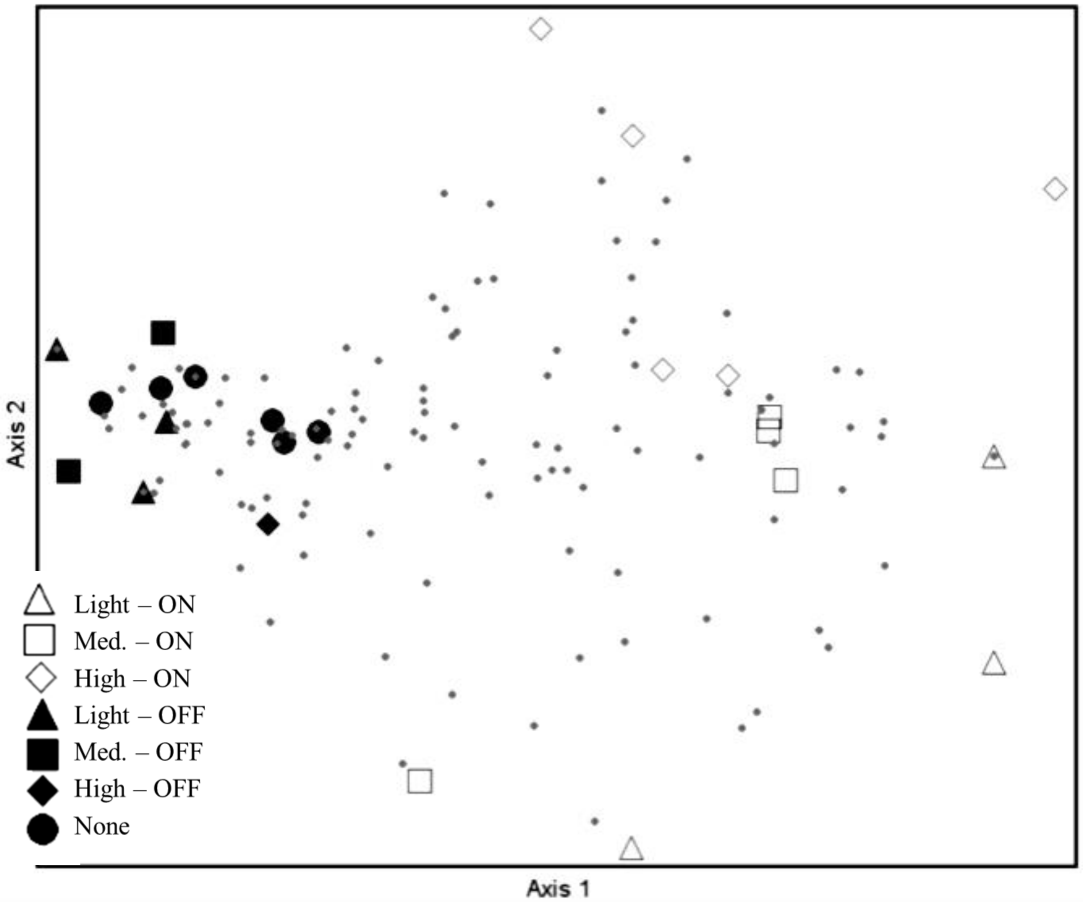

Figure 3.9. Non-metric multidimensional scaling results from an ordination examining differences in bird and plant communities on and off prairie dog towns (May-August of 2013) on mixed-grass prairie near McLaughlin, SD, USA. Each shape represents a sampled belt transect and gray background points are individual variable scores. The terms light, medium, high, or none refer to the extent of prairie dog occupancy in the pasture. The label "ON" refers to transects which are on the prairie dog town and "OFF" refers to transects located in areas not occupied by prairie dogs. Stress value=7.33. Primary axis (x-axis) and secondary axis (y-axis) account for 79% and 17% of variance in the dataset, respectively.

Table 3.6. Bird species strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Bird surveys were completed in 2013 (May-August) in grazed mixed-grass prairie in north central South Dakota, USA.

Bird Species	***R***	r^2
Grasshopper Sparrow	-0.86	0.75
Horned Lark	0.86	0.74
Brewer's Blackbird	0.60	0.36

Table 3.7. Vegetative characteristics strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Surveys were completed in 2013 in grazed mixed-grass prairie in north central South Dakota, USA.

Variable	***R***	r^2
% BG[1]	0.96	0.93
% Litter[2]	-0.90	0.81
MaxLv[3]	-0.83	0.69
VOR[4]	-0.78	0.61
Litter depth[5]	-0.71	0.50

[1]Percent cover bare ground, [2]Percent canopy cover litter, [3]Maximum live vegetation height, [4]Visual obstruction reading, [5]Litter depth in cm

Table 3.8. Plant species strongly correlated with the principal NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Surveys were completed in 2013 in grazed mixed-grass prairie in north central South Dakota, USA.

Species	***r***	***r^2***
Echinacea angustifolia	-0.83	0.70
Carex spp	-0.67	0.45
Aristida purpurea	-0.65	0.42
Grindelia squarrosa	-0.65	0.42
Hesperostipa comata	-0.64	0.41
Bromus tectorum	-0.60	0.35
Artemisia dracunculoides	-0.54	0.29
Psoralea argophylla	-0.52	0.27
Dyssodia papposa	0.80	0.64
Schedonnardus paniculatus	0.62	0.39
Pascopyrum smithii	0.55	0.30
Solidago missouriensis	0.50	0.25

Table 3.9. Bird species strongly correlated with secondary NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Bird surveys were completed in 2013 in north central South Dakota on grazed mixed-grass prairie.

Bird Species	***R***	***r^2***
Lark Sparrow	0.64	0.41
Western Kingbird	0.50	0.25

Table 3.10. Plant species strongly correlated with secondary NMS ordination axis. *r* is the Pearson correlation coefficient with the principal axis. Surveys were completed in 2013 on grazed mixed-grass prairie in north central South Dakota, USA.

Species	***R***	r^2
Trifolium dubium	-0.68	0.46
Amaranthus albus	-0.56	0.31
Poa pratensis	-0.54	0.29
Munroa squarrosa	-0.52	0.27
Nassella viridula	-0.52	0.27
Psoralea argophylla	-0.52	0.27
Spartina pectinata	-0.51	0.27
Artemisia absinthium	0.50	0.25
Rumex aquaticus	0.60	0.36
Lotus unifoliatus	0.50	0.25
Sphaeralcea coccinea	0.50	0.25

Discussion

Due to the focused study area and limited sample sizes of birds by species, we were unable to use distance sampling to estimate bird densities. However, density was not a crucial parameter and relative abundances were substituted without concern. It should also be noted that in 2013 the pasture with 75% of its area colonized by prairie dogs lacked the numbers of prairie dogs previously seen in the eastern part of the town. We are unsure if this change in population was due to natural or anthropogenic causes in our absence during the winter of 2012-2013. There is no recorded history of sylvatic plague at this complex.

The on-town and off-town transects were clearly separated in the ordination space in both 2012 and 2013 showing that the communities of birds and plants are different on prairie dog towns compared to off-town locations. PerMANOVA confirmed this difference ($p<0.01$) for both years. This separation in ordination space was driven by bare ground, the most strongly correlated variable with the principal axis in both years. All off-town transects are negatively correlated with the principal axis and on-town locations are positively correlated. When we examine individual parameters' Pearson correlation coefficients in association with the principal axis, the ordination begins to reveal what the bird and plant communities are like relative to the presence or absence of prairie dogs.

Off-town locations have greater visual obstruction, maximum live vegetation heights, percent litter cover, and litter depth. These plots are native graminoid dominated with native forbs and occasional silver sagebrush (*Artemisia cana*). Dominant graminoid species included sedges (*Carex* spp), western wheatgrass, needleandthread, and green needlegrass. Sagewort species (*Artemsia* spp), blacksamson echinacea, and prairie lettuce (*Latuca tatarica*) were common forbs on these native off-town locations. Bird species strongly correlated with these sites in 2012 included grasshopper sparrows and dickcissels (*Spiza americana*). Both these species prefer and require greater vegetative structure for successful nesting (Whitmore 1981; Zimmerman 1982). Dickcissels are an irruptive species and 2012 was considered to be one of the largest irruption years on record (eBird 2012). Higher population levels caused individuals to spill over the edge of typical range and be detected in good numbers at the study site. In 2013, no dickcissels were detected on the field site as it was a "normal" population year, which explains the lack of a correlation in the second year of the study (eBird 2012).

Prairie dog towns were characterized by short vegetation, high amounts of bare ground, low or no litter depth or cover, and low visual obstruction. On-town plots were forb dominated with few grasses. Grass species present tended to be short-grass varieties able to withstand the constant clipping and grazing by the prairie dogs, such as blue grama and western wheatgrass (Branson 1953; Fisher 1951; Stubbendieck et al. 1985; Welsh et al. 1987; NRCS USDA 2014). These findings are congruent with observations widely reported in the literature and results of other empirical studies conducted in both mixed-grass and short-grass prairies (Agnew et al 1986; Archer et al 1987; Whicker and Detling 1988). Dominant and strongly correlated plant species included fetid marigold, prostrate pigweed (*Amaranthus albus*), and Missouri goldenrod (*Solidago missouriensis*) in both years. These are species which are able to cope with the continuous disturbances created by prairie dog grazing and burrowing activities (NRCS USDA 2014). In 2013, some grass species capitalized on increased moisture and were strongly positively correlated with the principal axis. This included tumblegrass (*Schedonnardus paniculatus*) and western wheatgrass. More growth may have led to higher amounts of these species appearing in canopy cover surveys. This also created a greater abundance of grass as a food resource for both prairie dogs and cattle making it less likely that these species would be totally consumed and leaving a higher proportion to be detected during vegetation surveys. Bird species strongly correlated with prairie dog towns included horned larks (*Eremophila alpestris*), vesper sparrows (*Pooecetes gramineus*), and Brewer's blackbirds (*Euphagus cyanocephalus*). Horned larks were consistently associated with prairie dog towns in both years.

Some bird species were not strongly correlated in either direction with the principal axis. The upland sandpiper (*Bartramia longicauda*), for example, utilized both locations. Upland sandpipers prefer to nest in areas of greater vegetative structure characteristic of the off-town locations but were also observed in foraging groups on prairie dog colonies (Houston and Bowen 2001). Species that utilize both habitats speak to the need for maintenance of a heterogeneous landscape composed of different habitat types in order to support a robust bird and plant community. Heterogeneity has often been discussed as being important for providing wildlife habitat on many scales, particularly in grasslands (Roth 1976; Fuhlendorf and Engle 2001; Fuhlendorf et al. 2006; Derner et al. 2009). Evidence suggests that species diversity is often driven by habitat heterogeneity (Tews et al. 2004).

Percent bare ground was the single most important variable in driving the principal axes and transect locations in ordination space. Visual obstruction and maximum live plant height were also strong influences, although maximum plant height is most likely important because it is an indicator of an area with overall taller vegetative cover and greater structure rather than because it is a driver in its own right. Large amounts of bare ground were correlated with prairie dog towns and created habitats which supported different bird communities than off-town locations. The strong correlations of maximum live vegetation height, litter depth, and percent litter cover with the principal access are most likely not due to direct selection or avoidance by birds based on these vegetative characteristics. Instead, selection based on overall vegetative structure, as supported by many studies, is more likely the mechanism (Cody 1985).

In 2013, two-dimensions were needed to explain the majority of the variation in the dataset. However, the vertical spreading of the vertices is only significant on the on-town transects. We believe this additional axis was necessary due to greater expression of canopy cover that was occupied by live plants, particularly suckling clover in 2013 compared with the drier year of 2012. Adequate moisture allowed plants to achieve greater growth in 2013 relative to the previous year; therefore, occupying a greater percent of the area within an on-town plot. These unique plant communities, more similar within a pasture than across the whole study site, began to distinguish themselves. We hypothesize that the drought of 2012 stressed the continuously grazed plants on prairie dog towns and these areas struggled with regrowth during the drought, resulting in very high amounts of bare ground with minimal live plant cover. In previous studies, drought years decreased the significance of the differences between on-town and adjacent areas uncolonized by prairie dogs, which supports our above hypotheses (Barko et al. 1999).

In the study pasture containing 75% of its area as prairie dogs town is another example of weedy species on the prairie dog towns flourished with the ample precipitation of 2013. This created a habitat patch with very tall vegetation dominated by absinth wormwood, western dock (*Rumex aquaticus*), and thistle species (*Cirsium* spp and *Carduus nutans*). Western kingbirds (*Tyrannus verticalis*) and lark sparrows (*Chondestes grammacus*) benefited from this increased visual obstruction and inhabited the area. Western kingbirds are almost always found in areas where open prairie habitat converges with riparian areas, woodlands, shrubby habitats, or areas with tall human-made structures (Goldberg 1979). The weedy patch in question was bordered by electrical lines and just south of a large riparian area, making it an ideal foraging and nesting area for western kingbirds. Lark sparrows have also been shown to have an affinity for shrub-steppe or habitats with one to two meters of vertical structure, which fits the vegetative characteristics of this part of the pasture during the wetter growing season of 2013 (Fitch 1958). Previous research has also revealed that lark sparrows tend to occupy sites associated with poor soils, areas that have been previously disturbed by severe overgrazing, or fields that have been abandoned after cropping and are undergoing secondary succession. The habitat patch in the "high" extent prairie dog pasture embodied characteristics that fits these descriptions and provided the herbaceous, weedy cover lark sparrows often seek for nesting habitat (Newman 1970). The surrounding matrix was mostly short, grazed vegetation which made this weedy patch a more suitable nesting area in an undesirable matrix.

Differences in the other on-town transects were based on variation in the plant community between the two remaining pastures with prairie dog towns. For example, the pasture with only 18% prairie dog town is lowest on the landscape and accumulates more water in a creek bed that runs along the edge of the colonized prairie dog town. This riparian area was dominated by rush species and Kentucky bluegrass (*Poa pratensis* L.) and had high production in association with the increased moisture in 2013. This created a much different plant community compared to graminoid species found in other pastures.

Table A3 and Table A4 show that in all pastures, with only 2 exceptions (pasture 1 in 2012 and pasture 2 in 2013), on-town transects have higher Shannon diversity index values and greater avian species richness. These findings support those of previous studies that showed greater avian densities and species richness on mixed-grass and southern short-grass prairies occupied by prairie dogs as opposed to adjacent uncolonized areas (Agnew et al. 1986; Barko et al. 1999; Augustine and Baker 2013). Furthermore, the results of this study assert that the same patterns are consistent on a much smaller, more focused scales. Vegetation modification by prairie dogs results in shorter vegetation with less live plant cover and more bare ground compared with off-town locations. This may attract ground foraging insectivorous and granivorous birds because reduced litter and live plant cover make seeds and insects easier to locate and glean. The attraction of prairie dog towns for carnivorous raptors is obvious; prairie dogs are an abundant prey item and previous research has also shown that colonies support higher densities of other mammals by providing refugia in the form of their burrows (Agnew et al. 1986).

Augustine and Baker (2013) showed that the principal axis from an NMS ordination was most strongly positively correlated with percent bare ground cover and percent shrub cover and negatively with visual obstruction. This study was done further west geographically and some surveyed areas were sagebrush-steppe habitat, making shrubs an important habitat characteristic. In north central South Dakota, our site is entirely mixed-grass prairie so shrubs were not a significant community driver. Our bird survey data also matches the findings of Augustine and Baker (2013). Their research showed that grasshopper sparrows were most abundant at off-town locations and horned larks most abundant in areas colonized by prairie dogs. These species were the strongest correlated species with our principle axis in opposite directions. As opposed to using categorical grouping variables in the secondary matrix of their analysis, Augustine and Baker (2013) selected several important quantitative vegetative characteristics. We re-analyzed our data following the same method and found the same results as our original analysis. This allowed us to verify our findings and consult joint plots to confirm relationships. In addition, when the variable of percent cover bare ground (collected via Daubenmire frames) is used as opposed to bare ground values collected via 10-pin point frame, the relationships discussed above remained the same.

Conclusions

The strongly correlated bird species rely on the habitat they are associated with foraging, nesting, or both. In order to maintain robust bird populations maintenance of these habitats is important. The use of both prairie dog colonized and uncolonized habitats by some bird species was an interesting finding of this study. These species are utilizing patches of both prairie dog occupied habitat and native sites with greater visual obstruction and taller vegetation. In some cases, these birds may be able to cope with the loss of one habitat type and compensate by switching to using exclusively the remaining type available. However, birds that used only one habitat type relative to prairie dogs makes an even stronger argument for the importance of maintaining heterogeneity. Heterogeneity's impacts on bird communities is widely discussed (Wiens 1974; Roth 1976; Fuhlendorf and Engle 2001; Heikkinen et al. 2004; Tews et al. 2004; Derner at al. 2009). Grazers, whether livestock or wildlife, exert change on the landscape that can assist in the creation and maintenance of heterogeneous landscapes. The continued conservation of prairie dogs and their associated habitats could have long-standing repercussions for grassland bird diversity, as suggested by the Table A3 and A4. Appropriate livestock management on remaining habitat may help maintain ecological diversity while providing opportunities for economic returns to private landowners.

Landowners and producers should outline their specific goals and implement management plans that consider impacts to vegetation, soils, wildlife, and their livestock operation. Eradicating prairie dogs may have long-term impacts that negatively affect wildlife communities, so consideration of the implications of this action must be made. Maintenance of both off-town areas and colonized regions is the best balance for wildlife but may not be acceptable to all producers.

Many states within historic prairie dog range (including South Dakota, Utah, and Colorado) are now offering landowner incentive programs to encourage private land owners to maintain and create prairie dog habitat on their land. In addition, most Great Plains states have now developed conservation plans for prairie dogs. In exchange for annual monetary payments, landowners enroll a number of acres in the conservation and do not shoot or poison prairie dogs in these areas. Based on the findings of this study, these conservation plans and programs may assist in maintaining habitats that will support a wide variety of other prairie species, including declining grassland birds. Whether the effects of such efforts are of a great enough magnitude to impact the declines in both prairie dogs and grassland bird species remains to be seen.

Future Research

This study suggests that the presence of prairie dogs is correlated with a specific variable (percent cover bare ground) that may be shaping the biological communities. Further investigation should be made to determine if the bare ground correlated with prairie dogs is unique in providing habitat to birds or if other bare ground areas have the same community shaping influence.

Further investigation into soils on this particular site would also be insightful. Differences in soil chemistry and hydrology could also be contributing to observed differences in the plant community. Quantifying and exploring these possibilities would make for a stronger dataset. Unexpected trends may also be revealed upon examination of soils data relative to the presence and absence of prairie dogs.

Acknowledgements

I acknowledge and thank all those involved with this research for their time and efforts, particularly our summer technicians who assisted with data collection, A. DeRubeis and J. Chancey. A special measure of gratitude goes to A. Fields who volunteered his time to assist with vegetation

sampling. My graduate committee deserves recognition and thanks as they greatly improved the quality and content of this chapter and freely gave their time, professional insight, and guidance.

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4. NESTING HABITAT OF GRASSLAND PASSERINES ON BLACK-TAILED PRAIRIE DOG COLONIES IN GRAZED MIXED-GRASS PRAIRIE[1]

Abstract

Few studies have investigated total grassland bird community associations with black-tailed prairie dogs (*Cynomys ludovicianus*) and of those limited studies almost none aim to quantify nesting passerine habitat selection. We located and monitored passerine nests in mixed-grass prairie in north central South Dakota. We completed vegetative sampling on nests and paired random points in order to assess nesting habitat preferences of Brewer's blackbirds (*Euphagus cyanocephalus*), grasshopper sparrows (*Ammodrqamus savannarum*), lark sparrows (*Chondestes grammacus*), horned larks (*Eremophila alpestris*), and western meadowlarks (*Sturnella neglecta*). Analysis of community data was conducted in PC-ORD version 6 using Principle Components Analysis (PCA) followed by MANOVA for significance testing. All species nested in exclusively one habitat type relative to prairie dogs, excluding lark sparrows. Within a habitat type, random locations were not significantly different ($p \geq 0.05$) except for Brewer's blackbirds ($p \leq 0.01$). Lack of significance may be due to small sample sizes and the scale of vegetation sampled.

Introduction

Many North American grassland bird species declines began with the expansion of cultivation and ranching (Peterjohn and Sauer 1999; Vickery and Herkert 1999; Askins 2000). Concerns for declining populations continue to grow as researchers discover that even some common bird species have been experiencing steady declines in recent years. Many sources cite loss

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[1] This chapter is co-authored by Amanda Lipinski, Benjamin Geaumont, Ryan Limb, and Kevin Sedivec. Amanda Lipinski (graduate student) was the main co-author responsible for field study design, collecting data, data processing, statistical analysis, interpretation of statistical outputs, and incorporating those data into the information presented in this chapter. Benjamin Geaumont provided guidance on aspects of field design and statistical analyses. Ryan Limb assisted with statistical analysis in PC-ORD. Both Benjamin Geaumont and Kevin Sedivec helped with editing and added professional insight throughout the chapter.

of suitable habitat, by way of degradation and direct loss of acreage, as the primary cause for declines. Reasonably conservative estimates place the percentage of lost grassland ecosystems around 80% since the mid-1800s (Knopf 1994; Noss et al. 1995). Rangeland deterioration by way of exotic grass invasions, fire suppression, altered hydrology, overgrazing, erosion increases, and woody plant encroachment poses a substantial threat to critical grassland habitat across the Great Plains and throughout the western United States (Brennan and Kuvlesky 2005). The extirpation of bison (*Bison bison*) and declining populations of prairie dogs (*Cynomys sp.*), both important native grazers, throughout the majority of historic North American range further threaten specific grassland bird habitat that was historically maintained by these ecosystem engineers.

The decline of black-tailed prairie dog (*Cynomys ludovicianus*) populations due to eradication, loss of habitat, and disease may compound decreases in bird populations that utilize the successional habitat prairie dogs create (Mills et al. 1993). Evidence shows that prairie dog activities influence nutrient cycling, increase nitrogen content of vegetation and soil, change vegetation structure and community dynamics, aerate soil, deepen water penetration, and provide prey and shelter for other species, including species of concern such as burrowing owls (*Athene cunicularia*) and many diurnal raptor species (Detling 1998; Miller et al. 2007). Miller et al. (2007) argue that due to the extensive reduction of prairie dog populations, prairie dog species are now functionally extinct. In other words, prairie dogs do not exist in high enough population levels to allow them to fulfill their functional ecological and evolutionary roles. The loss of prairie dogs certainly impacts the ecosystem. Mills et al. (1993) assert that removal or loss of these modifiers can result in "changes in energy flow, loss of structure or materials that affect habitat flow and trophic interactions, and disappearance of other species that rely on specific successional habitats and resources."

Previous studies found that the presence of prairie dogs increases densities of other associated grassland species, including birds. Many members of the grassland bird community are considered closely connected to prairie dog towns, using burrows for dens or refuges and colonized areas as important foraging sites. Smith and Lomolino (2004) cite burrowing owls, mountain plover (*Charadrius montanus*), golden eagle (*Aquila chrysaetos*), ferruginous hawk (*Buteo regalis*), prairie falcon (*Falco mexicanus*), Swainson's hawk (*Buteo swainsoni*), lesser prairie chicken (*Tympanuchus pallidicinctus*), and long-billed curlew (*Numenius americanus*) as examples. Prairie dog towns often result in increased diversity of avian species in comparison to adjacent uncolonized areas (Bonham and Lerwick 1976; Hansen and Gold 1977; Coppock et al. 1983; Agnew et al. 1986).

Smith and Lomolino (2004) investigated avian communities associated with black-tailed prairie dogs in short-grass prairie ecosystems and found that unique avian communities were present on prairie dog towns compared to four other studied treatments (open rangeland, conservation reserve program plots, scrub habitats, and fallowed crop fields) in the Oklahoma panhandle. Relative densities of all observed avian species were higher on prairie dog towns compared to other sites in summer and fall. Mean species richness was higher on prairie dog towns during the summer (with no differences for mean species richness found in the fall). Species positively associated with prairie dog towns during the summer included burrowing owls, meadowlarks (*Sturnella magna*, *S. neglecta*), horned larks (*Eremophila alpestris*), and killdeer (*Charadrius vociferus*). Horned larks and ferruginous hawks were also associated with prairie dog towns during the fall. Individual species tended to strongly prefer prairie dog towns or avoid them, supporting the idea that a heterogeneous landscape is needed for a healthy, robust community.

Despite a large volume of research investigating bird abundances relative to prairie dogs, few studies have examined nesting grassland birds in relation to prairie dog colonies. The majority of nest studies considering the scope of nesting grassland birds and prairie dog habitat focus on the near threatened mountain plover (*Charadrius montanus*) whose range does not overlap with this study's geographic location. Other research focuses on differential nesting success. Nest predation is frequently cited as being the chief cause of nest failure for grassland birds (Martin 1993). Predation rates may be higher on prairie dog colonies because nests may be easier to locate and predators are more abundant, attracted by the amount of prey associated with these areas (O'Meilia 1982, Agnew et al. 1986).

Baker et al. (2000) conducted a study using artificial nests stocked with quail eggs in order to evaluate nest predation on prairie dog towns and paired off-town locations. They found that predation rates on the colonies were 29.5% higher than off-town sites. Further analysis revealed that there were correlations between differences in nest predation rates and estimates of the mean nesting cover, which supports the pattern found in previous studies (Martin 1993). Nesting cover on the prairie dog towns was less dense and more homogeneous in structure. Avian species associated with prairie dog colonies had smaller clutches and more broods per year compared with species associated with off-town sites, suggesting underlying mechanisms to compensate for an increase in the risk of nest failure. Today, prairie dog colonies exist as smaller and more fragmented patches compared to the historic expanses of prairie dog range. These isolated and condensed habitats may aid predators in locating nests by decreasing the area that must be searched, concentrating nests in greater densities, and increasing predator abundance via greater influence of edge effects. If this is true, then this pattern suggests that eradication of prairie dogs is also indirectly impacting the nesting success of grassland birds and makes a strong argument for coordinated efforts to conserve large, contiguous colonies as opposed to smaller, isolated ones.

Although this study does pose some interesting questions, the utility of application to grassland birds is debatable. Artificial nests have an inherently "human" influence. The nesting sites were chosen by humans, and the nests were constructed by humans. Artificial nests also lack the display of behaviors associated with a nesting pair of birds. This may impact both predation and parasitism estimates. Further study of nesting grassland birds is necessary to either validate or reject the conclusions of this study when applied to naturally occurring nests.

The International Union for the Conservation of Nature and Natural Resources (IUCN) lists many grassland bird species as species of “least concern” for conservation despite documented declines occurring over decades. Under current guidelines, many are not applicable for listing under a greater threat level because they have large ranges or populations have not yet reached critically low levels. Many grassland birds considered common are declining at higher than expected rates. Identifying and mitigating declines for these species early can help prevent conservation crises in the future. Investigating how birds use the landscape and the dynamics of grassland bird communities is also crucial for understanding relationships between bird species and available habitat.

Studying possible associations of birds and prairie dogs can inform management and community ecology related to both species. Examining and quantifying relationships between black-tailed prairie dogs, the habitats they engineer, and nesting grassland birds has not been thoroughly studied. Studies examining associations based on presence inform managers about birds using prairie dog towns but do not illuminate the specifics of species using colonized or nearby areas in the context of reproduction.

The goals of this project were to conduct a preliminary investigation into which bird species were utilizing areas occupied by prairie dogs or nearby habitats for nesting and to identify important nesting habitat characteristics.

Study Area

The study was conducted on leased land on the Standing Rock Indian Reservation near McLaughlin, South Dakota, USA (45°43'42.11"N, 100°38'41.60"W). McLaughlin is in Corson County, South Dakota, centrally located along the northern border with North Dakota (Figure 4.1).

The surrounding landscape is a mixture of rangeland and agricultural fields where topography is rolling to flat. This region consists of mixed-grass prairie dominated by mid-height cool season (C3) grasses. Dominant species of grasses include western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Löve), needle and thread (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), green needlegrass (*Nassella viridula* (Trin.) Barkworth), and prairie dropseed (*Sporobolus heterolepis* A. Gray) on native upland sites. Localized grass dominated areas on prairie dog towns consist of shorter warm season (C4) grasses including buffalo grass (*Bouteloua dactyloides* (Nutt.) J.T. Columbus) and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths). Forbs commonly encountered include blacksamson echinacea (*Echinacea angustifolia* DC.), scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.), and sagewort species (*Artemisia sp.*).

Woody vegetation is found in areas of concentrated moisture such as draws between slopes and bottomlands. Patches of western snowberry (*Symphoricarpos occidentalis* Hook.) can also be found interspersed with graminoid species. The majority of prairie dog towns are dominated by forbs including scarlet globemallow, fetid marigold (*Dyssodia papposa* (Vent.) Hitchc.), and woolly plantain (*Plantago patagonica* Jacq.). Area topography is a combination of rolling hills with relatively flat lowlands. These lowlands lie mostly along the northern edge of the field site nearest to a riparian area north of the study area and coincide with the majority of the area occupied by prairie dogs.

Figure 4.1. Relative location of the research study site (represented by the star) in Corson County, South Dakota, USA.

Web Soil Survey (NRCS USDA 2014) maps the dominant soil types on the study as Cabba-Reeder loams (6-25% slopes), Reeder-Cabba loams (6-9% slopes), Wayden-Cabba complexes (9 to 40% slopes), and similar soils with parent materials of clayey residuum weathered from shale. Other major soil map units include Dupree-Rock outcrop complexes (6-30% slopes), Regent-Wayden silty clay loams (6-15% slopes), and Sansarc-Opal-Dupree clays (9-25% slopes). The study area is dominated by shallow loamy and dense clay ecological sites which constitute approximately one-third of the overall site area. Smaller areas are occupied by loamy, shallow sandy, loamy terrace, thin claypan, clayey, shallow clay, and loamy overflow ecological sites.

Vegetative production based on soil type for this region typically ranges between 915-2492 $kg \cdot ha^{-1}$ per year (weights are air-dried vegetation; NRCS USDA 2014). The major soil map units have production estimates in the middle of this range (Cabba-Reeder loams approximately 1566 $kg \cdot ha^{-1}$ per year and Dupree-Rock outcrop complexes around 1059 $kg \cdot ha^{-1}$ per year).

The study site was delineated into four pastures of comparable size (±223 ha) with varying degrees of prairie dog occurrence (Figure 4.2). Each pasture represented a different level (treatment) of percent occurrence of prairie dogs, with four levels studied including 1) 0 percent, 2) 18 percent, 3) 40 percent, and 4) 75 percent (Table 4.1). This stratification of percent prairie dog colony by pasture was done for livestock research that was conducted on this study site during the same time frame.

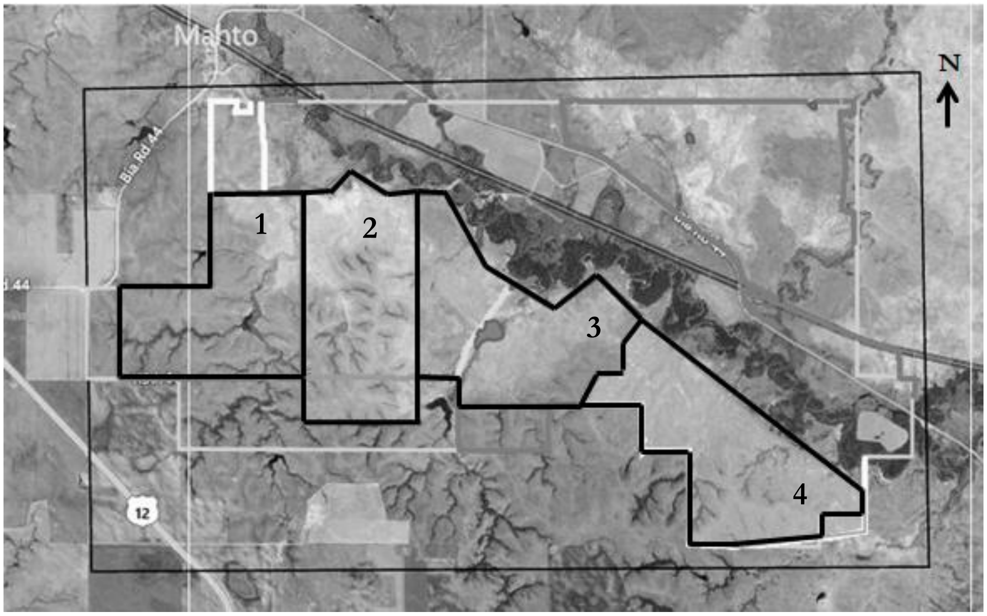

Figure 4.2. Aerial photograph of the field site near McLaughlin, South Dakota, USA with labeling of relevant boundaries and roads. Fence lines of the main research area are outlined in bold black. Numbers refer to pastures with 1) 18% 2) 40% 3) 75% and 4) 0% of pasture area colonized by prairie dogs. Imagery courtesy of USGS.

Each pasture treatment was stocked with Angus steers with a goal of achieving 50% degree of disappearance. Cattle were placed in their respective pastures 6 June 2012 and removed 9 October 2012. In 2013, cattle were placed on pasture 5 June and removed 22 October. See Table 2 for details regarding cattle numbers, and mean start and finishing weights. Since the stocking rates of the cattle were the same (achieve 50 percent disappearance of current years herbage produced) for all treatments (occurrence of prairie dogs) in this study, all pastures were considered to be the same in terms of livestock use. The focus of this investigation was comparing the off-town locations with areas colonized by prairie dogs.

Table 4.1. Total pasture area in hectares and extent of each pasture occupied by prairie dogs on study site near McLaughlin, South Dakota, USA.

Pasture	Pasture area (hectares)	Area occupied by prairie dogs (%)
1	193	18
2	207	40
3	208	75
4	204	0

Table 4.2. Number of cattle and starting and ending average weights of the four study pastures on rangeland near McLaughlin, SD, USA. Cattle grazed from 6 June 2012 to 9 October 2012, and 5 June 2013 to 22 October 2013. Standard deviations of mean weights are shown in parentheses[a]. Pastures were stocked for a goal of 50% degree of disappearance.

Year	Pasture	No. of cattle	Beginning mean weight[a]	Final mean weight[a]
2012	1	53	661 (84)	870 (59)
2012	2	44	653 (71)	867 (64)
2012	3	16	655 (74)	869 (68)
2012	4	72	657 (74)	844 (57)
2013	1	53	672 (34)	975 (42)
2013	2	44	672 (38)	966 (43)
2013	3	16	680 (32)	962 (46)
2013	4	72	673 (36)	915 (46)

This region is considered to be semi-arid. McLaughlin receives 44 centimeters of precipitation on average with approximately 75 percent occurring during the growing season (South Dakota Weather and Climate 2014). The 29-year average reports a mean annual winter (December-March) temperature of -8 ˚C and a mean annual summer (June-August) temperature of 20 ˚C (South Dakota Weather and Climate 2014). Figures 3.3 and 3.4 illustrate average precipitation and temperatures by month for McLaughlin, South Dakota. Precipitation in July of 2012 was slightly below average in north central South Dakota, similar to the majority of the United States, which was suffering from a significant drought. In 2013, McLaughlin received approximately 14.5 cm above average precipitation in late spring and throughout the growing season.

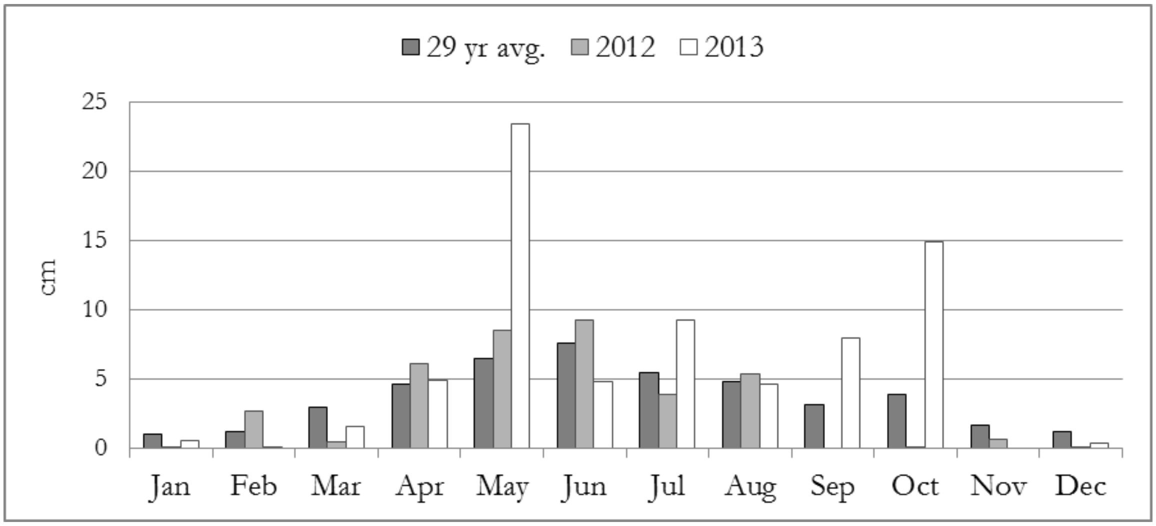

Figure 4.3. Average monthly precipitation for McLaughlin, South Dakota, USA, for 2012, 2013, and a 29-year average (1971-2000). Data for the 29-year average was provided by the South Dakota State Climate and Weather database (2014). Individual year data was provided by NOAA (2014).

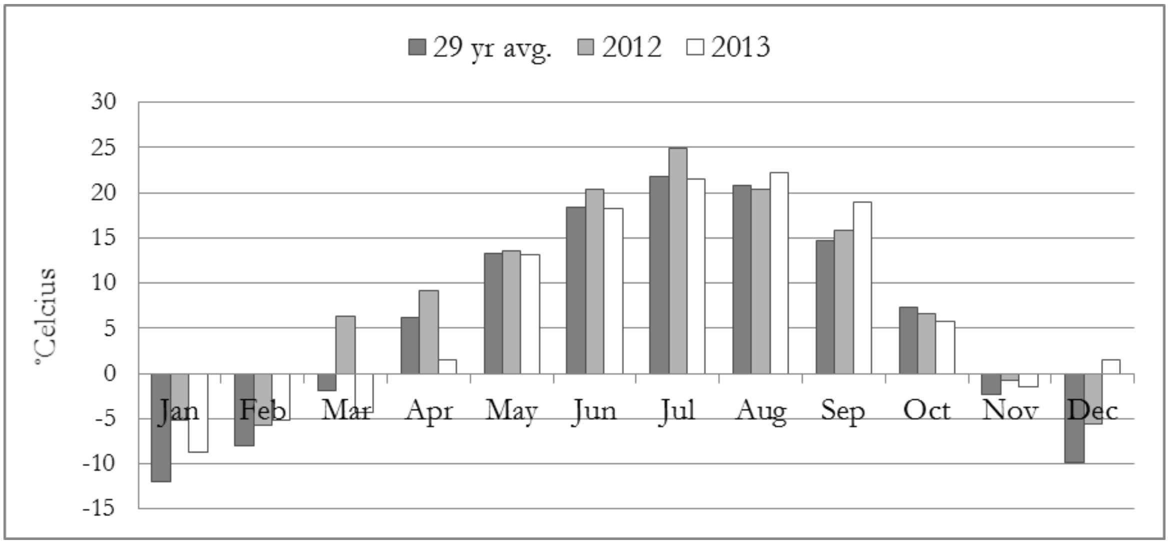

Figure 4.4. Average monthly temperatures for McLaughlin, South Dakota, USA, for 2012, 2013, and a 29-year average (1971-2000). Data for the 29-year average was provided by the South Dakota State Climate and Weather database (2014). Data for 2012 and 2013 were provided by NOAA (2014).

Prior to leasing, the study site was grazed by horses (*Equus ferus caballus*) (approximately 100 individuals). Some impacts from the presence of these horses may include localized soil erosion and compaction, grazing effects, and the introduction of invasive weeds through hay fed on the study site, particularly in the pasture with 75% of its area occupied by prairie dogs. These weeds include absinth wormwood (*Artemisia absinthium* L.), western dock (*Rumex aquaticus* L.), and Canada thistle (*Cirsium arvense* (L.) Scop.).

Methods

Locating Nests. Passerine nests (focusing mainly on grassland obligates) were located in a variety of ways over the course of this two-year study. In 2012, observers manually rope dragged (following methods by Koford 1999) six 16 hectare plots in each of the four pastures. Half of these plots were randomly placed in areas occupied by prairie dogs and the remaining three plots were placed in random off-town locations. Additional nests located via behavioral observation or incidentally all across the study site were also included.

In 2013, manual rope dragging was not repeated due to poor returns for invested time and labor the previous year. Instead, observers used the same 16 hectare plots but focused on behavioral observation as a means of locating nests. In the case of many secretive and elusive grassland birds, spot rope dragging with the same manual rope method was conducted after determining that a breeding pair was in a given area. Incidentally located nests were also monitored site-wide during this field season.

Nest Vegetation Sampling. Vegetative sampling was conducted on nests and a matching random point (within 100 m of the nest) once nesting was completed and chicks had fledged. We sampled basal cover using 10 pin-point frames (Evans 1957), canopy cover using 50x20 cm frames (Martin et al. 1997; Daubenmire 1959), visual obstruction using a modified Robel pole (Robel et al. 1970), maximum live standing vegetation heights (cm), and litter depth (cm). The modification to the Robel pole was sections marked in centimeters as opposed to the standard of decimeters. This allowed us to examine fine scale variation in the short vegetation typical of prairie dog towns. The vegetative sampling scheme surrounding the nests was loosely inspired by the BBIRD protocol from University of Montana (Martin et al. 1997). Visual obstruction readings and measurements of basal cover using the 10 pin-point frame were conducted at the nest bowl and 2.5 m and 5 m away in all cardinal directions (for a total of nine sampling locations). Canopy cover readings using the 50x20 cm frames were conducted by placing the nest bowl in the center of the frame for the first reading, and then doing four frames off the corners of the original frame placement. Figure 4.3 diagrams the sampling scheme at a surveyed nest.

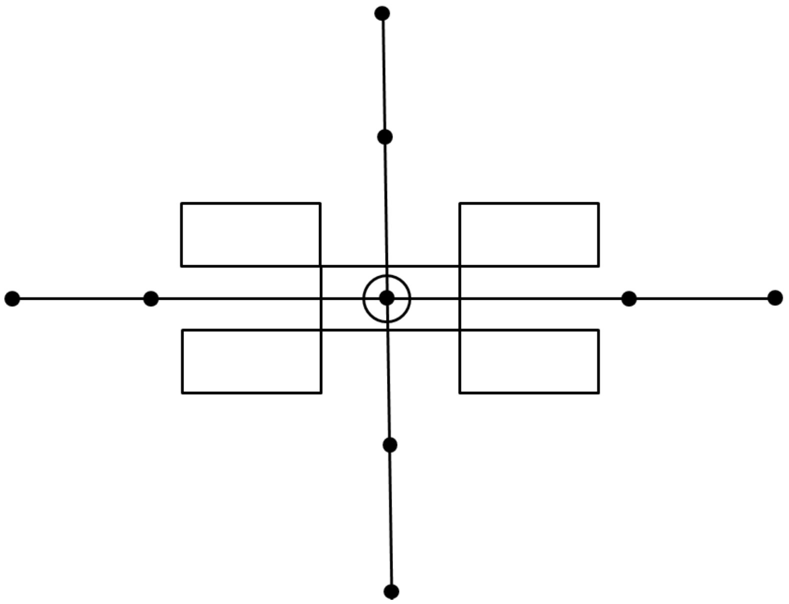

Figure 4.5. A diagram of the vegetative sampling scheme for passerine nests during ecological research conducted near McLaughlin, South Dakota, USA, during spring and summer of 2012 and 2013. The open circle in the center represents the nest bowl. Dark vertices show the locations of collected visual obstruction, maximum live standing vegetation heights, litter depth, and basal cover readings at 2.5 and 5 m from the nest bowl. Rectangles represent the placement of 50x20 cm frames for canopy cover readings.

Statistical Analyses. Statistical analyses were conducted in PC-ORD version 6 (McCune and Mefford 2011) using Principle Components Analysis (PCA; Goodall 1954) to examine linear interrelationships in the community data set. Since analysis was based on selected vegetative characteristics, nest samples were pooled across both years. Only species for which we had greater than or equal to 5 nests were examined.

Ordinations were run by bird species with the main matrix composed of quantitative vegetative characteristics in the form of averages from field sampling. The secondary matrix consisted of categorical indicator variables to identify each plot as a nest or random point and to achieve paired plot design. An additional categorical variable denoted samples as being on or off the prairie dog town in cases where sample locations relative to prairie dogs were mixed. The main matrix data was adjusted by the means of the variables. PCA ordinations were done with variance-covariance cross-product matrices. Significance of axes and their subsequent merit for interpretation was determined based on broken stick values (Jackson 1993). Interpretation of axes was aided using Pearson coefficients of correlation. Strong correlations were considered to be variables with Pearson correlation coefficients of $r \geq 0.50$. This is a conservative value due to our small sample sizes. Percent of variance as described in PCA output helped to evaluate the quality of the ordination. Revealed relationships were confirmed with non-metric multidimensional scaling (NMS) in PC-ORD.
We conducted MANOVA on PCA output scores for significant components in order to determine if vegetative characteristics were significantly different between nests and the paired random plots.

Results

We located nests for Brewer's blackbirds, dickcissels, eastern kingbirds, grasshopper sparrows, horned larks, killdeer, lark sparrows, mourning doves, red-winged blackbirds, upland sandpipers, vesper sparrows, and western meadowlarks. A subset of these species with sufficient sample sizes were used in nest vegetation analyses. These species included Brewer's blackbirds (n=5), grasshopper sparrows (n=6), horned larks (n=11), killdeer (n=6), lark sparrows (n=9), mourning doves (n=7) and western meadowlarks (n=13). The number of plots included in analysis was double these numbers due to the inclusion of the random paired plots (i.e. there are 10 plots in the Brewer's analysis). PCA was the most appropriate ordination type for all species based on gradient length of the first axis as revealed by Detrended Correspondence Analysis (DCA; DCA produced a critical value less than 2).

All Brewer's blackbird nests were located on the edge of the prairie dog town in a shrubby area close to a slough. PCA of Brewer's blackbird nests and associated random points revealed a solution with two components accounting for 66% and 13%; respectively, for a total of 79% of the variation in the data. Graphing the solution reveals visual separation of nest and random locations (Figure 4.6). Tables 4.3 and 4.4 show the strongly correlated variables with the principle components and respective Pearson correlation coefficient values. MANOVA confirms that Brewer's blackbird nests are vegetatively different from associated random plots (F=22.62, $p<0.01$).

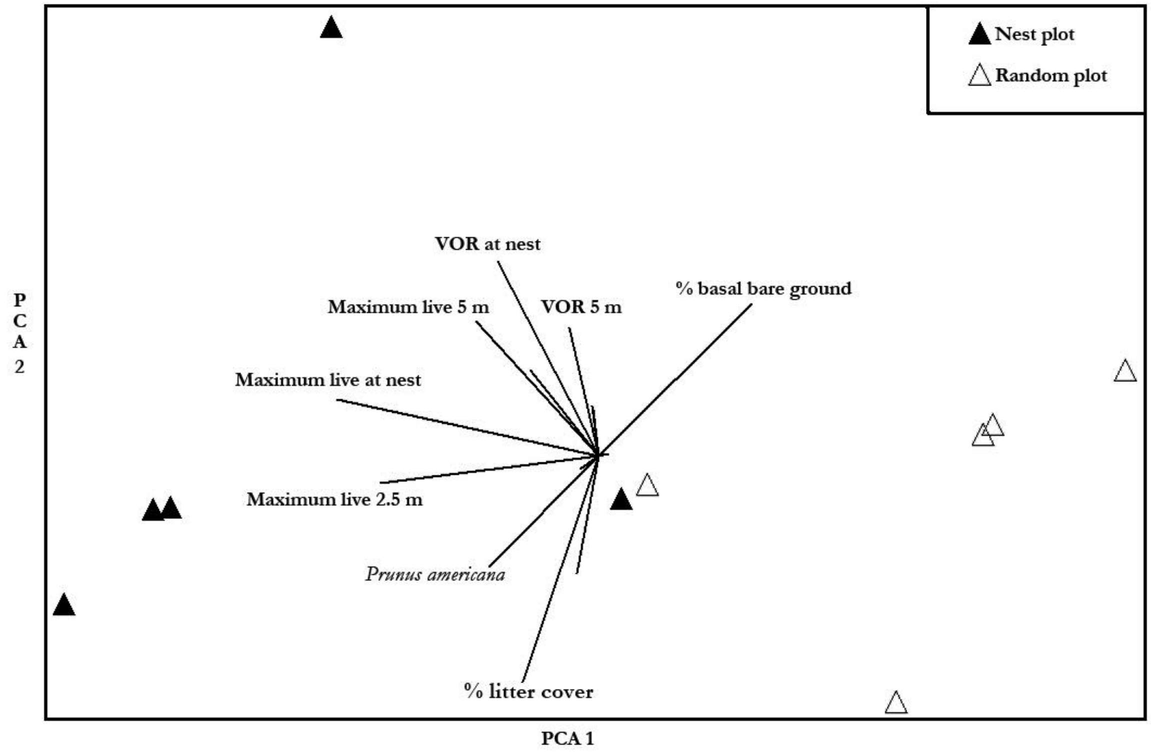

Figure 4.6. PCA results of Brewer's blackbird nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. VOR refers to visual obstruction reading and maximum live is the maximum height of surrounding live vegetation.

Table 4.3. Pearson correlation coefficients for strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of Brewer's blackbird nesting habitat (n=5) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. [1]Maximum live vegetation height, [2]visual obstruction reading, [3]percent litter canopy cover, and [4]percent basal cover bare ground.

Variable	***r***	***r^2***
Maximum live[1] (2.5 m)	-0.95	0.90
Maximum live (at nest)	-0.94	0.88
VOR[2] (2.5 m)	-0.82	0.58
Maximum live (5 m)	-0.80	0.64
Prunus americana	-0.76	0.57
VOR (at nest)	-0.63	0.40
Litter[3]	-0.50	0.25
Basal % BG[4]	0.82	0.67

Table 4.4. Pearson correlation coefficients for strongly correlated variables with component 2 of Principle Component Analysis relating to vegetative sampling of Brewer's blackbird nesting habitat (n=5) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. [1]Percent litter canopy cover and [2]visual obstruction reading.

Variable	***r***	***r^2***
Litter[1]	-0.67	0.45
Pascopyrum smithii	-0.58	0.34
VOR[2] (5 m)	0.74	0.55
VOR (at nest)	0.55	0.30

Grasshopper sparrow nests were located in areas free of prairie dogs as expected. The PCA solution for grasshopper sparrows contained three components, which cumulatively explained 82% of the variation. Components one, two, and three accounted for 49%, 17%, and 16%, of the variation, respectively. Graphing the PCA results illustrated some separation of nests and random locations based on specific habitat characteristic gradients but MANOVA results on PCA output for nests and associated random plots could not confirm differences in vegetation between nest and random locations (F=0.72, $p>0.05$). Tables 4.5 and 4.6 show Pearson correlation coefficient values for the first two principle components.

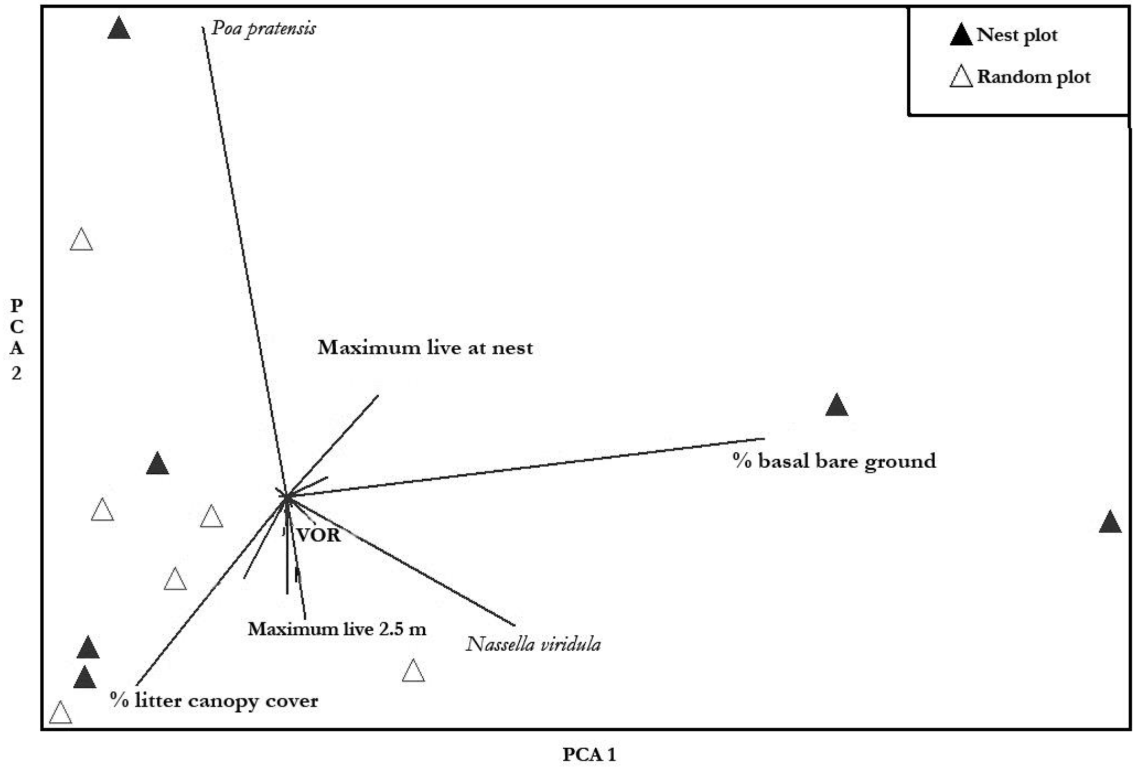

Figure 4.7. PCA results of grasshopper sparrow nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. VOR refers to visual obstruction reading and maximum live is the maximum height of surrounding live vegetation.

Table 4.5. Pearson correlation coefficients for strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of grasshopper sparrow nesting habitat (n=6) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. [1]Percent litter canopy cover, [2]percent basal bare ground, and [3]maximum live vegetation height.

Variable	***r***	***r^2***
Litter[1]	-0.59	0.34
Basal % BG[2]	0.95	0.91
Nassella viridula	0.67	0.45
Litter depth (2.5 m)	0.63	0.40
Litter depth (0 m)	0.52	0.27
Koeleria macrantha	0.51	0.26
Maximum live[3] (at nest)	0.51	0.26
Panicum spp	0.50	0.30

Horned lark nests were located on prairie dog towns. PCA returned a three component solution, explaining 91% of variance in the data for horned lark nests and associated random points. Component one extracted 52% of the variation and component two explained another 29%. Graphing PCA results of the first two components reveals that the on-town habitat appears to be more homogeneous than off town locations sampled for other species as the majority of sample plots are clustered along a gradient representing percent bare ground (Figure 4.8). Pearson correlation coefficients for variables strongly correlated with components one and two can be found in Tables 4.7 and 4.8. MANOVA on PCA output scores could not confirm vegetative differences between horned lark nests and random locations (F=0.95, $p>0.05$).

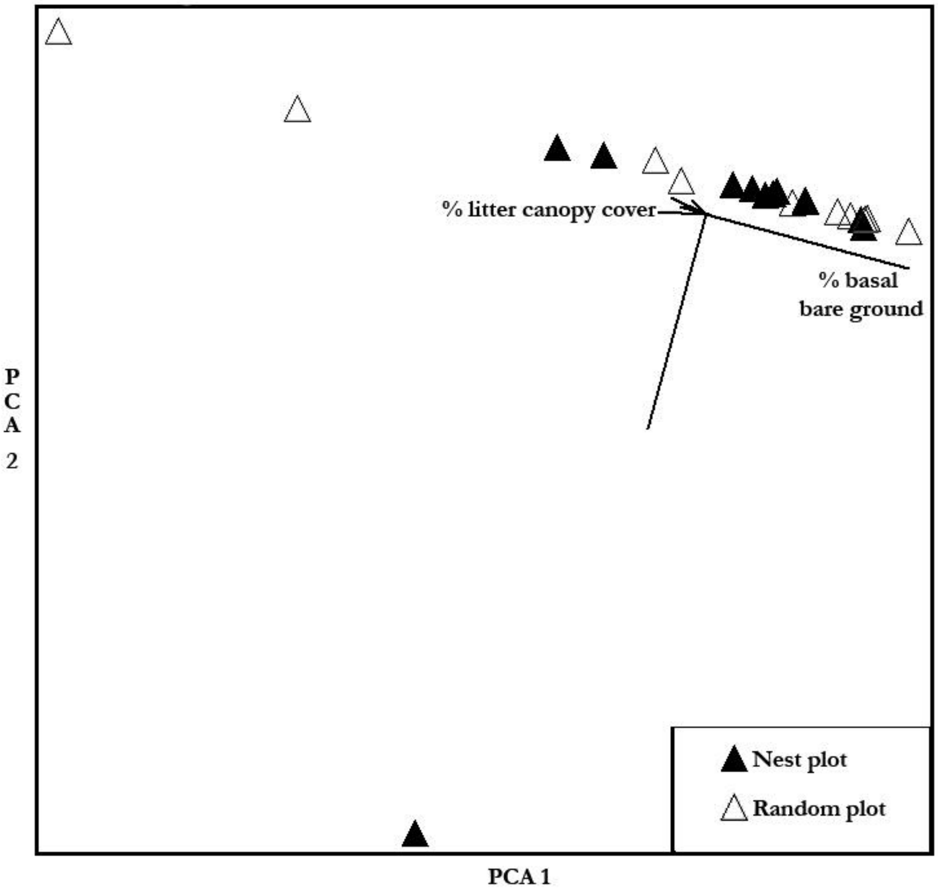

Figure 4.8. PCA results of horned lark nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. Maximum live is the maximum height of surrounding live vegetation.

Table 4.6. Pearson correlation coefficients for the strongly correlated variable with component 1 of Principle Component Analysis relating to vegetative sampling of horned lark nesting habitat (n=11) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. Maximum live refers to like maximum live vegetation height in the surrounding area. Basal % BG is the percent of basal cover that is bare mineral soil.

Variable	***r***	***r*** ^{2}
Litter depth (2.5 m)	-0.81	0.66
Litter depth (5 m)	-0.75	0.57
Bouteloua gracilis	-0.69	0.47
Maximum live (5 m)	-0.64	0.40
Maximum live (2.5 m)	-0.53	0.28
Basal % BG	0.97	0.57

Table 4.7. Pearson correlation coefficient for the strongly correlated variable with component 2 of Principle Component Analysis relating to vegetative sampling of horned lark nesting habitat (n=11) and paired random plots. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. VOR refers to visual obstruction reading.

Variable	***r***	***r*** ^{2}
VOR (5 m)	-0.93	0.87

All killdeer nests were associated with prairie dog colonies. PCA of killdeer nests and random plots revealed a solution with three components cumulatively explaining 96% of variation. Components one, two, and three accounted for 67%, 23%, and 6%, respectively. Plotting the PCA ordination reveals clustered points, similar to the results of the horned lark analysis (Figure 4.9). MANOVA could not confirm differences between killdeer nest location vegetation and associated random plots (F=0.83, *p*>0.05). Pearson correlation coefficients for variables strongly correlated with PCA components can be found in Tables 4.9 and 4.10.

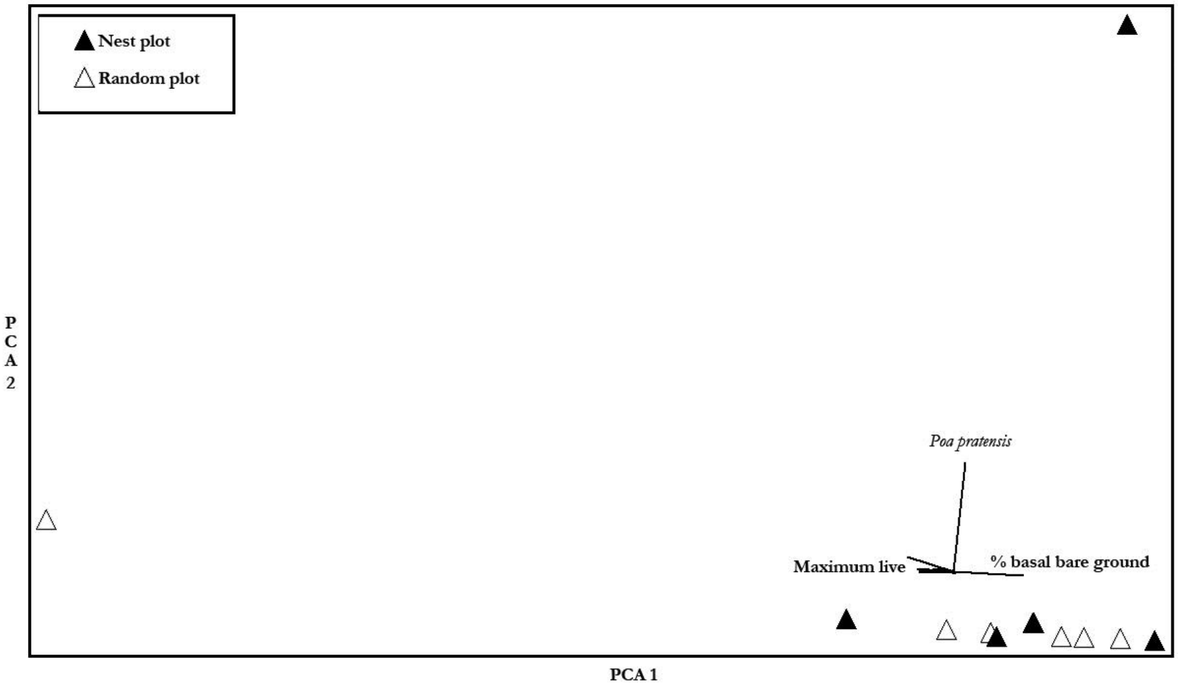

Figure 4.9. PCA results of killdeer nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. Maximum live is the maximum height of surrounding live vegetation.

Table 4.8. Pearson correlation coefficients for the strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of killdeer nesting habitat (n=6) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. VOR refers to the visual obstruction reading and maximum live is the maximum height of surrounding vegetation. Litter is the percent canopy cover of litter and basal % BG refers to the percent of basal cover that is bare mineral soil.

Variable	**r**	**r 2**
VOR (2.5 m)	-0.98	0.95
VOR (at nest)	-0.97	0.95
VOR (5 m)	-0.97	0.93
Litter depth (at nest)	-0.97	0.94
Litter depth (2.5 m)	-0.97	0.94
Maximum live (5 m)	-0.96	0.91
Litter depth (5 m)	-0.96	0.93
Maximum live (2.5 m)	-0.95	0.90
Maximum live (at nest)	-0.94	0.89
Litter	-0.92	0.85
Basal % BG	0.94	0.88

Table 4.9. Pearson correlation coefficient for the strongly correlated variable with component 12 of Principle Component Analysis relating to vegetative sampling of killdeer nesting habitat (n=6) and paired random plots. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA.

Variable	r	r^2
Nassella viridula	0.98	0.97

All lark sparrow nests were located on prairie dog towns, in areas that were previously occupied by prairie dogs, and on the edges of these areas. PCA of lark sparrow data produced a solution with two components accounting for a cumulative 86% of the variance. Component one extracted 63% and component two accounted for 23% of the variance. Results are difficult to interpret due to no clear separation between nest and random points (Figure 4.10). Component one represents a gradient of increasing vegetation height and component two is a gradient of increasing amounts of basal litter cover, with larger amounts of bare ground near the origin and larger percent cover litter as you move up the y-axis. Pearson correlation coefficients of strongly correlated variables can be found in Tables 4.11 and 4.12. MANOVA could not confirm differences in vegetative characteristics for nest and random locations (F=0.18, *p*>0.05).

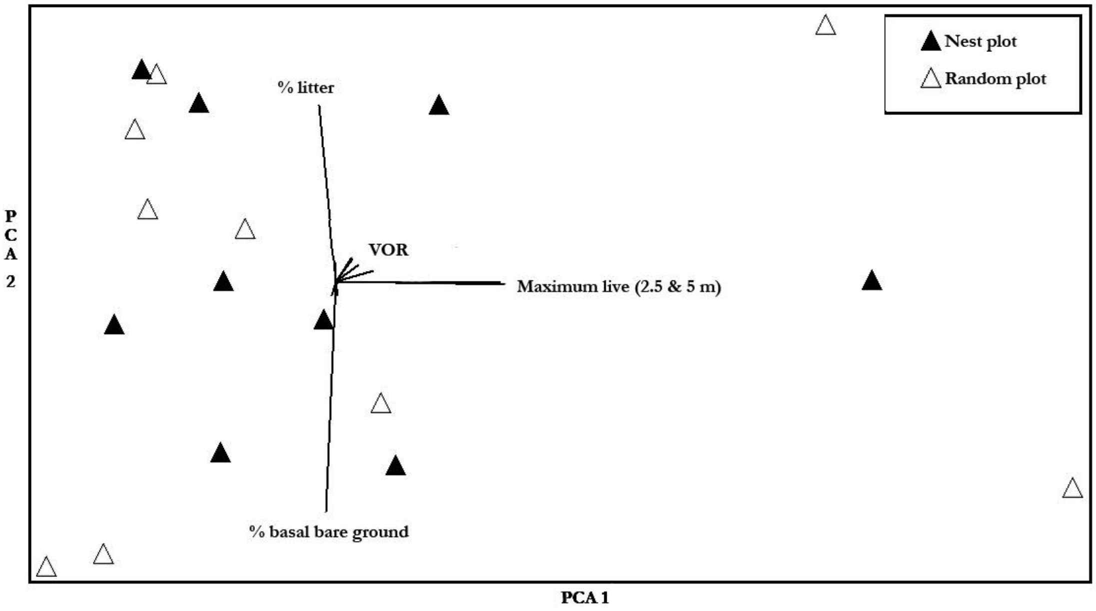

Figure 4.10. PCA results of lark sparrow nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. Maximum live is the maximum height of surrounding live vegetation, VOR refers to visual obstruction reading, and % litter is the percent of litter canopy cover.

Table 4.10. Pearson correlation coefficients for the strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of lark sparrow nesting habitat (n=9) and paired random plots. Values are arranged by directionality and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. VOR refers to the visual obstruction reading and maximum live is the maximum height of surrounding vegetation.

Variable	***r***	***r*** ^{2}
Maximum vegetation (2.5 m)	0.98	0.96
Maximum vegetation (5 m)	0.98	0.96
Maximum vegetation (at nest)	0.98	0.96
VOR (at nest)	0.60	0.36
VOR (2.5 m)	0.57	0.33
VOR (5 m)	0.46	0.21

Table 4.11. Pearson correlation coefficients for the strongly correlated variables with component 2 of Principle Component Analysis relating to vegetative sampling of lark sparrow nesting habitat (n=9) and paired random plots. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. Basal % BG refers to the percent of basal cover that is bare mineral soil while litter refers to percent litter in canopy cover.

Variable	***r***	***r*** ^{2}
Litter	-0.93	0.87
Basal % BG	0.85	0.71

Analysis of vegetation data for mourning doves returned a solution with three major components extracting a cumulative 78% of variance. These components accounted for 44%, 25%, and 9% of the variance. Graphically, nest habitat selection appears to be weak based on collected data, as random points and nests overlap in the middle of the plot (Figure 4.11). However, all mourning dove nests located did occur in off-town areas, suggesting that this species may be avoiding prairie dog colonies for nesting habitat. Tables 4.13 and 4.14 list strongly correlated variables and their associated Pearson correlation coefficients. MANOVA on PCA scores could not confirm differences between random and nest vegetative characteristics (F=1.12, *p*>0.05).

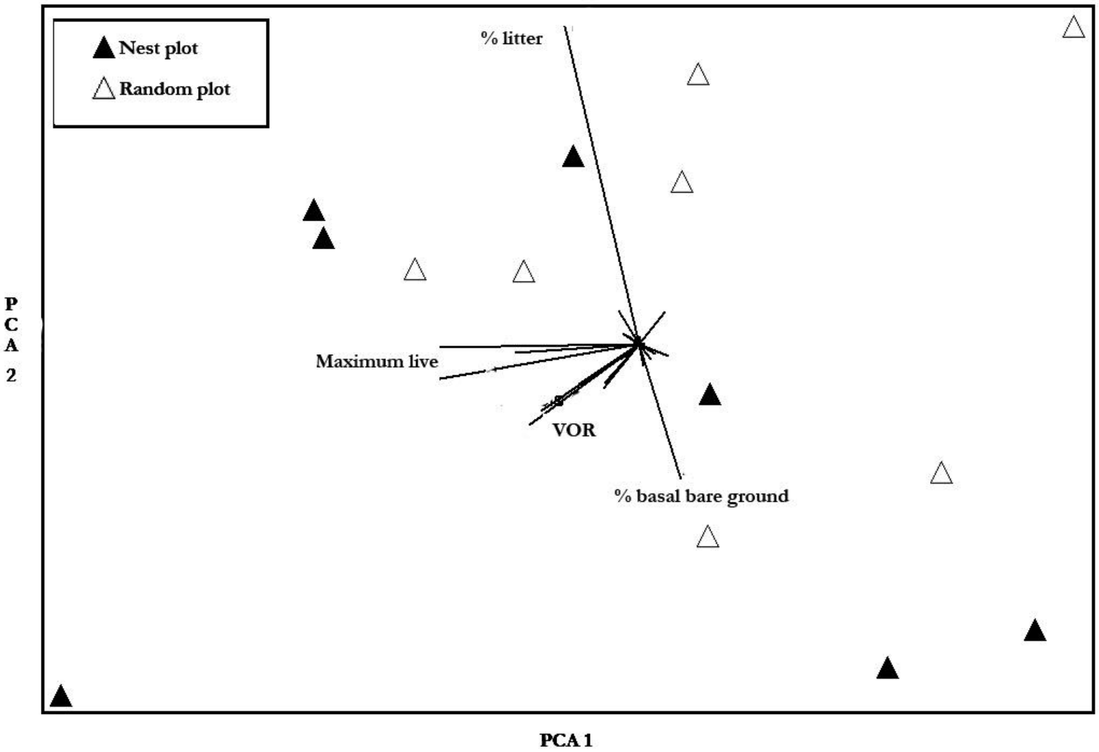

Figure 4.11. PCA results of mourning dove nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. Maximum live is the maximum height of surrounding live vegetation, VOR refers to visual obstruction readings, and % litter is the percent litter canopy cover. % basal BG refers to the percentage of basal bare ground that is mineral soil.

Table 4.12. Pearson correlation coefficients for the strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of mourning dove nesting habitat (n=7) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. VOR refers to the visual obstruction reading and maximum live is the maximum height of surrounding vegetation. Litter is the percent canopy cover of litter and basal % BG refers to the percent of basal cover that is bare mineral soil.

Variable	***r***	r^2
Maximum live (2.5 m)	-0.95	0.90
Maximum live (5 m)	-0.95	0.90
VOR (at nest)	-0.73	0.53
Maximum live (at nest)	-0.73	0.53
VOR (2.5 m)	-0.70	0.50
VOR (5 m)	-0.68	0.46
Litter depth (5 m)	-0.68	0.45
Rosa arkansana	-0.64	0.04
Cirsium spp.	-0.58	0.34
Artemisia absinthium	-0.57	0.32
Litter depth (2.5 m)	-0.54	0.29

Table 4.13. Pearson correlation coefficients for the strongly correlated variables with component 2 of Principle Component Analysis relating to vegetative sampling of mourning dove nesting habitat (n=7) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. Litter is the percent canopy cover of litter and basal % BG refers to the percent of basal cover that is bare mineral soil.

Variable	***r***	r^2
Basal % BG	-0.69	0.47
Litter	0.93	0.86

All western meadowlark nests were located in off-town locations. PCA returned a solution with four components. Components one and two accounted for 53% and 17%, respectively. Components three and four accounted for less variation, extracting 9% and 8%, respectively. Cumulative extracted variance of all four components was 87%. Graphing the PCA results 2-dimensionally reveals no clear pattern between nest and random plots within the ordination (Figure 4.12). Strongly correlated variables and their Pearson correlation coefficients can be found in Tables 4.15 and 4.16. MANOVA on PCA scores was unable to confirm any differences between vegetative characteristics and those on random plots (F=1.52, *p*>0.05).

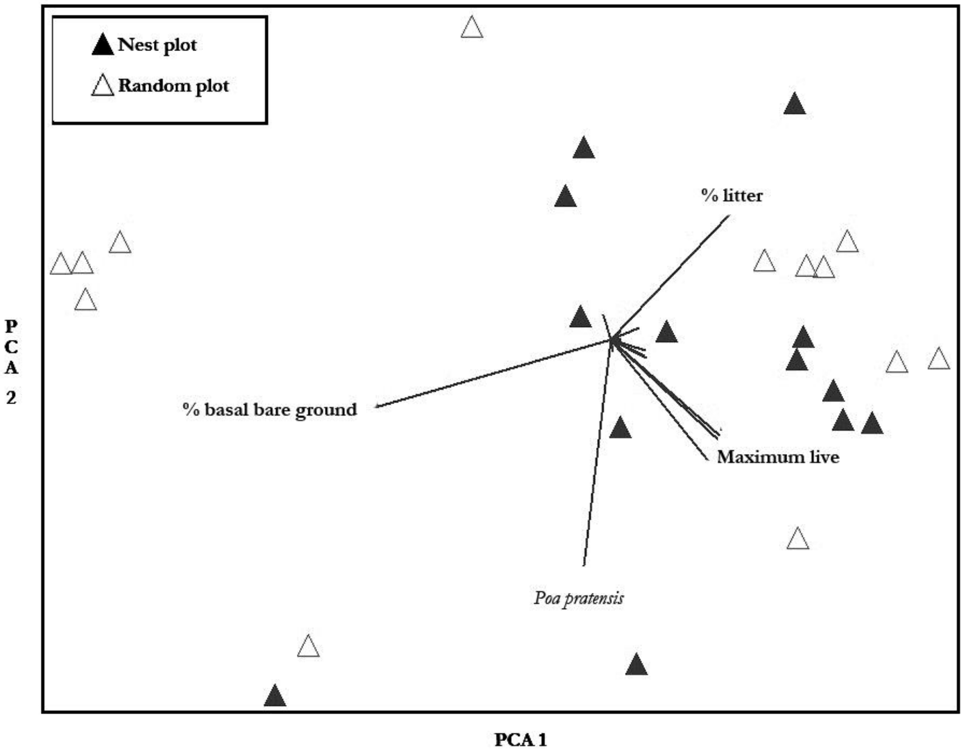

Figure 4.12. PCA results of western meadowlark nesting habitat and paired random plots in north central South Dakota, USA during the 2012 and 2013 breeding seasons. Open triangles are random plots and closed represent nest sites. Vector lines show the strength and direction of the correlation of the labeled variable to both principle components. VOR refers to the visual obstruction reading and maximum live is the maximum height of surrounding vegetation. Litter is the percent canopy cover of litter and basal % BG refers to the percent of basal cover that is bare mineral soil.

Table 4.14. Pearson correlation coefficients for the strongly correlated variables with component 1 of Principle Component Analysis relating to vegetative sampling of western meadowlark nesting habitat (n=11) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. VOR refers to the visual obstruction reading and maximum live is the maximum height of surrounding vegetation. Litter is the percent canopy cover of litter and basal % BG refers to the percent of basal cover that is bare mineral soil.

Variable	***r***	***r*** ^{2}
Basal % BG	-0.93	0.86
VOR (2.5 m)	0.80	0.64
Maximum live (2.5 m)	0.80	0.64
Maximum live (at nest)	0.77	0.59
VOR (at nest)	0.75	0.56
Maximum live (5 m)	0.75	0.57
VOR (5 m)	0.67	0.45
Litter	0.67	0.44

Table 4.15. Pearson correlation coefficients for the strongly correlated variables with component 2 of Principle Component Analysis relating to vegetative sampling of western meadowlark nesting habitat (n=11) and paired random plots. Values are arranged by negative and positive correlation and by strength of correlation. Analysis was conducted in PC-ORD version 6 on data collected in the 2012 and 2013 breeding seasons in north central South Dakota, USA. Maximum live is the maximum height of surrounding vegetation.

Variable	***r***	***r*** ^{2}
Poa pratensis	-0.82	0.67
Maximum live (5 m)	-0.54	0.29

Discussion

Based on the literature, individual bird species behaved as would be expected, by selecting exclusively on or off-town locations as nesting sites. Results from PCA and MANOVA analyses regarding Brewer's blackbirds are not surprising. Brewer's blackbirds are colonial nesters (Williams 1952; Horn 1970). A colony nested in a patch of short wild plum (*Prunus americana* Marsh.) on the edge of a pasture and our study site. The shrubby habitat patch was surrounded by a matrix of prairie dog town creating a sharp contrast between the two habitat types. The results reflect this observation with clear separation between the random plots and the nests and differences confirmed by MANOVA analysis. The overall selection of this location for the nesting colony is also not surprising based on early work examining microhabitat of Brewer's blackbird nests (Williams 1952; Horn 1970). Many studies suggest that proximity to water is a common theme, although other characteristics of nests are widely variable across the large range of the species (Horn 1968). The patch of plum shrubs at our site was near small potholes which tended to hold water during wet periods and also reasonably close to a riparian area.

Grasshopper sparrows nested exclusively in off-town locations. Graphically, the nest plots tend towards the outside of random points. The strongest gradients are greater litter cover moving towards increasing amounts of bare ground for component one and an association with Kentucky bluegrass (*Poa pratensis* L.). Maximum live vegetation height, and visual obstruction dominate component two. The other strongly related plants species are native plants typically found in these off-town locations. Green needlegrass is strongly correlated with the principle component and is a native species of grass that provides more structure for nesting compared to short-grass species located on shallow soils or on prairie dog towns. Figure 4.7 illustrates the PCA results relative to components one and two with the strongest correlated variables labeled, which revealed that principle components for grasshopper sparrows were largely influenced by gradients of bare ground and vegetative structure. This was true for both nests and associated random locations, and although we were unable to show differences between nest vegetative plots and nearby random locations, the data does suggest that grasshopper sparrows were nesting in areas of higher vegetative structure overall. Patterns in the PCA output are not obvious between nest and random plots for this species and adding more nests and associated random points may help to further clarify any trends that may currently be obscured by the small sample size. Very little is known about nest selection or nest microhabitat for grasshopper sparrows, which makes the data collected in the course of this study all the more valuable. The association with both Kentucky bluegrass and green needlegrass does match accounts of nests located in Pennsylvania, where domed nests were located under sweeps of grasses, with dead grass and sedges often woven to form the nest bowl (Smith 1963).

Horned larks and killdeer typically nest in low structure areas (Beason 1995). The close clustering of the points on these PCA result plots shows much less overall variation in the plant community. Any differences between nests and the surrounding matrix are subtle. For both species, plots are arranged in relation to amount of basal bare ground, with a few other strongly correlated variables tied to only a single plot. Killdeer nest in locations that are characteristically open, with only sparse vegetation or completely devoid of plants (Kantrud and Higgins 1992). In the north-central U.S. and south-central Canada, no nests out of a study examining 157 had effective vegetation height >0.15 meters. The average vegetation height at the nest bowl for the located Killdeer nests (both years) in this study was 0.02±0.004 meters. Horned Larks generally prefer bare ground or plowed fields for nesting habitat throughout their range, so the results are not surprising for either of these species (Beason and Franks 1974).

The results do suggest that some cover is still important for these species. Visual obstruction or maximum vegetation height are strongly correlated with one of the components for each species solution. The inclusion of Kentucky bluegrass as a strongly correlated species with component two in the case of killdeer is associated with one single nest that had a high percent cover of this species. It was not a major component of the other nests sampled.

Lark sparrows nested both on and off prairie dog towns contrary to other bird species that tended to select one habitat type over the other. Visual obstruction, maximum live vegetation height, and the same gradient of percent litter to increasing amounts of bare ground were strongly correlated with the two major components of this analysis. Previous work investigating nest habitat preferences of lark sparrows does suggest that they tend to prefer areas with high amounts of bare ground (McNair 1985). However, similar to grasshopper sparrows, the specifics of plant cover, vegetation density, composition, and structure are poorly described in the literature making vegetation data collected during the course of this study even more critical. The majority of these nests were located within the 75% prairie dog occupancy pasture. This pasture is dominated by weedy vegetation including absinth wormwood, western dock, and Canada thistle in the on-town areas. Nests in these on-town locations were frequently in thistle species or a dense clump of wormwood. There tended to be low amounts of litter and tall surrounding vegetation (average visual obstruction at nest bowl was 0.13±0.05 m compared to 0.08±0.03 m at random locations). Lark sparrow nests located in the off-town areas nested in low sagebrush or a thick patch of native grass. Previous nest studies have shown that lark sparrows nest on the ground greater than 50% of the time (McNair 1985). In addition, previous research investigating avian assemblages in relation to prairie dog documented use of both uncolonized and colonized locations by lark sparrows, matching our findings (Barko et al. 1999).

Mourning doves selected both areas dominated by native grass cover and weedy areas of very tall vegetative structure for nesting, matching accounts in the literature of the greatly varied nest locations and substrates utilized by this widespread species (Eng 1986; Drobney et al. 1998). All located nests were substantially removed from the nearest prairie dog town, similar to grasshopper sparrows; however, bird surveys conducted in this study and previous ones confirmed that mourning doves heavily use prairie dog towns for foraging (Barko et al. 1999). The diversity of mourning dove nesting habitat also explains the lack of a clear observable pattern in the PCA. Pearson correlation coefficients do confirm that vegetative structure is most strongly correlated with PC 1. The vast majority of studies report that mourning doves have widely varied nesting habits and so even with greater sample sizes clear trends may be absent.

The PCA results plot for western meadowlarks shows an interesting potential trend. The majority of the nest scores are in the middle of the plot with random plots as satellites on the edges. There appears to be some visual separation of nest points and associated random plots when examining the PCA ordination output, suggesting differences in vegetation. However, MANOVA analysis did not confirm these differences (p>0.05). The dominant variables when examining correlation coefficients all pertain to vegetative height and density, which is supported by accounts in the literature where western meadowlarks avoided nest patches with high forb cover and selected areas with greater visual obstruction and grass cover (Dieni and Jones 2003). Our analysis shows that Kentucky bluegrass is associated with PC 2 and was the dominant grass (by percent cover) in all but one sampled nest location where it was dominant in only one random plot. There were few forbs present at nest locations, making up very little of the overall canopy cover. When present as a monoculture, Kentucky bluegrass creates thick swards that often become swept over by the elements, potentially providing excellent cover for a nesting bird, particularly a species that tends to select for grass cover. Contrary to what was reported in the literature, nest locations and random plots had almost identical litter depth and percent litter cover (Dieni and Jones 2003). Many of the western meadowlark nests were found not far removed from prairie dog towns, often nesting in edges along colonized areas where vegetation was taller but access to towns for foraging was readily available.

PCA results suggest that, for all bird species examined, density and height of vegetation determines nesting location. Even within the short vegetation found on the prairie dog towns varying microhabitat structure appears to influence nest site selection. The bare ground to litter gradient was consistently present in PCA results and further illuminated differences between and among nests and random plots. This is most likely less a direct influence on nest selection and more a correlation with the types of habitats that have (or lack) greater vegetation structure. Small sample sizes currently limit more clear separation between nest and random locations, and may obscure potential trends. However, extremely little is known about the nest selection of several of the species examined and so this work begins to illuminate some characteristics associated with those species' nesting microhabitat.

Conclusions

Despite being somewhat limited due to small sample sizes, this study does inform us about the dynamics of nesting in relation to black-tailed prairie dog colonies. Bird species that nest on the prairie dog towns, such as killdeer and horned larks, are well-adapted to doing so and find subtle differences in vegetation structure in order to suit their needs. Other bird species require much more vegetative cover and completely avoid prairie dog towns altogether and still others did not seem to be bothered by a surrounding matrix of colonized town as long as they could find sufficient structure for their nest, like Brewer's blackbirds. Quantifying the distance from any individual nest to the nearest prairie dog town may be even more informative. Some species may experience a threshold distance to colonized areas beyond which they will not nest while others, such as the Brewer's blackbird, select a patch of appropriate cover and disregard the distance to the nearest prairie dog town.

Managing for a diverse rangeland community within this region means maintaining some level of prairie dogs in addition to uncolonized areas. Specific goals should be set on a case by case basis depending on the wishes of the landowner or managers.

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5. GENERAL CONCLUSIONS

Over the course of this study we made great strides towards collecting a comprehensive dataset on grazed mixed-grass prairie occupied by black-tailed prairie dogs. A grazed community perspective helps to inform managers and landowners about the complex interactions and associations inherent in this system and allows for widely applicable results. Throughout the course of this two-year study, we completed more than 206 bird surveys, sampled vegetation on 48 transects at more than 1,000 plots made up of over 6,000 vegetation points, and monitored and sampled nests of at least 10 bird species. The analyses contained herein are just a few examples of the possibilities associated with the complete data set we have worked to begin building.

Bird and vegetation belt transects confirmed relationships of bird species, vegetative characteristics, and black-tailed prairie dogs that have been previously reported. Grasshopper sparrows were most strongly negatively correlated with our principle NMS axis while horned larks were strongly positively correlated, associating them with on-town locations. Bare ground is highly correlated with prairie dog towns and may help to shape the biological communities. Presumably, the ecosystem engineering activities of prairie dogs are the driving force behind the creation of these habitats. Future studies to investigate prairie dog modified habitat as unique when compared with other high bare ground areas would be beneficial. Bird surveys and vegetation sampling also revealed the importance of vegetative structure for some bird species. Visual obstruction and maximum vegetation heights were strongly negatively correlated with the same principle NMS axis. These surveys give us the ability to both reasonably predict bird and plant communities in mixed-grass black-tailed prairie dog range grazed by cattle based on habitat but also better inform us about how to effectively manage these landscapes.

Vegetative sampling and PCA further informed us about reproductive dynamics in landscapes utilized by prairie dogs. Similar to what we found during abundance surveys, the majority of bird species preferred or avoided prairie dog towns. Sample sizes are somewhat limited but results suggest that a few species can nest in either on or off-town locations, selecting based on vegetative structure in either location. All aspects of this study supported the conclusion that while many species completely avoid or select for prairie dog habitat, others utilize both on and off-town locations. Analysis revealed that the biological communities are different but they do overlap and share species. These species are arguably the ones we should be most concerned about because they may rely on habitat heterogeneity for them to persist. These findings reinforce the need for examining systems on multiple scales and considering heterogeneity on rangelands.

Grazers, whether livestock or wildlife, exert change on the landscape that can assist in the creation and maintenance of heterogeneous landscapes. Livestock and wildlife do not always need to be considered conflicting forces. Incorporating a grazing regime with livestock may help to provide habitat needed by grassland birds and could potentially increase bird diversity. Our results also suggest that allowing prairie dogs to act as the modifiers they have evolved to be may also help to support more diverse, robust bird communities. Landowners, producers, and managers should outline their specific goals and implement management plans that consider impacts to vegetation, soils, wildlife, and their livestock operation. Maintenance of both colonized prairie dog towns and uncolonized regions is the best balance for wildlife but may not be acceptable to all producers.

Other field research as a part of the larger project will also contribute to the complexity and completeness of this dataset. Having access to such a complete ecosystem dataset is rare and it will aid the local people of the Standing Rock Indian Reservation as they strive to develop a sustainable and ecologically conscious beef operation.

APPENDIX

Table A1. Four-letter Alpha codes and common names of 45 bird species detected during grassland bird surveys on mixed-grass rangeland in north-central South Dakota during the 2012 and 2013 breeding seasons (May-August).

4-letter code	**Common name**	**4-letter code**	**Common name**
AMGO	American goldfinch	GRCA	Gray catbird
AMKE	American kestrel	GRSP	Grasshopper sparrow
AMRO	American robin	HOLA	Horned lark
BAEA	Bald eagle	KILL	Killdeer
BANS	Bank swallow	LASP	Lark sparrow
BARS	Barn swallow	LEFL	Least flycatcher
BBMA	Black-billed magpie	MODO	Mourning dove
BEVI	Bell's vireo	NOFL	Northern flicker
BHCO	Brown-headed cowbird	NOHA	Northern harrier
BLGR	Blue grosbeak	OROR	Orchard oriole
BRBL	Brewer's blackbird	RHWO	Red-headed woodpecker
BRTH	Brown thrasher	RNEP	Ring-necked pheasant
BUOW	Burrowing owl	RWBL	Red-winged blackbird
CCSP	Clay-colored sparrow	SPTO	Spotted towhee
CLSW	Cliff swallow	STGR	Sharp-tailed grouse
COGR	Common grackle	TRES	Tree swallow
DICK	Dickcissel	TUVU	Turkey vulture
EAKI	Eastern kingbird	UPSA	Upland sandpiper
EUST	European starling	VESP	Vesper sparrow
FEHA	Ferruginous hawk	WEKI	Western kingbird
FISP	Field sparrow	WEME	Western meadowlark
FRGU	Franklin's gull	YEWE	Yellow warbler
GOEA	Golden eagle		

Table A2. Alphabetical list of plant species detected during vegetative surveys on fixed width belt transects used to sample bird communities coinciding with black-tailed prairie dog range on mixed-grass prairie in north-central South Dakota, USA.

Achillea millefolium
Agropyron cristatum
Agrostis scabra
Amaranthus alba
Amelanchiver spp
Ambrosia artemisiifolia
Amorpha canescens
Amorpha fruticosa
Andropogon gerardii
Androsace occidentalis
Anemone canadensis
Antennaria neglecta
Antennaria parvifollia
Aristida purpurea
Artemisia absinthium
Artemisia cana
Artemisia dracunculoides
Artemisia frigida
Artemisia ludoviciana
Artemisia spp
Asclepias pumila
Asclepias sullivantii
Aster spp
Astragalus crassicarpus
Bouteloua curtipendula
Bouteloua dactyloides
Bouteloua gracilis
Bromus inermis
Bromus tectorum
Cactaceae spp
Calamovilfa longifolia
Carduus nutans
Carex filifolia
Carex spp
Cirsium arvense
Cirsium flodmanii
Cirsium undulatum
Convolvulus arvensis
Dalea candida
Dalea purpurea
Descurainia sophia
Dicanthelium spp
Dichanthelium oligsanthes
Digitaria ischaemum
Distichlis spicata
Dyssodia papposa
Echinacea angustifolia
Elymus trachycaulus
Erigeron annuus
Erigeron divergens
Eriophyllum spp
Escobaria vivipara
Chamaesyce maculata
Gaura coccinea
Geranium maculatum
Glychyrrhiza lepidota
Grindelia squarrosa
Gutierrizia sarothrae
Helianthus pauciflorus
Hesperostipa comata
Hordeum jubatum
Hordeum pusillum
Kochia scoparia
Koeleria macrantha
Latuca tatarica
Liatris punctata
Lotus unifoliatus
Lupinus Spp
Lygodesmia juncea
Medicago sativa
Melilotus officinalis
Mentha spp
Monarda fistulosa
Muhlenbergia cuspidata
Munroa squarrosa
Nassella viridula
Opuntia macrorhiza
Panicum spp
Panicum virgatum
Pascopyrum smithii
Phalaris arundinacea
Physalis heterophylla
Plantago patagonica
Poa pratensis
Poa spp
Polygala alba
Polyganum erectum
Potentilla spp
Prunus americana
Psoralea argophylla
Ratibida columnifera
Ratibida pinnata
Rosa acicularis
Rosa arkansana
Rosa woodii
Rumex aquaticus
Salsola kali
Schedonnardus paniculatus
Schizachyrium scoparium
Solanum triflorum
Solidago missouriensis
Solidago mollis
Solidago spp
Spartina pectinata
Sphaeralcea coccinea
Sporobolus compositus
Sporobolus cryptandrus
Sporobolus spp
Symphoricarpos occidentalis
Symphyotrichum ericoides
Taraxacum officionale
Thlaspi arvense
Thynopyrum intermedium
Toxicodendron radicans
Tragopogon dubius
Trifolium dubium
Urtica dioica
Vicia americana
Vicia spp
Yucca glauca

Table A3. Shannon diversity index values (H' and E^H), species richness (S), and number of transects for 2012 bird surveys. Higher H' values represent more diverse and/or more even communities. E^H values closer to one are more even.

2012	**P1**		**P2**		**P3**		**P4**		**P5**		**All**	
Town Status	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**
H'	2.49	2.39	1.53	2.30	1.45	2.50	1.92	NA	1.11	2.00	2.33	2.72
E^H	0.78	0.88	0.52	0.80	0.70	0.78	0.63	NA	0.54	0.81	0.66	0.76
S	24	15	20	18	8	25	21	NA	8	12	34	36
No. transects	6	3	5	4	2	7	9	NA	2	3	24	17

Table A4. Shannon diversity index values (H' and E^H), species richness (S), and number of transects for 2013 bird surveys. Higher H' values represent more diverse and/or more even communities. E^H values closer to one are more even.

2013	**P1**		**P2**		**P3**		**P4**		**P5**		**All**	
Town Status	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**	**OFF**	**ON**
H'	2.30	2.50	2.20	2.18	1.63	2.42	1.72	NA	1.22	2.00	2.20	2.51
E^H	0.73	0.69	0.74	0.16	0.16	0.82	0.11	NA	0.24	0.15	0.07	0.07
S	20	23	19	14	10	19	15	NA	5	13	31	33
No. transects	6	3	5	4	2	7	9	NA	2	3	24	17